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EVERYTHING-AS-A-SERVICE: A NEW SUSTAINABLE MODEL FOR MANUFACTURING

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Niente di splendido è mai stato
raggiunto se non da coloro che
hanno avuto il coraggio di credere
che qualcosa dentro di loro fosse
più forte delle circostanze

ABSTRACT

This doctoral thesis investigates the emergence and development of Everything-as-a-Service (XaaS) as a transformative business model within manufacturing industries, positioning the analysis at the intersection of servitization, digital transformation, and environmental sustainability. Over the past decades, manufacturing firms have progressively shifted from traditional product-centric logics toward more integrated product–service offerings, a phenomenon widely conceptualized as servitization. This transition reflects broader structural changes in industrial markets, including increasing customer demand for flexibility, the growing importance of lifecycle services, and the need for more resilient and adaptive value creation models. Within this evolving landscape, XaaS has emerged as a further evolution of servitization, characterized by the provision of functionality, performance, or outcomes rather than the transfer of ownership of physical assets. In such configurations, value is increasingly associated with the use phase of industrial equipment rather than with its acquisition, leading to a redefinition of the roles, responsibilities, and interactions between providers and customers

The diffusion of digital technologies has played a fundamental enabling role in this transformation. Technologies such as the Internet of Things, advanced data analytics, cloud computing, and remote monitoring systems allow manufacturers to continuously track asset performance, optimize maintenance activities, and deliver data-driven services throughout the lifecycle of the equipment. These technological capabilities support the implementation of usage-based, subscription-based, and outcome-based contractual arrangements, which represent the core revenue logic of XaaS models. As a result, XaaS is not merely a contractual or pricing innovation, but rather a systemic transformation of the business model, involving the integration of products, services, and digital infrastructures into coherent value propositions centered on performance delivery.

Despite its increasing relevance, the adoption of XaaS within manufacturing contexts remains limited and uneven. While many firms have initiated pilot projects or exploratory initiatives, only a small proportion have successfully developed scalable and fully operational XaaS configurations. This discrepancy highlights the complexity of the transition, which requires substantial organizational, financial, and technological changes. In particular, the shift from one-off product sales to recurring revenue streams implies delayed cash flows, increased financial exposure due to retained ownership of assets, and the need to manage lifecycle-related responsibilities over extended time horizons. At the same time, XaaS requires the development of new organizational capabilities, cross-functional coordination mechanisms, and collaborations with ecosystem partners, including technology providers, financial institutions, and service partners. These challenges contribute to explaining why many firms struggle to move beyond experimental implementations.

In parallel, XaaS has been increasingly associated with sustainability objectives and circular economy principles. By retaining ownership and responsibility for assets throughout their lifecycle, manufacturers may be incentivized to extend product lifetimes, improve resource efficiency, and implement practices such as maintenance, refurbishment, remanufacturing, and recycling. The shift from ownership-based to access-based consumption models may also contribute to reducing material throughput and optimizing asset utilization. However, the relationship between XaaS adoption and environmental performance is not straightforward and remains insufficiently explored in empirical manufacturing contexts. Potential benefits may be counterbalanced by rebound effects, increased operational complexity, or misaligned incentives, highlighting the need for a more nuanced and evidence-based understanding of the sustainability implications of XaaS.

The motivation for this research arises from a set of interrelated gaps identified in the existing literature. A first critical issue concerns the conceptual fragmentation of XaaS, as the term is used to describe a wide range of heterogeneous phenomena, often overlapping with related constructs such as Product-Service Systems, digital servitization, subscription-based models, and outcome-based contracting. This lack of conceptual clarity limits the development of cumulative knowledge and hinders the comparability of research findings. A second gap relates to the absence of integrative frameworks capable of systematically capturing the multidimensional nature of XaaS business models. Existing studies tend to focus on specific aspects, such as revenue models or digital technologies, without providing a holistic representation of how different elements interact within the overall business model configuration. A third limitation concerns the scarcity of empirical evidence on XaaS implementation in manufacturing, particularly with respect to how firms operationalize these models in practice and which configurations emerge across different contexts. Finally, the link between XaaS and environmental sustainability remains underdeveloped, with limited empirical investigation of the mechanisms through which XaaS may enable or hinder sustainable outcomes.

In response to these gaps, this thesis aims to provide a comprehensive and structured understanding of XaaS in manufacturing by integrating conceptual development with empirical investigation. The research addresses how XaaS can be clearly defined and distinguished from related concepts, which dimensions and variables characterize its business model configurations, how these configurations are implemented across different industrial contexts, what challenges and best practices emerge during implementation, and how XaaS relates to environmental sustainability outcomes. Accordingly, the study pursues the objectives of consolidating the conceptual foundations of XaaS, developing an integrative analytical framework, empirically investigating adoption patterns, identifying managerial implications, and clarifying the sustainability implications of XaaS models.

The research adopts a mixed methodological approach combining a systematic literature review and multiple case study analysis. The literature review is conducted following a structured and transparent protocol, enabling the identification and classification of relevant contributions within the field. This process provides a comprehensive overview of the evolution of XaaS research, highlighting key trends, methodological approaches, and thematic areas, and serves as the basis for identifying research gaps and informing the conceptual development. Building on these insights, the study develops a multidimensional framework for characterizing XaaS business models, grounded in a business model perspective and structured around key dimensions such as value proposition, revenue logic, ownership structure, lifecycle involvement, digital infrastructure, and ecosystem configuration. Each dimension is further operationalized through a set of variables, allowing for a systematic and comparable analysis of different XaaS implementations.

The empirical component of the research is based on multiple case studies involving manufacturing companies operating in different sectors and experimenting with XaaS configurations. The application of the proposed framework to these cases enables the identification of different patterns of XaaS adoption and provides insights into how firms combine various business model elements in practice. The findings reveal that XaaS adoption is inherently configurational, with no single dominant model but rather a variety of configurations shaped by contextual factors such as industry characteristics, technological capabilities, and organizational maturity. Several recurring archetypes emerge, reflecting different degrees of service integration, performance orientation, and digital enablement.

In addition to identifying adoption patterns, the empirical analysis highlights a set of key challenges associated with the implementation of XaaS models. These include financial challenges related to investment requirements and cash flow management, organizational challenges linked to cultural change and capability development, contractual challenges associated with defining and measuring performance outcomes, and technological challenges related to data collection, integration, and analysis. Furthermore, the study emphasizes the importance of customer readiness and trust in enabling the adoption of XaaS models, as well as the need to align incentives across different actors within the value ecosystem.

At the same time, the research identifies a set of best practices that can support the effective implementation of XaaS. These include the adoption of a gradual and iterative approach to business model transformation, the development of digital and data analytics capabilities, the integration of cross-functional teams, and the establishment of partnerships with external actors. The importance of aligning the business model with customer needs and operational contexts is also emphasized,

highlighting the role of co-creation and long-term relational interactions in the success of XaaS initiatives.

With respect to environmental sustainability, the findings suggest that XaaS has the potential to enable several environmental value drivers, including improved resource efficiency, extended product lifecycles, enhanced maintenance practices, and the adoption of circular strategies. However, the realization of these benefits depends on specific business model configurations and on the alignment of economic and environmental incentives. The study also identifies potential barriers that may hinder sustainability outcomes, such as increased energy consumption due to higher utilization rates, complexity in managing reverse logistics, and trade-offs between economic performance and environmental objectives. These results highlight the need for a more nuanced understanding of the sustainability implications of XaaS, moving beyond simplified assumptions and considering the configurational nature of the model.

Overall, this thesis demonstrates that XaaS should be understood not as a single, homogeneous business model, but as a configuration-dependent transformation that reshapes manufacturing value creation through the integration of products, services, and digital technologies. By providing conceptual clarity, an integrative analytical framework, and empirical evidence on implementation patterns, challenges, best practices, and sustainability implications, the study contributes to advancing the academic debate on servitization and offers practical guidance for manufacturing firms navigating this transition.

The structure of the thesis reflects this research journey. Chapter I introduces the research context and theoretical foundations, presenting the evolution of servitization and the emergence of XaaS, together with the problem statement. Chapter II provides a systematic literature review of XaaS in manufacturing, identifying key trends and characteristics of the existing body of knowledge. Chapter III discusses the research gaps and defines the research questions, objectives, and methodological approach. Chapter IV develops the conceptualization of XaaS and presents the proposed multidimensional framework. Chapter V applies the framework through multiple case studies, analyzing XaaS configurations and identifying adoption patterns. Chapter VI examines implementation challenges and derives best practices and managerial implications. Chapter VII investigates the relationship between XaaS and environmental sustainability, focusing on enabling mechanisms and barriers. Chapter VIII provides an integrative discussion of the findings, linking conceptual and empirical insights. Finally, Chapter IX concludes the thesis by summarizing the main contributions, outlining theoretical and practical implications, and suggesting directions for future research.

ABSTRACT (In italiano)

Questa tesi di dottorato indaga l'emergere e lo sviluppo dell'Everything-as-a-Service (XaaS) come modello di business trasformativo all'interno delle industrie manifatturiere, collocando l'analisi all'intersezione tra servitizzazione, trasformazione digitale e sostenibilità ambientale. Negli ultimi decenni, le imprese manifatturiere hanno progressivamente abbandonato logiche tradizionali incentrate sul prodotto a favore di offerte integrate prodotto–servizio, un fenomeno ampiamente concettualizzato come servitizzazione. Questa transizione riflette cambiamenti strutturali più ampi nei mercati industriali, tra cui la crescente domanda di flessibilità da parte dei clienti, l'importanza sempre maggiore dei servizi lungo il ciclo di vita e la necessità di modelli di creazione del valore più resilienti e adattivi. In questo contesto in evoluzione, lo XaaS è emerso come un'ulteriore evoluzione della servitizzazione, caratterizzato dalla fornitura di funzionalità, prestazioni o risultati piuttosto che dal trasferimento della proprietà dei beni fisici. In tali configurazioni, il valore è sempre più associato alla fase d'uso degli asset industriali piuttosto che alla loro acquisizione, portando a una ridefinizione dei ruoli, delle responsabilità e delle interazioni tra fornitori e clienti .

La diffusione delle tecnologie digitali ha svolto un ruolo abilitante fondamentale in questa trasformazione. Tecnologie come l'Internet of Things, l'analisi avanzata dei dati, il cloud computing e i sistemi di monitoraggio remoto consentono ai produttori di monitorare continuamente le prestazioni degli asset, ottimizzare le attività di manutenzione e fornire servizi data-driven lungo tutto il ciclo di vita delle attrezzature. Queste capacità tecnologiche supportano l'implementazione di modelli contrattuali basati sull'utilizzo, sull'abbonamento e sui risultati, che rappresentano la logica di ricavo alla base dei modelli XaaS. Di conseguenza, lo XaaS non rappresenta semplicemente un'innovazione contrattuale o di pricing, ma una trasformazione sistemica del modello di business, che implica l'integrazione di prodotti, servizi e infrastrutture digitali in proposizioni di valore coerenti incentrate sulla fornitura di performance.

Nonostante la sua crescente rilevanza, l'adozione dello XaaS nei contesti manifatturieri rimane limitata e disomogenea. Sebbene molte imprese abbiano avviato progetti pilota o iniziative esplorative, solo una piccola parte è riuscita a sviluppare configurazioni XaaS scalabili e pienamente operative. Questa discrepanza evidenzia la complessità della transizione, che richiede cambiamenti significativi non solo nella proposta di valore, ma anche nelle strutture organizzative, nei modelli finanziari, nelle infrastrutture tecnologiche e nelle relazioni di ecosistema. Allo stesso tempo, lo XaaS è sempre più associato a obiettivi di sostenibilità e ai principi dell'economia circolare. Mantenendo la proprietà e la responsabilità sugli asset lungo tutto il ciclo di vita, i produttori possono essere incentivati a estendere la durata dei prodotti, migliorare l'efficienza delle risorse e implementare pratiche come manutenzione, refurbishment, remanufacturing e riciclo. Il passaggio da modelli di

consumo basati sulla proprietà a modelli basati sull'accesso può inoltre contribuire a ridurre il consumo di materiali e ottimizzare l'utilizzo degli asset. Tuttavia, la relazione tra adozione dello XaaS e performance ambientale non è lineare e rimane ancora poco esplorata nei contesti manifatturieri empirici. I benefici potenziali possono essere controbilanciati da effetti rebound, maggiore complessità operativa o disallineamenti negli incentivi, evidenziando la necessità di una comprensione più approfondita e basata su evidenze delle implicazioni di sostenibilità dello XaaS.

La motivazione di questa ricerca nasce da una serie di lacune interconnesse identificate nella letteratura esistente. Un primo problema critico riguarda la frammentazione concettuale dello XaaS, poiché il termine viene utilizzato per descrivere un'ampia gamma di fenomeni eterogenei, spesso sovrapposti a concetti correlati come i Product-Service Systems, la servitizzazione digitale, i modelli basati su abbonamento e il contracting basato sui risultati. Questa mancanza di chiarezza concettuale limita lo sviluppo di conoscenza cumulativa e ostacola la comparabilità dei risultati di ricerca. Una seconda lacuna riguarda l'assenza di framework integrativi in grado di catturare sistematicamente la natura multidimensionale dei modelli di business XaaS. Gli studi esistenti tendono a concentrarsi su aspetti specifici, come i modelli di ricavo o le tecnologie digitali, senza fornire una rappresentazione olistica di come i diversi elementi interagiscano all'interno della configurazione complessiva del modello di business. Una terza limitazione riguarda la scarsità di evidenze empiriche sull'implementazione dello XaaS nel manifatturiero, in particolare rispetto a come le imprese operazionalizzano questi modelli nella pratica e quali configurazioni emergano nei diversi contesti. Infine, il legame tra XaaS e sostenibilità ambientale risulta ancora poco sviluppato, con limitate analisi empiriche dei meccanismi attraverso cui lo XaaS può abilitare o ostacolare risultati sostenibili.

In risposta a queste lacune, la presente tesi si propone di fornire una comprensione completa e strutturata dello XaaS nel manifatturiero attraverso l'integrazione di sviluppo concettuale e analisi empirica. La ricerca affronta il tema di come lo XaaS possa essere chiaramente definito e distinto dai concetti correlati, quali dimensioni e variabili caratterizzino le sue configurazioni di business model, come tali configurazioni vengano implementate in diversi contesti industriali, quali sfide e best practice emergano durante l'implementazione e come lo XaaS si relazioni agli esiti di sostenibilità ambientale. Coerentemente, lo studio persegue l'obiettivo di consolidare le basi concettuali dello XaaS, sviluppare un framework analitico integrativo, analizzare empiricamente i pattern di adozione, identificare implicazioni manageriali e chiarire le implicazioni di sostenibilità dei modelli XaaS.

La ricerca adotta un approccio metodologico misto che combina una revisione sistematica della letteratura e un'analisi basata su casi di studio multipli. La revisione della letteratura è condotta seguendo un protocollo strutturato e trasparente, consentendo l'identificazione e la classificazione dei contributi rilevanti nel campo. Questo processo fornisce una panoramica completa dell'evoluzione

della ricerca sullo XaaS, evidenziando trend, approcci metodologici e aree tematiche principali, e costituisce la base per l'identificazione delle lacune e per lo sviluppo concettuale. Su queste basi, lo studio sviluppa un framework multidimensionale per caratterizzare i modelli di business XaaS, fondato su una prospettiva di business model e articolato in dimensioni chiave quali proposta di valore, logica di ricavo, configurazione della proprietà, coinvolgimento nel ciclo di vita, infrastruttura digitale e configurazione dell'ecosistema. Ogni dimensione è ulteriormente operazionalizzata attraverso un insieme di variabili, consentendo un'analisi sistematica e comparabile delle diverse implementazioni XaaS.

La componente empirica della ricerca si basa su casi di studio multipli che coinvolgono imprese manifatturiere operanti in diversi settori e impegnate nell'implementazione o sperimentazione di configurazioni XaaS. L'applicazione del framework a questi casi consente di identificare diversi pattern di adozione dello XaaS e fornisce insight su come le imprese combinino nella pratica i diversi elementi del modello di business. I risultati evidenziano che l'adozione dello XaaS è intrinsecamente configurazionale, senza un modello dominante unico, ma piuttosto con una varietà di configurazioni influenzate da fattori contestuali quali le caratteristiche del settore, le capacità tecnologiche e la maturità organizzativa. Emergono diversi archetipi ricorrenti, che riflettono differenti livelli di integrazione dei servizi, orientamento alla performance e abilitazione digitale.

Oltre all'identificazione dei pattern di adozione, l'analisi empirica evidenzia un insieme di sfide chiave associate all'implementazione dei modelli XaaS. Tra queste si includono sfide finanziarie legate agli investimenti e alla gestione dei flussi di cassa, sfide organizzative connesse al cambiamento culturale e allo sviluppo di nuove competenze, sfide contrattuali legate alla definizione e misurazione delle performance, e sfide tecnologiche relative alla raccolta, integrazione e analisi dei dati. Inoltre, lo studio sottolinea l'importanza della readiness e della fiducia dei clienti nell'abilitare l'adozione dei modelli XaaS, così come la necessità di allineare gli incentivi tra i diversi attori dell'ecosistema.

Parallelamente, la ricerca identifica un insieme di best practice che possono supportare l'implementazione efficace dello XaaS. Tra queste emergono l'adozione di un approccio graduale e iterativo alla trasformazione del modello di business, lo sviluppo di capacità digitali e di analisi dei dati, l'integrazione di team cross-funzionali e la costruzione di partnership con attori esterni. Viene inoltre enfatizzata l'importanza di allineare il modello di business alle esigenze dei clienti e ai contesti operativi, evidenziando il ruolo della co-creazione e delle relazioni di lungo periodo nel successo delle iniziative XaaS.

Per quanto riguarda la sostenibilità ambientale, i risultati suggeriscono che lo XaaS ha il potenziale di abilitare diversi driver di valore ambientale, tra cui una maggiore efficienza delle risorse,

l'estensione del ciclo di vita dei prodotti, il miglioramento delle pratiche di manutenzione e l'adozione di strategie circolari. Tuttavia, la realizzazione di tali benefici dipende dalle specifiche configurazioni del modello di business e dall'allineamento tra incentivi economici e ambientali. Lo studio evidenzia inoltre potenziali barriere che possono ostacolare i risultati di sostenibilità, come l'aumento dei consumi energetici dovuto a maggiori tassi di utilizzo, la complessità nella gestione della logistica inversa e i trade-off tra performance economiche e obiettivi ambientali. Questi risultati sottolineano la necessità di una comprensione più articolata delle implicazioni di sostenibilità dello XaaS, andando oltre visioni semplificate e considerando la natura configurazionale del modello.

Nel complesso, la tesi dimostra che lo XaaS deve essere interpretato non come un modello di business unico e omogeneo, ma come una trasformazione configurazionale che ridefinisce la creazione del valore nel manifatturiero attraverso l'integrazione di prodotti, servizi e tecnologie digitali. Fornendo chiarezza concettuale, un framework analitico integrativo ed evidenze empiriche su pattern di implementazione, sfide, best practice e implicazioni di sostenibilità, lo studio contribuisce ad avanzare il dibattito accademico sulla servitizzazione e offre indicazioni pratiche per le imprese manifatturiere impegnate in questa transizione.

La struttura della tesi riflette questo percorso di ricerca. Il Chapter I introduce il contesto di ricerca e le basi teoriche, presentando l'evoluzione della servitizzazione e l'emergere dello XaaS, insieme al problema di ricerca. Il Chapter II presenta la systematic literature review sullo XaaS nel manifatturiero, identificando i principali trend e le caratteristiche della letteratura esistente. Il Chapter III discute le lacune di ricerca e definisce le research questions, gli obiettivi e l'approccio metodologico. Il Chapter IV sviluppa la concettualizzazione dello XaaS e presenta il framework multidimensionale proposto. Il Chapter V applica il framework attraverso casi studio multipli, analizzando le configurazioni XaaS e identificando i pattern di adozione. Il Chapter VI esamina le sfide di implementazione e deriva best practice e implicazioni manageriali. Il Chapter VII indaga la relazione tra XaaS e sostenibilità ambientale, concentrandosi sui meccanismi abilitanti e sulle barriere. Il Chapter VIII fornisce una discussione integrata dei risultati, collegando insight concettuali ed empirici. Infine, il Chapter IX conclude la tesi riassumendo i principali contributi, delineando le implicazioni teoriche e pratiche e suggerendo direzioni per ricerche future.

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List of Abbreviations

ITEM	DESCRIPTION
XaaS	Everything-as-a-Service
EaaS	Equipment-as-a-Service
PSS	Product-Service System
IPSS	Industrial Product-Service System
CaaS	Cooling-as-a-Service
LaaS	Lighting-as-a-Service
PaaS	Product-as-a-Service
BM	Business Model
BMI	Business Model Innovation
TCO	Total Cost of Ownership
CAPEX	Capital Expenditure
OPEX	Operational Expenditure
IoT	Internet of Things
ICT	Information and Communication Technologies
AI	Artificial Intelligence
PLM	Product Lifecycle Management
LCC	Lifecycle Cost
CbM	Condition-based Maintenance
OEM	Original Equipment Manufacturer
SME	Small and Medium Enterprise
R&D	Research and Development
LR	Literature Review
SLR	Systematic Literature Review
EVD	Environmental Value Drivers
CE	Circular Economy

INTRODUCTION

The transformation of manufacturing business models from product-centric logics toward integrated service-based configurations represents one of the most significant shifts in contemporary industrial strategy. Over the past decades, the servitization literature has extensively documented the progressive integration of services into manufacturing offerings, highlighting how firms increasingly move from transactional product sales toward relational and lifecycle-oriented solution provision. Within this broader transformation, the Everything-as-a-Service (XaaS) paradigm has emerged as a further evolution, characterized by the provision of integrated, on-demand solutions in which customers access functionality or outcomes rather than acquiring ownership of physical assets.

While the conceptual foundations of servitization are well established, the diffusion of XaaS models within manufacturing remains uneven and operationally complex. Although many industrial firms recognize the strategic relevance of access-based and outcome-oriented offerings, empirical evidence suggests that only a limited proportion have successfully implemented scalable XaaS configurations. The transition from traditional capital sales to recurring, performance-based revenue models requires substantial organizational, financial, technological, and contractual reconfiguration. Providers must retain responsibility for asset performance across extended lifecycles, manage delayed cash flows, integrate digital monitoring infrastructures, and coordinate ecosystem actors within new governance arrangements.

At the same time, XaaS models are increasingly associated with sustainability objectives. By retaining ownership and maintaining lifecycle responsibility, manufacturers may gain incentives to extend product lifetimes, improve resource efficiency, and support circular strategies. However, the relationship between XaaS adoption and environmental performance remains insufficiently clarified, particularly within empirical manufacturing contexts.

Despite growing academic and managerial interest, the literature remains fragmented across partially overlapping constructs and disciplinary streams. Conceptual ambiguity, the absence of integrative analytical frameworks, limited configurational evidence from real-world implementations, and underdeveloped empirical analysis of sustainability mechanisms collectively limit cumulative knowledge development in this domain.

Against this background, this thesis aims to consolidate the conceptual foundations of XaaS within manufacturing contexts, propose an integrative multidimensional framework for its systematic analysis, empirically investigate implementation patterns across industrial cases, and clarify the structural mechanisms linking XaaS configurations to environmental sustainability outcomes.

By combining theoretical consolidation with empirical investigation, the study seeks to advance understanding of XaaS as a configuration-dependent business model transformation rather than as a mere pricing or contractual innovation. In doing so, it contributes to both academic debate and managerial practice by providing conceptual clarity, analytical structure, and evidence-based insights into the implementation and sustainability implications of XaaS in manufacturing.

1 CHAPTER I - CONTEXT AND THEORETICAL BASIS

1.1 Background and context

1.1.1 Servitization and Everything-as-a-Service (XaaS)

In the current global economy, manufacturing firms can no longer rely exclusively on traditional product-centric business models based on competitive priorities such as cost, quality, flexibility, delivery time, or environmental performance (Adrodegari et al., 2017). Increasingly, industrial customers are demanding more flexible contractual arrangements rather than one-off capital investments, while demand for new equipment has declined as firms seek to preserve liquidity and reduce capital expenditures. At the same time, recent global disruptions such as the COVID-19 pandemic have highlighted the need to enhance supply chain resilience and rethink value creation logics. In this evolving environment, services are progressively taking a leading role in the global economy in terms of wealth generation and value added (Kindström and Kowalkowski, 2014).

As a consequence, manufacturing companies are increasingly moving from product-centric offerings towards integrated solutions combining products and services. This phenomenon has been extensively discussed in the literature since the late 1980s and conceptualized through different but related perspectives, such as servitization (Vandermerwe and Rada, 1988), transition from products to services (Oliva and Kallenberg, 2003), going downstream in the value chain (Wise and Baumgartner, 1999), product-service systems (Tukker, 2004), moving towards high-value and integrated solutions (Davies, 2004; Windahl and Lakemond, 2010), service infusion in manufacturing (Kowalkowski et al., 2012), and manufacturing–service integration (Schmenner, 2009). Beyond conceptual contributions, notable cases such as IBM and Rolls-Royce are often cited as emblematic of successful shifts from product sales towards solution-based offerings (Wise and Baumgartner, 1999; Davies, 2004; Lazonick and Prencipe, 2005; Chesbrough, 2007; Ng et al., 2012).

Servitization is commonly defined as the innovation of an organization's capabilities and processes to create added value through a shift from selling products to selling an integrated combination of products and services, also referred to as Product-Service Systems (PSS) (Baines et al., 2009). Servitization therefore implies that the value proposition expands from the delivery of a physical asset to the provision of broader solutions that support customers across the asset's lifecycle (Oliva and Kallenberg, 2003; Kowalkowski et al., 2012). In this perspective, services become a core element of the offering rather than complementary add-ons, as they support customer value creation during installation, operation, maintenance, and potentially end-of-life activities (Oliva and Kallenberg, 2003).

From a strategic standpoint, services can generate an increasing share of revenues and profits for manufacturing firms while simultaneously improving customer retention and strengthening long-term competitive advantage (Gebauer et al., 2017). In addition, the integration of services into manufacturing offerings supports a shift in the nature of the customer–provider relationship: from discrete transactions centered on the exchange of goods towards more relational interactions based on ongoing solution provision (Adrodegari and Saccani, 2017). This transition enables manufacturers to remain involved throughout the operational phase of their products and to support customer activities beyond the initial transaction (Oliva and Kallenberg, 2003; Kowalkowski et al., 2012).

However, servitization is not simply the extension of an after-sales portfolio. The transition towards servitized offerings is inherently complex and requires substantial organizational changes in terms of structure, culture, and competencies (Baines et al., 2009; Oliva and Kallenberg, 2003; Dimache and Roche, 2013). To succeed in this transformation, companies must redesign not only their value proposition but also their underlying business model (Kindström, 2010; Slepniov et al., 2010; Adrodegari and Saccani, 2017). Servitized business models enable firms to establish long-term partnerships with customers by continuously delivering integrated solutions in exchange for recurring payments, thereby shifting the revenue logic from transactional to relational (Adrodegari and Saccani, 2017; Duan et al., 2015).

Within the servitization literature, Product-Service Systems (PSS) provide a useful lens to describe how manufacturers combine tangible products and intangible services to create value (Tukker, 2004; Baines et al., 2009). PSS configurations are often represented along a continuum (Figure 1), where offerings range from product-oriented solutions to use-oriented and result-oriented solutions (Tukker, 2004). This classification helps clarify how the relative importance of products and services may vary across different servitization strategies, and how value creation may progressively shift from product delivery towards the use and performance of industrial assets.

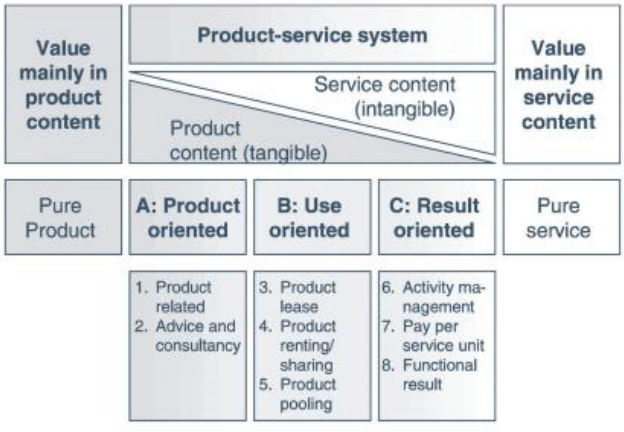


Figure 1 Product–Service System (PSS) configurations along the servitization continuum (adapted from Tukker, 2004)

In particular, product-oriented PSS focus on the provision of ownership-related services such as maintenance and repair, whereas use-oriented models emphasize access to product functionalities throughout the operational phase without necessarily transferring ownership. At the opposite end of the continuum, result-oriented configurations are characterized by value propositions centered on the delivery of predefined outcomes, with providers remaining responsible for ensuring the expected level of performance over time (Tukker, 2004; Baines et al., 2009).

In addition to the classification of PSS configurations, servitization has also been conceptualized as a progressive transformation process through which manufacturing firms increase the level of service integration within their offerings. This evolutionary perspective is often represented through the so-called *service* staircase (Figure 2), which describes the transition from basic product-related services towards more advanced solution-oriented offerings (Baines et al., 2019). As firms move along this continuum, the role of services progressively shifts from supporting product ownership to enabling customer processes through more integrated offerings.

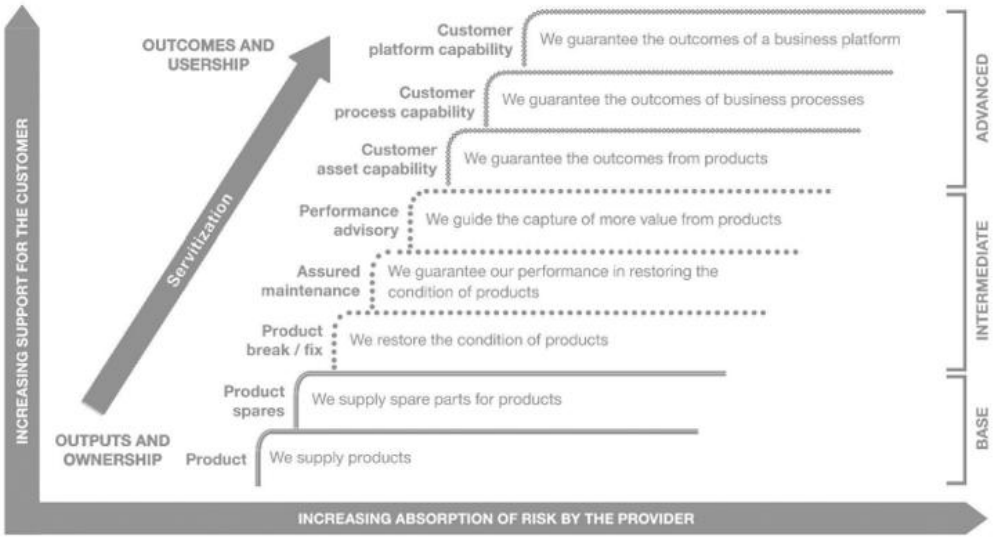


Figure 2 Service Staircase representing the increasing integration of services in manufacturing offerings (Adapted from Baines et al., 2019)

This progression reflects an increasing involvement of the provider throughout the lifecycle of the product and a corresponding evolution in the nature of the customer–provider relationship, from transactional exchanges towards more continuous interactions based on integrated solutions (Kowalkowski et al., 2012).

Within this context, the Everything-as-a-Service (XaaS) paradigm has recently gained increasing attention among both scholars and practitioners. Originating in the Information Technology domain with the emergence of cloud computing in the late 2000s, XaaS initially referred to IT delivery models

based on the virtualization of resources, whereby infrastructures, applications, and data are provided on-demand via the Internet (Duan et al., 2015; Durao et al., 2014). Over time, the concept has evolved beyond software-based applications to encompass a wide range of offerings across industries, including Software-as-a-Service, Mobility-as-a-Service, Heat-as-a-Service, and Equipment-as-a-Service.

Despite the heterogeneity of these applications, XaaS models share a common underlying logic centered on the provision of functionality or outcomes rather than the transfer of ownership of physical assets. Digital technologies and cloud infrastructures act as key enablers of these models by allowing providers to deliver integrated product–service solutions on demand through subscription-based or usage-based pricing mechanisms (Classen et al., 2023). In this regard, XaaS is often associated with alternative revenue logics typically categorized into subscription-based models, which involve periodic fixed payments, and Pay-per-X models, in which customers are charged based on actual usage (pay-per-use), performance (pay-per-performance), or achieved outcomes (pay-per-outcome) (Gebauer et al., 2017).

From an implementation perspective, the adoption of XaaS models entails significant organizational and financial implications for providers. Since payments are received incrementally over time and firms often retain ownership and lifecycle responsibility for the assets, XaaS requires substantial investment capacity as well as the ability to manage increased operational complexity (Opresnik and Taisch, 2015; Pieroni et al., 2019). Consequently, the implementation and effectiveness of XaaS configurations are contingent upon contextual factors such as the maturity of the implementing organization, the structure of the revenue model, and the characteristics of the offered equipment (Reim et al., 2015; Schaefers et al., 2021).

1.1.2 XaaS in manufacturing

While the Everything-as-a-Service (XaaS) concept originated in the Information Technology domain, its application is becoming increasingly relevant within manufacturing industries, where the transition from product ownership to service-based value propositions represents a fundamental shift in value creation logic. In this context, XaaS can be interpreted as a business model innovation that operationalizes servitization by enabling the provision of integrated product-service offerings focused on delivering functionality rather than transferring ownership of physical assets (Mourtzis et al., 2021; Mustonen et al., 2019).

This shift reflects a transition towards value propositions that emphasize access to capabilities during the use phase of industrial assets, rather than the exchange of ownership at the point of sale, thereby aligning the delivery of industrial solutions with customer operational needs over time (Schaefers et

al., 2021). In line with the progressive integration of services within manufacturing offerings described in the servitization literature, such configurations imply an increasing involvement of the provider throughout the operational phase of the asset lifecycle (Oliva and Kallenberg, 2003; Kowalkowski et al., 2012). In this regard, the delivery of industrial solutions is no longer limited to the transfer of ownership at the point of sale but extends to supporting customer activities during the utilization of the equipment. This increased lifecycle involvement enables manufacturers to ensure the expected level of functionality and performance over time through the continuous provision of service-based support (Mourtzis et al., 2021).

In manufacturing settings, one of the most widely adopted configurations of the XaaS business model is Equipment-as-a-Service (EaaS), in which the provider retains ownership of the equipment and assumes responsibility for ensuring its proper functioning throughout the lifecycle. This typically includes maintenance activities, spare parts management, calibration, upgrades, and other support services required to guarantee the expected performance level of the asset. Customers, in turn, are charged based on the actual usage of the equipment or the output generated, rather than on the acquisition of the asset itself (Gebauer et al., 2017; Buerkle et al., 2023). Within this configuration, manufacturers are able to remain involved throughout the operational phase of the asset, ensuring the continuous provision of services required to meet predefined performance requirements over time (Mourtzis et al., 2021).

In practice, the implementation of Equipment-as-a-Service models within manufacturing industries entails a reconfiguration of service delivery activities across the lifecycle of industrial equipment. Providers adopting EaaS configurations are typically responsible not only for maintenance and repair operations but also for monitoring, spare parts logistics, upgrades, and operational support activities during the utilization phase of the equipment. Such service-based arrangements enable manufacturers to support customer operations beyond installation by ensuring the continuous functioning of the equipment and by intervening in case of performance degradation or unexpected failures. In this regard, the provider's involvement throughout the operational phase may contribute to reducing unplanned downtime and improving overall equipment availability through preventive and condition-based maintenance interventions.

Although often presented as a recent development, the shift from one-off sales of capital goods to recurring revenue streams based on usage or performance has already been implemented in selected industrial sectors for several decades. A well-known example is Rolls-Royce's "power-by-the-hour" model, in which customers pay for the operational availability of aircraft engines instead of purchasing them outright. Similar approaches are increasingly emerging across manufacturing industries, such as usage-based contracts in the laundry equipment sector offered by companies

operating under the Electrolux Group. In such configurations, the value derived from the offering is increasingly associated with the performance delivered during the utilization phase of the equipment rather than with the transfer of ownership itself (Schaefers et al., 2021).

Within the XaaS business model, the variable "X" may refer to a physical product (e.g., Tires-as-a-Service), a service (e.g., Storage-as-a-Service), or a specific functionality (e.g., Mobility-as-a-Service). Consequently, alternative terminologies such as access-based, performance-based, or outcome-based business models are often used to describe comparable arrangements (Schaefers et al., 2021). Regardless of terminology, these models share the common objective of enabling customers to access tailored solutions aligned with their operational requirements without assuming ownership-related responsibilities for the physical assets involved (Mustonen et al., 2019).

From a financial perspective, XaaS business models shift expenditures from capital expenditure (CAPEX) to operating expenditure (OPEX), transforming large upfront investments into smaller periodic payments and aligning costs with the actual value-in-use derived from the equipment (Gebauer et al., 2020; Uski et al., 2022). This transition can support longer-term planning and resource allocation, albeit at the cost of higher upfront investments and delayed cash flows (Cenamor et al., 2017). In addition, XaaS configurations may influence the cost composition associated with industrial equipment throughout its lifecycle, as the Total Cost of Ownership is often largely determined by operational expenditures such as maintenance services, spare parts replacement, and repair activities rather than by the initial acquisition cost (Reim et al., 2015).

For manufacturers, XaaS adoption may support the development of new, stable, and recurring revenue streams, smoothing revenue volatility and reducing dependence on cyclical capital investments (Gebauer et al., 2017; Visnjic Kastalli and Van Looy, 2013; Reim et al., 2015). Recurring revenues can enhance financial predictability while enabling deeper and more continuous customer relationships (Kohtamäki et al., 2013; Story et al., 2017). Rather than episodic transactional exchanges, manufacturers engage in ongoing relational processes that facilitate cross-selling, service innovation, and co-development opportunities (Visnjic Kastalli and Van Looy, 2013). Additional benefits relate to competitiveness and differentiation, as integrated product–service solutions enable firms to compete on performance, reliability, and total value delivered rather than solely on technical specifications or price (Cenamor et al., 2017; Tukker, 2015).

Another important aspect concerns innovation improvement, particularly in terms of upgradability and continuous enhancement of offerings (Coreynen et al., 2017; Kohtamäki et al., 2013). XaaS models incentivize manufacturers to innovate throughout the lifecycle of the solution, shifting innovation efforts from discrete product generations to ongoing service and system enhancements supported by data-driven feedback loops.

Customers may also benefit from XaaS adoption through improved financial predictability, risk reduction, operational flexibility, and relational dynamics with providers (Reim et al., 2015; Tukker, 2015). By enabling customers to move from capital-intensive investments toward operational expenditures, XaaS reduces upfront financial commitments and improves cash-flow predictability while facilitating more accurate budgeting through bundled service agreements (Reim et al., 2015; Baines et al., 2017; Cenamor et al., 2017). Under such arrangements, manufacturers often assume responsibility for availability, performance, and lifecycle management, transferring a portion of technical and operational risk away from customers (Reim et al., 2015; Visnjic Kastalli and Van Looy, 2013; Story et al., 2017).

Higher service reliability and flexibility may also result from the provider's retained ownership and responsibility for the asset, enabling continuous availability, rapid maintenance, and performance optimization (Kohtamäki et al., 2013; Rapaccini et al., 2020). This may allow customers to scale usage in response to changing operational needs and benefit from continuous technological upgrades without bearing the full cost and risk associated with ownership (Coreynen et al., 2017; Tukker, 2015). In addition, outsourcing asset management, maintenance, and technological complexity to specialized providers may enable customers to focus on core business activities and support the development of long-term collaborative relationships with providers that facilitate joint problem-solving and continuous improvement (Visnjic Kastalli and Van Looy, 2013; Story et al., 2017; Kohtamäki et al., 2013).

Overall, the adoption of XaaS models may generate a combination of financial, operational, and relational advantages for both manufacturers and customers. Revenue stability, relational advantages, differentiation, innovation, and flexibility collectively motivate firms to reconsider traditional product-centric business models despite the organizational and financial challenges involved (Reim et al., 2015; Cenamor et al., 2017).

To illustrate how XaaS business models are implemented in the manufacturing sector, some of the most well-known and widely adopted industrial examples are presented below.

- **Xerox – Print-as-a-Service**

Xerox represents one of the earliest industrial examples of outcome-oriented service provision applied to physical equipment. Already between the 1960s and 1970s, the company introduced leasing-based commercial arrangements for photocopiers, enabling customers to access printing functionality through recurring payments rather than through outright equipment ownership. A prominent example of Xerox's XaaS-oriented offering is the **PagePack** commercial model, which can be interpreted as a pay-per-use configuration within a Print-as-a-Service (PaaS) framework. Under this arrangement, customers are charged a periodic fee calculated on the basis of a predefined

cost per printed page, thereby shifting expenditures from capital investment towards operating expenses. In exchange, Xerox assumes responsibility for the installation, maintenance, technical support, toner supply, and replacement of consumables (excluding paper) throughout the operational lifecycle of the equipment. From a business model perspective, PagePack exemplifies an outcome-based contractual logic in which customers pay for the functionality delivered, namely, document reproduction, rather than for the physical ownership of printing devices. By retaining responsibility for equipment performance and service continuity over time, Xerox is able to ensure system availability while supporting customers' operational activities through lifecycle-oriented service provision.

- **Rolls-Royce – Power-by-the-Hour and TotalCare**

Rolls-Royce Holdings provides one of the most widely recognized industrial applications of service-based business models in the aerospace sector. In 1962, the company introduced the **Power-by-the-Hour** offering, under which airlines were charged a fixed fee for each hour of engine operation rather than purchasing and maintaining the propulsion system outright. Under this arrangement, Rolls-Royce retained ownership of the engines and assumed responsibility for maintenance, repair, and overhaul activities throughout their operational lifecycle. This contractual configuration enabled customers to pay for engine availability and performance rather than for the physical asset itself, thereby transferring technical and operational risks associated with engine maintenance to the manufacturer. For airlines, this translated into improved cost predictability and reduced exposure to unexpected maintenance expenses, while allowing Rolls-Royce to remain directly involved in the operational phase of the equipment. Building upon this model, Rolls-Royce introduced the **TotalCare®** service in 2010, which expanded the scope of lifecycle support through the integration of advanced monitoring and maintenance capabilities. TotalCare includes real-time Engine Health Monitoring enabled by embedded sensors, allowing for the continuous assessment of engine performance during flight operations. In addition, the service provides access to replacement leased engines during off-wing maintenance operations in order to minimize aircraft downtime and ensure operational continuity. Support is further ensured through a global network of authorized maintenance centers capable of delivering repair and overhaul services when required. Through these service-based arrangements, Rolls-Royce is able to maintain responsibility for propulsion system performance over extended time horizons, aligning its revenue generation mechanisms with engine availability and operational outcomes rather than with one-off product sales.

- **Epson – ReadyPrint Subscription Model**

Seiko Epson Corporation is a global technology company operating in both consumer and industrial printing markets. In 2020, Epson introduced the **ReadyPrint** subscription service, which represents

a transition from traditional product ownership towards usage-based access to printing functionality. The service is available for selected printer models within the Expression, WorkForce, and EcoTank product lines. ReadyPrint includes multiple commercial configurations tailored to different usage patterns. The **ReadyPrint Flex** option provides customers with ink supply through a monthly subscription fee determined by the selected number of printed pages, while the printing device itself remains customer-owned. In contrast, the **ReadyPrint EcoTank** configuration combines both ink supply and printer hardware within a single recurring payment, enabling customers to access printing capabilities without requiring upfront capital investment in equipment. Additionally, the **ReadyPrint Go** plan adopts a pay-as-you-go structure in which customers are billed exclusively for the pages effectively printed, without predefined usage thresholds. Across these configurations, Epson assumes responsibility for the continuous provision of ink throughout the operational lifecycle of the device, thereby ensuring service continuity and reducing the need for user-managed consumable replacement. Through these subscription-based arrangements, Epson aligns revenue generation with the actual usage of printing services, shifting expenditure from capital to operational costs while supporting more predictable budgeting for customers. At the same time, the integration of hardware and consumable supply within a single contractual framework allows Epson to maintain ongoing service relationships with users beyond the point of sale.

- **Candy (Haier) – WashPass**

Haier, through its subsidiary Candy, has introduced service-based offerings in the household appliance sector by integrating connected technologies into traditionally product-oriented equipment. In October 2022, the company launched **WashPass**, a subscription-based laundry service that enables customers to access washing functionality through a monthly fee rather than through the ownership of standalone appliances and consumables. WashPass combines connected washing machines equipped with embedded sensors and artificial intelligence capabilities with the automated supply of detergent cartridges. Through this configuration, the system is able to dose cleaning agents based on usage conditions and operational parameters, thereby optimizing washing performance throughout the appliance lifecycle. Customers can select among different contractual plans, all of which include installation, maintenance services, and the replenishment of active ingredients through an automatic reordering system. Under this arrangement, the provider assumes responsibility for the continuous operation and servicing of the appliance, while ensuring the timely replacement of consumables required for its functioning. By integrating hardware, digital monitoring capabilities, and consumable supply within a single contractual framework, WashPass enables the provision of laundry services based on recurring payments, allowing users to access washing functionality without managing maintenance or supply activities independently.

- **TRUMPF – Pay-per-Part Model**

TRUMPF is a high-technology manufacturing company specializing in machine tools and laser-based industrial production systems, complemented by software platforms and consulting services. Since 2020, the company has adopted a **pay-per-part** business model that enables customers to access advanced production equipment without requiring upfront capital investment. Under this configuration, TRUMPF provides high-performance manufacturing machines together with integrated material storage systems equipped with cameras, sensors, and remote monitoring capabilities. These technologies allow for the continuous collection and analysis of operational data throughout the production process. Rather than purchasing the equipment outright, customers are charged a fee proportional to the number of parts produced using the installed system. This outcome-based contractual arrangement aligns payment with actual production output, while allowing TRUMPF to retain an active role in monitoring machine performance and supporting operational continuity over time. For existing customers, TRUMPF also offers access to the **TruServices** platform, which includes a portfolio of digital and technical service solutions aimed at supporting long-term collaboration between provider and customer. Through this platform, TRUMPF is able to maintain ongoing interaction with the installed base of equipment and deliver lifecycle-oriented support services beyond the point of sale.

- **Homie – Appliance-as-a-Service**

Homie is a rental-based service provider founded in 2018 that offers access to a range of household appliances through a subscription model. Its portfolio includes washing machines, tumble dryers, washer–dryers, dishwashers, refrigerators, freezers, microwaves, vacuum cleaners, and ironing equipment. Customers are granted access to these appliances in exchange for a recurring monthly fee, which typically includes delivery, installation, repair services, and equipment replacement when necessary. Rather than purchasing appliances outright, users are able to access their functionality through service-based contractual arrangements. In the case of washing machines and tumble dryers, Homie adopts a pay-per-use configuration whereby the monthly fee is prepaid and progressively deducted according to the number of washing or drying cycles performed. This billing structure links customer expenditure directly to actual usage while allowing the provider to retain responsibility for equipment maintenance and operational continuity over time. Through these arrangements, Homie enables access to household appliance functionality without requiring ownership of the physical assets, while maintaining responsibility for servicing and replacement throughout the usage period.

1.1.3 XaaS and enviromental sustainability

In recent years, increasing regulatory pressure and growing societal expectations regarding environmental responsibility have led manufacturing firms to reconsider their business models in light of sustainability objectives. Within this context, servitization has been identified as a potential enabler for aligning economic value creation with more resource-efficient production and consumption systems (Yang and Evans, 2019; Saccani et al., 2024). In particular, the integration of services into traditional manufacturing offerings allows firms to shift the focus from ownership-based exchanges towards value provision during the operational phase of industrial assets, thereby supporting the decoupling of revenue generation from resource utilization (Yang and Evans, 2019).

The adoption of XaaS business models is frequently associated with sustainability-oriented strategies, particularly in relation to circular economy principles. In XaaS configurations, manufacturers typically retain ownership of physical assets while assuming responsibility for their performance throughout the entire lifecycle. This ownership structure creates incentives for providers to adopt practices aimed at extending product lifetimes and improving resource productivity, including preventive maintenance, repair, refurbishment, and end-of-life recovery activities (Bressanelli et al., 2018; Kjaer et al., 2019).

In practice, XaaS-based service offerings may include end-of-life support activities such as refurbishment, repair, component replacement, remanufacturing, and recycling, allowing providers to extend the operational lifespan of industrial equipment beyond the initial usage cycle. Such lifecycle-oriented service configurations enable manufacturers to retain responsibility for asset performance across multiple stages of use, thereby supporting continued functionality over time and facilitating more effective lifecycle management strategies (Bressanelli et al., 2018).

By maintaining responsibility for the product beyond the point of sale, providers are able to manage its operational phase more directly, thereby supporting lifecycle-oriented strategies consistent with circular economy principles and enabling the recovery of valuable materials and components through remanufacturing or recycling processes (Kjaer et al., 2019). From this perspective, XaaS business models may facilitate the transition from linear production systems towards more circular configurations by enabling the continuous management of products across multiple lifecycle stages (Bressanelli et al., 2018).

By shifting the focus from ownership to value-in-use, XaaS business models support more efficient utilization of industrial equipment and material resources. The possibility to monitor asset usage and performance throughout the operational phase enables providers to optimize maintenance schedules, improve operational efficiency, enhance product durability, and ensure that equipment operates at optimal efficiency levels throughout its use phase (Gebauer et al., 2017; Classen et al., 2023). In turn,

this may contribute to reducing material consumption, minimizing waste generation, and improving overall lifecycle management practices.

Additional environmental benefits may arise from the responsible use of products enabled by XaaS arrangements. Provider ownership and usage- or outcome-based contractual structures can increase utilization rates, reduce idle capacity, and discourage inefficient consumption patterns by aligning customer behavior with performance objectives (Reim et al., 2015; Tukker, 2015; Bressanelli et al., 2018). Continuous monitoring and data-driven optimization may also support improvements in energy efficiency throughout the operational phase of industrial assets (Coreynen et al., 2017; Rapaccini et al., 2020).

Through optimized operation, preventive maintenance, and reduced material throughput, XaaS configurations may indirectly support the reduction of greenhouse gas emissions associated with industrial activities, thereby contributing to decarbonization objectives (Bressanelli et al., 2018; Moreno et al., 2016). Overall, by enabling manufacturers to maintain responsibility for asset performance and lifecycle management, XaaS business models provide a foundation for implementing business practices aimed at improving resource efficiency and supporting more sustainable patterns of production and consumption within industrial contexts (Gebauer et al., 2017; Saccani et al., 2024; Reim et al., 2015).

Examples of sustainability-oriented applications of XaaS business models include outcome-based service offerings such as Lighting-as-a-Service (LaaS) and Cooling-as-a-Service (CaaS), where providers deliver lighting or cooling performance as a service while maintaining ownership and lifecycle responsibility for the installed systems, thereby supporting more efficient resource use over time.

- **Lighting-as-a-Service (LaaS)**

The introduction of new energy-efficient technology is considered a fundamental strategy for lowering environmental impact. Lighting currently accounts for 14% of electricity use worldwide, making it a big concern (Darsy, 2021). The impact of a lighting system occurs largely during use; hence the most efficient method is to limit the impact during periods of product use through lower energy consumption and to lengthen the time of use by increasing longevity, repairability, and upgradeability. To this purpose, the adoption of circular luminaires is a possible alternative, as they employ lights that consume significantly less than the market average and are easy to repair, maintain, and replace. Modularity also permits the design of a product to be changed during its life cycle in response to new needs indicated by customers. Instead of replacing the full luminaire, modules can be replaced or added, helping to protect value and reduce waste (Dzombak et al., 2020; Kouki et al., 2024).

Lighting-as-a-service (LaaS) business models have developed as a potential strategy for the adoption of such technologies. Technological innovation in LED lighting also supported the LaaS model, as the longer life of LEDs meant that the constant sale of bulbs, as in the case of incandescent lights, was no longer a financially feasible business strategy. The deployment of LEDs gives more cost savings and environmental benefits than conventional lighting, from a life-cycle viewpoint, giving energy savings of 50% to 90% compared to conventional lighting technologies. In addition, LED luminaires have an operational lifetime of up to 20 years, or more if constructed correctly. LED technology, paired with the Internet of Things, offers ultimate traceability. Intelligent systems constantly monitor the luminaires and enable preventive maintenance, while also modifying the usage during the life of the product (Dzombak et al., 2020; Darsy, 2021; Kouki et al., 2024).

LaaS offers an alternative based on the use of services rather than ownership of the lighting system. Users pay for the light provided rather than for the lighting equipment itself. This method is based on service contracts in which the lighting providers install, maintain, and take care of the end-of-life of the luminaire, during a certain period based on the customer's demands and contractually stated. In this way, the company offers a circular service in which users purchase a lighting service rather than lights. The result is a preference on both sides for efficiency and durability. In the LaaS business model, there is a change from a transactional relationship to a contractual partnership with a performance commitment. It is the quality of the service offered that defines consumer happiness rather than the product. In practice, the consumer buys a light level (in lux), a rate of availability of amenities, and a guarantee on energy use. This is a long-term model, about 10 years, which requires an ecosystem of financial partners, installations, maintainers, and recyclers (Darsy, 2021; Kouki et al., 2024).

Implementing LaaS as a circular economy paradigm offers economic, environmental, and operational advantages by harmonizing performance and sustainability goals. Typically, the Light-as-a-Service solution includes the design, financing, installation, and maintenance of lighting under a single contract, allowing clients to focus entirely on managing their own business. Upon the termination of a LaaS contract, the company assumes the responsibility of reclaiming the value of the equipment, primarily through the processes of reuse or recycling. The design and ongoing monitoring of product life enable the supplier to select the optimal scenario for each individual product. Through the provision of a financing approach, LaaS enables customers to renovate lighting without the need for any initial investment, so often resulting in prompt reductions in operational expenses. Moreover, the provider assumes the responsibility of both maintaining and updating the systems, thus ensuring their optimal and uninterrupted performance, and facilitating long-term cost savings (Darsy, 2021; Kouki et al., 2024).

Implementing a LaaS business model necessitates a transformation in the company's organizational and cultural practices to generate value for its customers and manage its interactions with other stakeholders. Conversely, from the customers' perspective, outsourcing lighting results in a reliance on the operational efficiency and dependability of the service provider. Any malfunction or disruption of service can immediately impact their industrial operations. Furthermore, the long-term cost to the customer may be greater, as cumulative monthly expenditures for lighting services may eventually surpass the expenses incurred in acquiring and maintaining conventional lighting systems. The privacy concern emerges in LaaS contracts that provide intelligent lighting systems capable of data collection (Kouki et al., 2024).

In around 2012, Philips Lighting (now Signify), in partnership with the Ellen MacArthur Foundation and Dutch architect Thomas Rau, initiated trials of the Light-as-a-Service (LaaS) or pay-per-lux concept (Darsy, 2021). The company provides expert evaluation and strategic planning services to identify the optimal lighting solution for the client's requirements, full implementation of new energy-efficient lighting systems, and elimination of outdated luminaires, together with continuous maintenance and support services. In addition, it offers periodic upgrades and replacements of luminaires and lighting components to guarantee that the system remains current with the most recent technology and energy efficiency criteria (Darsy, 2021; Kouki et al., 2024).

- **Cooling-as-a-Service (CaaS)**

Cooling includes any human activity, design, or technology that dissipates heat and reduces temperatures, typically including refrigeration and air conditioning. Cooling is essential for industrial production, for example for the preservation of food and medicine. The demand for refrigeration is, however, increasing dramatically: the energy required for cooling alone is expected to triple by 2050 (K-CEP, 2018; Khosla et al., 2020). Cooling consumption places a heavy burden on energy resources and the production of cooling technology has significant impacts on sustainability throughout its life cycle. In fact, it contributes not only to increasing energy consumption but also to greenhouse gas emissions and the use of ozone-sensitive refrigerants with high global warming potential (Palafox-Alcantar et al., 2022; Park, 2022). There is therefore an urgent need to reduce energy intensity and pollution from cooling and to ensure that efficient cooling systems are accessible to all who need them. Technological advances can promote energy-efficient cooling based on cleaner and more affordable refrigerants, yet manufacturers often lack incentives to reduce energy and resource use, while demand-side barriers limit the deployment of efficient technologies. To move towards a fair and circular economy for cooling, it is therefore necessary to change the economic models of production and consumption, with servitization business models representing a potential solution to

overcome these barriers and unlock investments in cleaner technologies (Khosla et al., 2022; Zhang et al., 2021).

Cooling-as-a-Service (CaaS) is an example of servitization in which users pay for a certain amount of cooling provided by a service provider instead of purchasing the cooling equipment themselves. The CaaS business model enhances the availability of environmentally sustainable cooling by enabling outcome-based service provision, such as maintaining a specific temperature range, rather than focusing on the physical infrastructure used to supply cooling (Khosla et al., 2020; Park, 2022). A technology provider is responsible for the installation and maintenance of the cooling equipment, with costs recovered through regular payments made by the customer. Payments may be based on usage metrics, such as euros per tonne of refrigeration or euros per kilo of food held in a cold room, or fixed at regular intervals. These arrangements enhance the client's ability to anticipate costs and visualize cost reductions, which is particularly advantageous in highly volatile markets. Alternative business models for cooling increasingly employ advanced equipment technologies and leverage the Internet of Things to provide remote monitoring and embedded sensors, allowing for continuous monitoring and improvement of cooling appliance performance and efficiency (Zhang et al., 2021).

Cooling as a Service offers cost-effective access to cooling solutions, facilitates the reduction of material and resource use, and encourages the adoption of energy-efficient technologies. Customers benefit from reduced energy and maintenance expenses, the absence of initial capital investment, access to advanced equipment, and a predictable pricing system (Khosla et al., 2022; Palafox-Alcantar et al., 2022). In addition, CaaS mitigates perceived technological risks for customers, as they are not required to make direct investments in equipment. By adopting CaaS, technology suppliers are motivated to enhance profitability by selecting effective technologies, optimizing operating efficiency, and ensuring proper maintenance of cooling systems. Preliminary research suggests that CaaS business models have the potential to reduce customer expenses by up to 23% and reduce carbon emissions by optimizing electricity usage and minimizing refrigerant losses (K-CEP, 2018; Khosla et al., 2020). Effective maintenance practices can also lead to significant reductions in electricity consumption, with potential savings of up to 20% (K-CEP, 2018). From an environmental standpoint, CaaS can accelerate the adoption of energy-efficient cooling systems and promote the use of environmentally friendly refrigerants. Providers are incentivized to create solutions with extended lifetimes, for example by employing modular designs that allow for the reuse, replacement, and recycling of components (Park, 2022).

The CaaS business model encounters similar obstacles to other servitization models, including organizational and cultural transformations, risk reduction, increasing client awareness of CaaS, and establishing appropriate monitoring, documentation, and pricing protocols (Khosla et al., 2022).

Furthermore, the financial advantages of energy-efficient equipment are usually realized over a long period, meaning that customers may not immediately experience cost savings. As a result, they often prefer to invest in their core business activities, where the risks and returns of investments are more familiar.

Nevertheless, notable instances of the model's implementation can already be observed. For example, ColdHubs adopted the CaaS model in solar off-grid refrigeration in Nigeria's agriculture industry, resulting in a 50% decrease in food waste and a reduction of 460 tonnes of CO_2 emissions per year by eliminating the use of diesel generators and harmful refrigerants (Khosla et al., 2020). Similarly, Kaer implemented a Cooling-as-a-Service solution in an Indian real estate complex using an AI-powered chiller plant operating with high efficiency and supported by renewable energy sources (Palafox-Alcantar et al., 2022).

1.2 Problem statement

Despite the growing managerial interest in Everything-as-a-Service (XaaS) business models, their effective implementation within manufacturing contexts remains limited. Empirical evidence suggests that, although many industrial firms have initiated pilot projects aimed at exploring as-a-service offerings, only a relatively small proportion has progressed toward fully operational XaaS configurations or succeeded in scaling these initiatives beyond experimental deployments (Scalvini et al., 2023; Relayr, 2022). This discrepancy between strategic interest and actual adoption indicates that the transition from traditional product-centric models to service-based and outcome-oriented offerings entails implementation challenges that are not yet fully understood or systematically addressed.

In particular, the introduction of usage- or outcome-based revenue models requires manufacturers to assume extended responsibility for asset performance throughout the lifecycle, while simultaneously managing delayed cash flows and increased financial exposure associated with retained ownership of physical assets (Rapaccini and Adrodegari, 2022; Arioli et al., 2022). This shift implies that providers remain involved throughout the operational phase of industrial equipment, supporting availability and performance over time rather than transferring ownership at the point of sale. As a result, value creation increasingly depends on the ability to manage lifecycle-related activities such as maintenance, upgrades, monitoring, and operational support across extended time horizons.

Moreover, the implementation of Pay-per-X contractual arrangements relies heavily on the availability of operational data generated during the use phase of industrial equipment, making digital infrastructures and Industry 4.0 technologies a necessary, but not sufficient, enabling condition for the successful deployment of XaaS models. While technological solutions such as remote monitoring,

predictive maintenance, and data analytics may support performance-based service delivery, prior research suggests that manufacturers often lack a clear understanding of how such technological capabilities should be integrated with organizational structures, contractual mechanisms, and ecosystem partnerships in order to support outcome-oriented business models (Zambetti et al., 2021; Cenamor et al., 2017).

The successful implementation of XaaS offerings typically requires the development of new cross-functional competences, coordination mechanisms, and collaborations with financial institutions, service providers, and digital technology partners, representing a substantial transformation of traditional manufacturing business models (Scalvini et al., 2023; Arioli et al., 2022). These transformations affect not only the value proposition but also the revenue logic, risk allocation mechanisms, and governance structures underlying industrial service provision. In this regard, the transition toward XaaS entails the need to align technological infrastructures with contractual arrangements, lifecycle responsibilities, and organizational capabilities across multiple actors within the value ecosystem.

In addition to the challenges highlighted in the existing literature, empirical evidence suggests that manufacturing firms encounter substantial difficulties in translating XaaS concepts into operational business practices. An expert panel study conducted by Scalvini et al. (2023), involving 20 manufacturing firms currently exploring XaaS initiatives, provides insights into the current adoption status of as-a-service business models in industrial contexts. The results indicate that, although the XaaS paradigm is generally perceived as relevant for manufacturing firms, its implementation remains limited across the analyzed sample (Figure 3).

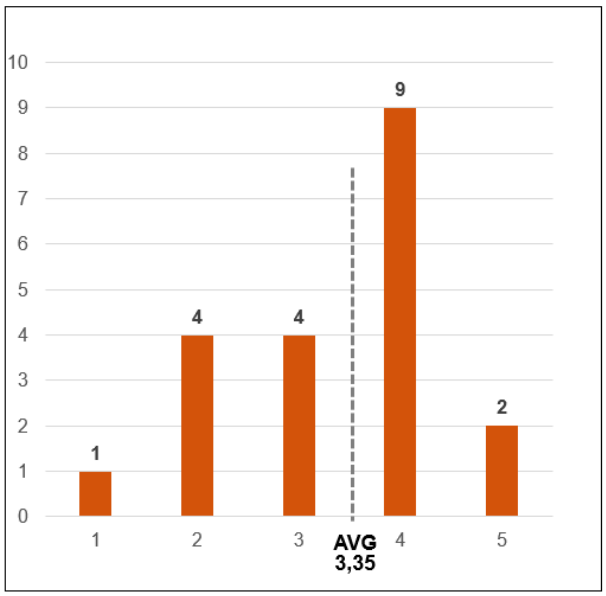


Figure 3 Relevance of the topic (scale ranging from 1 = low to 5 = high) (Scalvini et al., 2023)

Furthermore, while more than half of the surveyed companies reported having initiated internal discussions or pilot projects related to XaaS adoption, only a minority currently provide integrated product–service offerings under an as-a-service logic. In particular, companies expressed a stronger interest in offering services in an as-a-service mode, whereas providing the physical product or industrial equipment through such configurations was generally considered less likely in the short term (Figure 4).

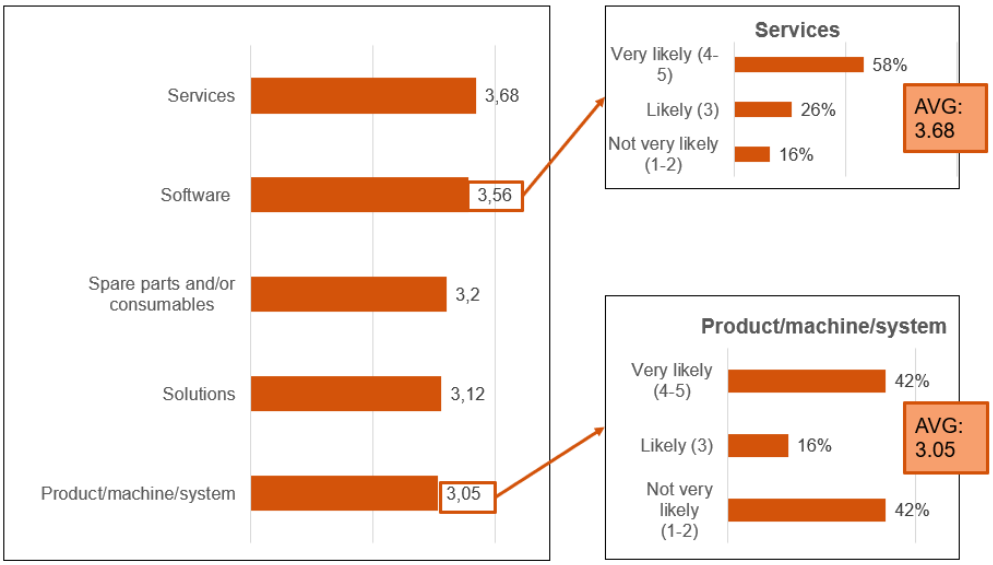


Figure 4 What to sell (Scalvini et al., 2023)

From a revenue model perspective, the study further reveals that manufacturing firms tend to favor subscription-based or pay-per-use schemes, while more advanced outcome- or performance-based contractual arrangements are perceived as less feasible due to challenges associated with the collection and monitoring of operational data during the use phase of industrial equipment (Figure 5).

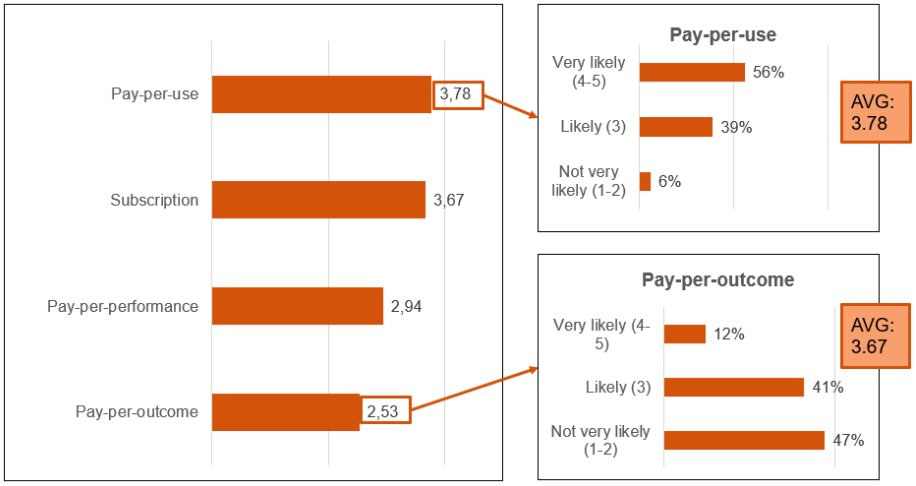


Figure 5 How to sell (Scalvini et al., 2023)

Moreover, the organizational impact of XaaS adoption appears to be unevenly distributed across company functions. While after-sales and marketing roles are identified as key actors in the transition toward XaaS offerings, internal functions such as finance, logistics, and project management are currently less involved in these initiatives, suggesting that XaaS adoption may often occur without a fully integrated organizational transformation (Figure 6).

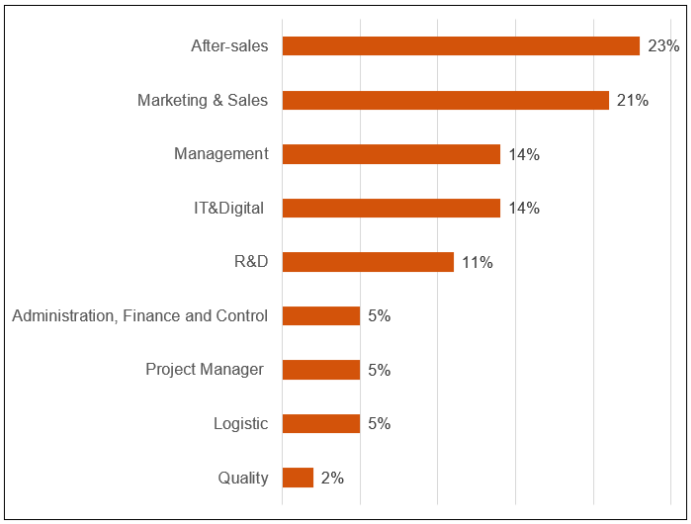


Figure 6 Key roles for the transformation (Scalvini et al., 2023)

In addition to internal organizational challenges, participating firms also reported difficulties related to customer readiness, contractual complexity, digital infrastructure requirements, and financial risk allocation (Scalvini et al., 2023) (Figure 7).

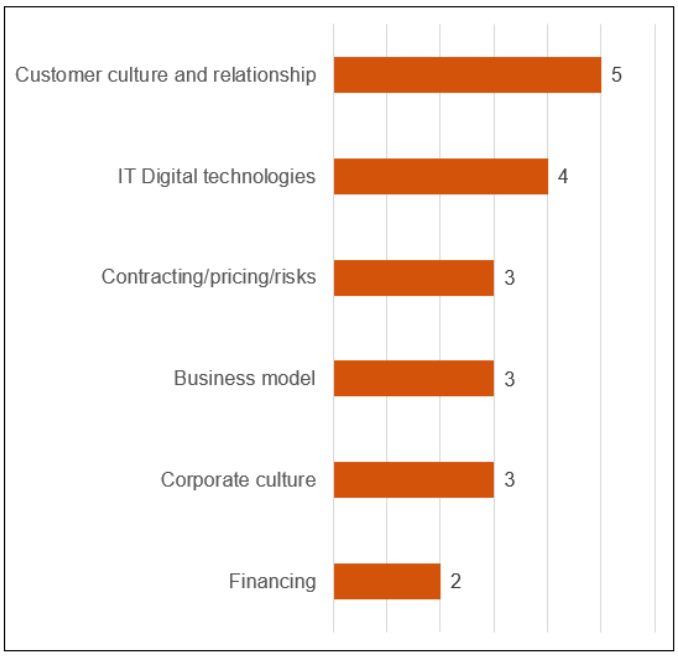


Figure 7 Main challenges (Scalvini et al., 2023)

Taken together, these observations point to a critical problem: although XaaS business models are increasingly explored as a pathway for enhancing competitiveness and sustainability in manufacturing, companies still face significant difficulties in understanding how to configure and implement such models effectively in real-world industrial settings.

2 CHAPTER II – LITERATURE REVIEW

2.1 Review of the existing research

To address the identified research gaps, a systematic literature review was conducted. Following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology (Moher et al., 2009; Page et al., 2021), articles focusing on the XaaS model within the manufacturing sector were retrieved from the Scopus database. In order to refine the research focus and clearly delimit the boundaries of the study (specifically, the context of manufacturing) three keyword groups were defined: (i) XaaS model, representing the core theme of the research; (ii) manufacturing sector, used to ensure contextual relevance; and (iii) servitization, as a foundational concept underlying XaaS in industrial environments. During the preliminary search design, a fourth keyword category related to **model** (including the terms *model*, *business model*, *framework*, and *requirements*) was initially included to capture contributions focusing on conceptual and structural approaches to XaaS implementation. However, this additional filter proved excessively restrictive: a comparison of results confirmed that all publications captured through this preliminary set were also included within the final three-group approach. Moreover, particular attention was devoted to validating the categorization of the keyword **"pay-per***". A targeted assessment confirmed that this expression effectively encompassed specific related terms, such as *pay-per-x*, *pay-per-use*, *pay-per-outcome*, *pay-per-performance*, and *pay-per-availability*. Finally, within the manufacturing category, the keyword **"industry"** was excluded due to the limited consistency and relevance of the papers retrieved, which could have hindered the precision of the sector-specific analysis.

The research was conducted following the four phases of the PRISMA standard:

1. **Identification:** Search queries were developed by combining three keyword categories using the "AND" and "OR" operators and were applied to the Title, Abstract, and Keywords fields of the selected databases. Table 1 reports the keywords that yielded meaningful results for the analysis. This process resulted in the identification of 246 initial records. Prior to screening, 5 records were removed by restricting the search to English-language publications and to specific document types (journal articles, conference papers, reviews, books, and book chapters), leading to 241 papers retained for screening.

Topic	Keywords
XaaS model	As-a-service, *aaS, Everything-as-a-service, Equipment-as-a-service, pay-per*, use-oriented, outcome-oriented, result*-oriented, subscription, Rental, outcome-based
Manufacturing	Manufacturing, Machinery, Product centric, durable good*, manufacturer*, industrial compan*, capital good*
Servitization	Servitization, servitisation, PSS, Product Service System*, Integrated solution*, Hybrid offering*, service transition, service infusion

Table 1 Research keywords

2. **Screening:** The screening phase involved a preliminary assessment of titles and abstracts to evaluate relevance with respect to the research objective. Two main exclusion criteria were applied:
    - papers not related to the manufacturing sector of physical goods in a broad sense (motivation 1);
    - papers that did not provide a comprehensive description of the XaaS model or its specific manifestations (motivation 2).

    As a result of this process, 131 papers were excluded, and 110 papers were retained for full-text retrieval.
3. **Eligibility:** The 110 retrieved papers were subsequently examined in full to assess their eligibility and alignment with the research scope. Following the full-text analysis, 17 papers were excluded due to insufficient relevance or misalignment with the study objectives. Consequently, 93 papers were deemed eligible.
4. **Included:** To enhance the completeness of the review, 4 additional papers not directly captured through the keyword-based search were included using a citation-based selection technique. Specifically, a citation analysis was conducted using the Biblioshiny interface of the Bibliometrix package to identify highly influential and frequently cited contributions within the initial dataset. These papers were subsequently screened against the predefined inclusion criteria and incorporated when found to be relevant to the research scope. Through this process, four key publications, including foundational works by Tukker (2004; 2015), were identified and included due to their recurring presence and recognized relevance in the literature.
5. The final pool consists of 97 articles (Figure 8).

To ensure the currency and completeness of the review, the literature search was updated in December 2025 using the same search protocol, databases, keywords, and inclusion criteria adopted in the original search. Any additional publications identified through this update were screened and incorporated into the final dataset where relevant.

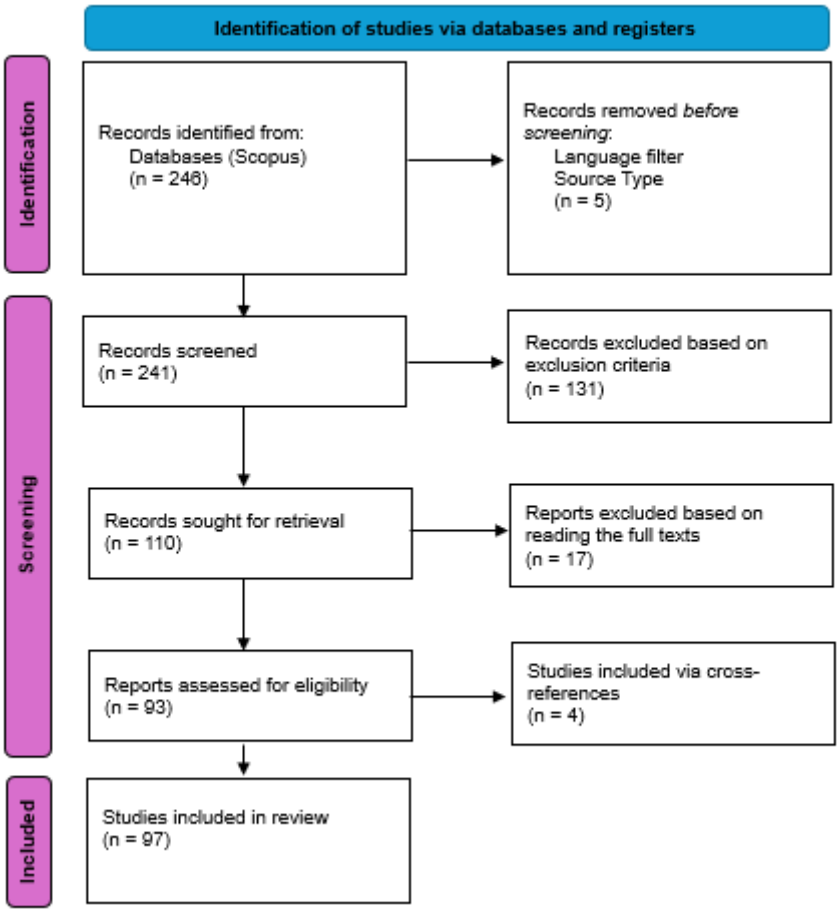


Figure 8 Literature review steps

2.2 Findings from the Systematic Literature Review

The analysis encompassed a descriptive and thematic examination of all pertinent articles. The descriptive analysis employed a deductive technique, which involved categorizing the articles based on various criteria such as year, number of citations, paper type, subject area, methodology used and relevant sector. The purpose was to detect any patterns or trends. The theme analysis, however, followed an inductive approach to provide a panoramic of XaaS in the literature by examining the key features of this model.

2.2.1 Temporal distribution and citations

The analyzed articles were all published between 2006 and 2026 (extraction period) (

Figure *9*). The first contributions appeared in 2006, followed by a limited production until 2015, suggesting that the topic was still in an early exploratory stage within the academic landscape. A substantial growth can then be observed from 2016 onwards, with a remarkable surge in publications from 2018 to 2022, during which more than 53% of the sample was released. This trend highlights

the recent and evolving nature of the phenomenon and how it has increasingly been framed using the *aaS terminology*, particularly in connection with digital transformation processes.

Furthermore, the analysis of the most cited papers in those years reveals a growing emphasis on the *aaS model* and its correlation with circular economy principles (Yang et al., 2018; Souza-Zomer et al., 2018), confirming the theoretical convergence between servitization, digitalization, and sustainability. Although two highly cited foundational papers (Tukker, 2004; Tukker, 2015) were included in the dataset and significantly increased the citation peak in those years, their presence should be interpreted as a reflection of their seminal role in shaping the theoretical foundations of product–service systems and, by extension, XaaS models. These papers do not represent an early concentration of aaS-focused research but rather constitute theoretical cornerstones that continue to influence contemporary studies. Their citation spikes, therefore, act as methodological anchors rather than indicators of publication trends within the extraction period. The apparent decline in scientific production after 2023 should be interpreted with caution, as it is likely due to indexing delays in Scopus that affect the most recent years (2024–2026), rather than indicating a reduced interest in the subject.

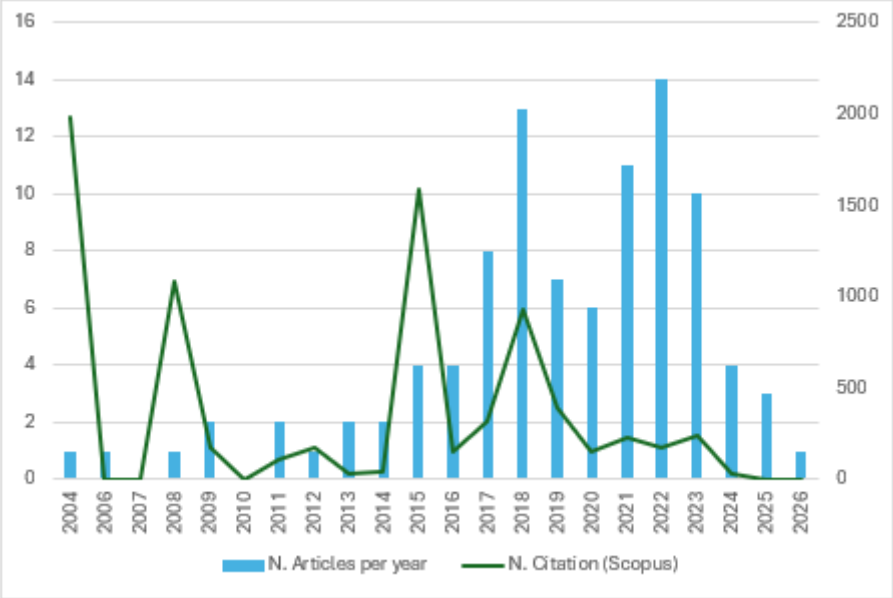


Figure 9 Temporal article distribution and number of citations

Table 2 reports the most cited articles within the dataset, based on Scopus citation counts retrieved during the extraction period. These publications represent the seminal and most influential contributions in the field, shaping the theoretical foundations of product–service systems (PSS) and XaaS-related research. Their prominence reflects both the consolidation of core conceptual frameworks (e.g., Tukker, 2004; Tukker, 2015) and the evolution of the domain toward themes such

as circular economy, business model innovation, and outcome-based services. The table provides an overview of these cornerstone works, highlighting their authorship, year of publication and citation impact.

Most cited papers Scopus	Ref.	N. Citations
Eight types of product-service system: Eight ways to sustainability? Experiences from suspronet	Tukker, 2004	1982
Product services for a resource-efficient and circular economy - A review	Tukker, 2015	1535
Exploring the financial consequences of the servitization of manufacturing	Neely, 2008	1087
Product-service systems business models for circular supply chains	Yang et al., 2018	179
Industrial ecology at factory level - A conceptual model	Despeisse et al., 2012	168
Exploring the challenges for circular business implementation in manufacturing companies: An empirical investigation of a pay-per-use service provider	Souza-Sommer et al., 2018	157
The path to outcome delivery: Interplay of service market strategy and open business models	Visnjic et al, 2018	146

Table 2 Most cited papers

2.2.2 Type of pubblications

Figure 10 illustrates the temporal distribution segmented by the type of publications included in this review. Journal articles consistently represent the dominant document type. A relevant portion of the contributions consists of conference papers, especially during the years of highest productivity. This trend reflects the exploratory nature of the topic and its strong positioning within engineering and management-focused venues. Book chapters and review articles remain less represented, though their presence in the most recent years is noteworthy: the increasing (although still modest) number of reviews highlights a growing effort to consolidate and characterize the XaaS model, signaling a maturing body of knowledge. Overall, the diversification of document types and the rise in review papers provide additional evidence of the increasing maturity and academic attention devoted to the domain.

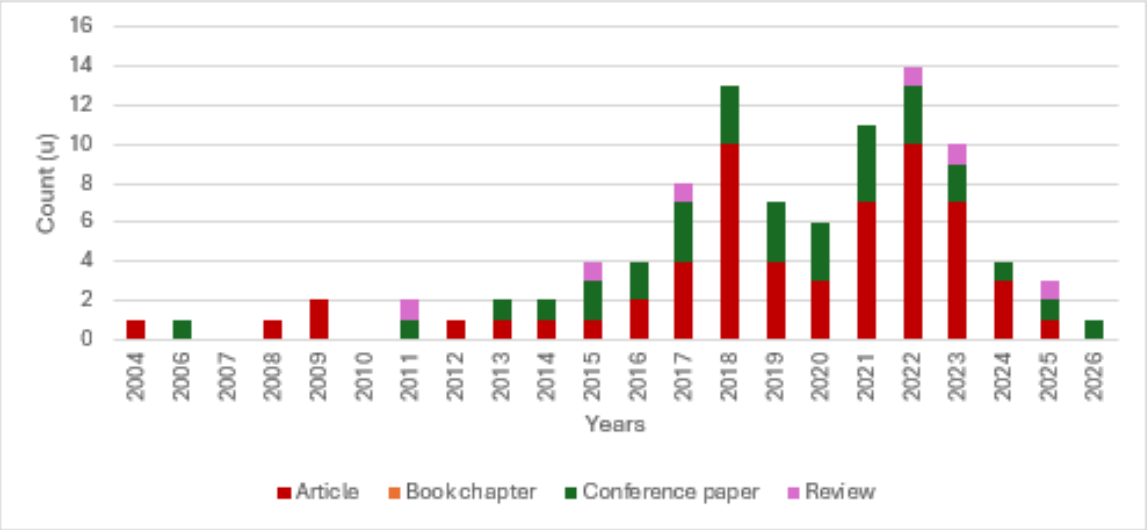


Figure 10 Type distribution

2.2.3 Scopus classification

Figure 11 illustrates the distribution of the analyzed papers across Scopus subject areas, highlighting the interdisciplinary nature of the research domain and confirming the fragmented structure of the related literature. The classification of the selected documents according to the Scopus database reveals a pronounced multidisciplinary orientation, with the Multidisciplinary category representing the most relevant area in terms of published output (39 articles across 16 journals). This result reflects the cross-cutting character of the topic, which spans multiple scientific and managerial perspectives. A significant contribution also emerges from the Business, Management and Accounting domain, which includes 28 articles published in 17 journals, underscoring the strong managerial and strategic relevance of the topic. Computer Science further contributes to the research landscape, with 14 articles distributed across 8 journals, highlighting the importance of digital, informational, and systems-related aspects. Environmental considerations are also present, as evidenced by 6 articles published in 4 journals classified under Environmental Science, while Engineering plays a more limited role in the final sample, accounting for 4 articles across 3 journals. It should be noted that for 6 articles included in the review, Scopus did not provide information regarding the associated journal source; consequently, these contributions could not be assigned to any specific subject area and are therefore not reflected in the journal-based classification. Overall, the observed distribution confirms the inherently interdisciplinary nature of the research field, with contributions spanning multiple Scopus domains rather than being concentrated within a single disciplinary area.

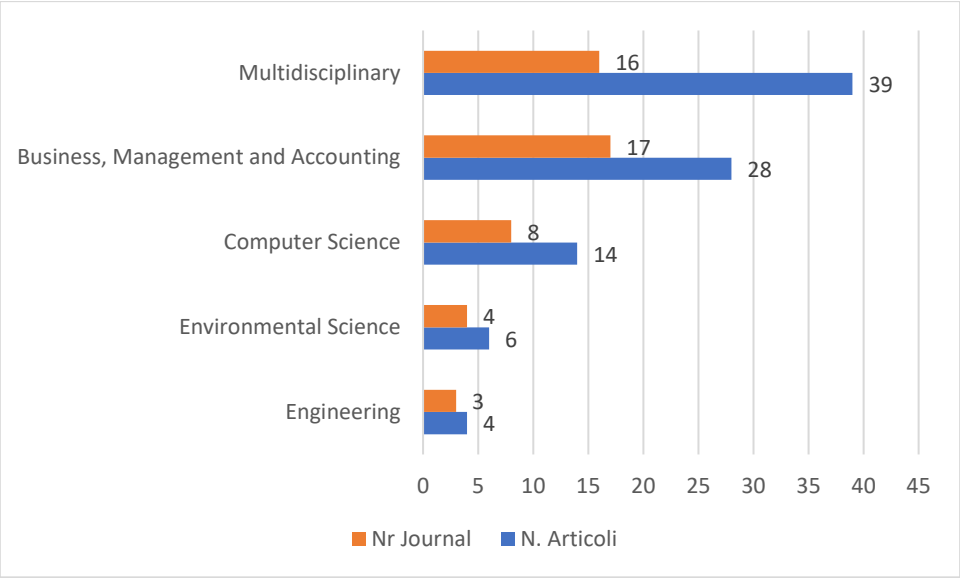


Figure 11 Classification according to the Scopus database

2.2.4 Methodology

The 97 final papers were categorized according to their methodological approach into two main groups: “theoretical” (27) and “empirical” (70) (Figure 12).

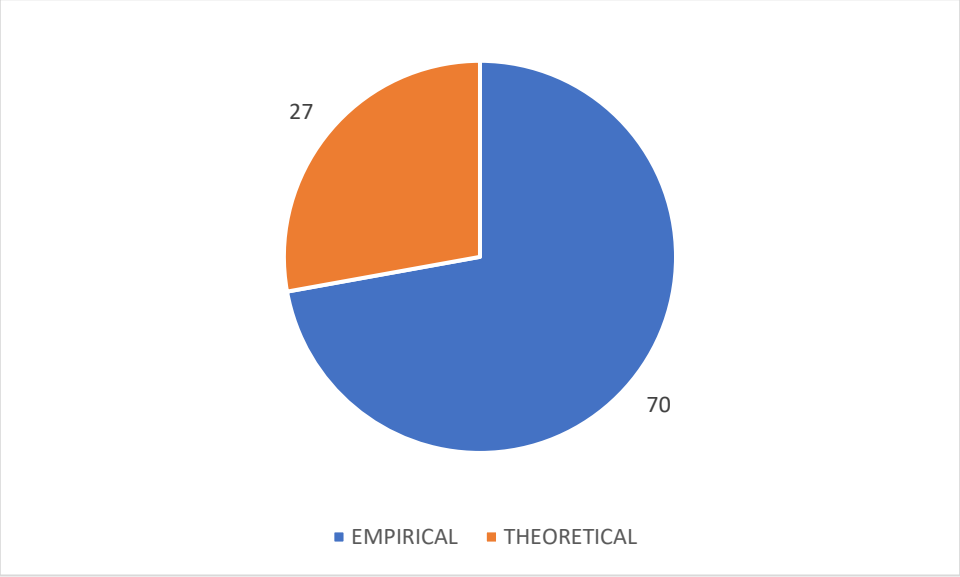


Figure 12 Empirical and Theoretical papers

Furthermore, within each group, qualitative and quantitative approaches were differentiated (Table 3)

PAPER TYPE	TYPOLOGIES	METHODS	TOTAL	%
Theoretical	Qualitative	Literature review	8	8%
		Conceptual development	15	15%
	Quantitative	Analytical model	4	4%
Total			**27**	**28%**
Empirical	Qualitative	Case studies	50	52%
		Action research	3	3%
		Expert panel	3	3%
	Quantitative	Survey	2	2%
		Panel data Analysis	3	3%
		Analytical model	9	9%
Total			**70**	**72%**
Overall Total			**97**	**100%**

Table 3 Methodology

The theoretical articles were subdivided into three methodological subgroups: i) literature reviews (8, qualitative), ii) conceptual development (15, qualitative) and iii) analytical models (4, quantitative). Articles in the first category provide a structured synthesis of existing knowledge on a specific topic. The second category focuses on the development of interpretive or conceptual models aimed at advancing theoretical understanding. Lastly, the third subgroup includes computational or mathematical models intended to simulate or explain system behaviours. Empirical papers were categorized based on their methodological orientation. For qualitative approaches, three subcategories were identified: case studies (50), action research (3), and expert panels (3). For quantitative methodologies, three groups were defined: surveys (2), panel data analysis (3), and analytical models (9). Case studies, action research, and expert panels examine real-world contexts through observations, interviews, and expert insights. In contrast, quantitative analysis relies on numerical data, statistical analysis, or computational modelling to generalize, test, or predict phenomena. Out of the publications analyzed, 72% were empirical, while 28% were theoretical. This distribution highlights the limited presence of conceptual or theory-building works in the XaaS field, reinforcing the relevance of this study in contributing to a more structured conceptualization and clearer definition of the model. Among the empirical papers, 71% employed case studies (50 articles), confirming the strong emphasis on observing organizations that have already implemented XaaS-related models. This pattern reflects the field's orientation toward understanding practical adaptations, identifying challenges, and deriving actionable recommendations for firms considering this transition. This tendency is further supported by the number of works dedicated to conceptual development (15) and those proposing analytical models derived from empirical data (9), which suggests a progressive movement toward formalizing theoretical constructs and developing more

rigorous explanatory or predictive models within the XaaS domain. Additionally, the presence of multiple methodological families (qualitative, quantitative, hybrid analytical approaches) indicates a maturing research field, where descriptive investigations are increasingly complemented by model-based analyses aimed at generalization and theory refinement.

2.2.5 Sectors distribution

Focusing only on empirical papers, it is notable that the majority of the publications (52) concentrate on a single sector, while 17 studies address two or more sectors simultaneously. This distribution (Figure 13) indicates that empirical research on XaaS tends to focus on sector-specific implementations, suggesting a strong interest in understanding how the model is adopted within particular industrial contexts, rather than exclusively through cross-sector comparisons.

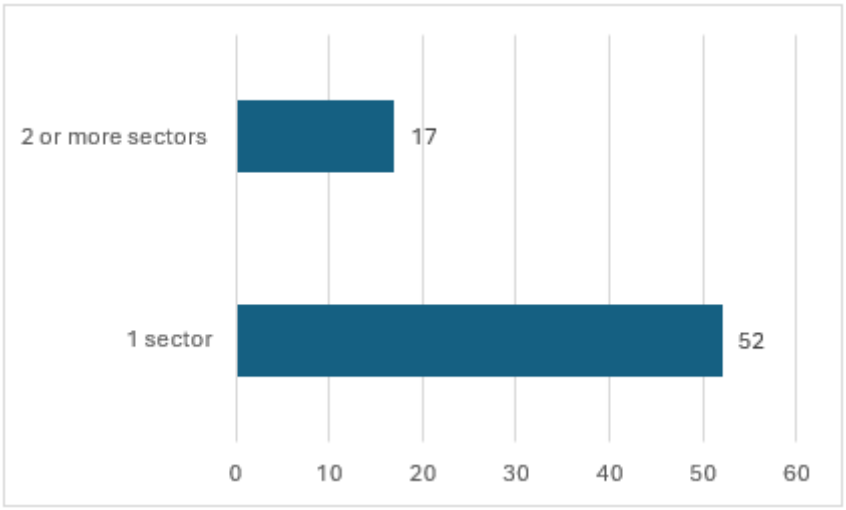


Figure 13 Number of sectors per paper

Upon examining the distribution of sectors depicted in Figure 14, it becomes evident that the machinery and equipment sector is the most frequently investigated, with 29 occurrences. The automotive industry follows with 15 cases, while studies also address the household appliance and consumer electronics sector 17 times. The defence, aviation, and aerospace sector appears in 10 publications, whereas 13 papers analyse XaaS implementations in generic or non-sector-specific industrial settings. The remaining sectors, energy and gas (6), construction (4), textile and clothing (4), material handling (2), and furniture (2), are less represented. These findings highlight the predominance of manufacturing-oriented OEMs in XaaS research, confirming their central role in advancing servitized and usage-based business models. At the same time, the presence of multiple sectors, ranging from mobility-as-a-service in the automotive industry to pay-per-wash models in the appliance sector, and the historical power-by-the-hour model in aviation, demonstrates the broad applicability of XaaS and its diffusion across heterogeneous industrial domains. This variety

reinforces the idea that XaaS adoption is not limited to high-tech industries but is progressively permeating diverse markets with different levels of technological maturity.

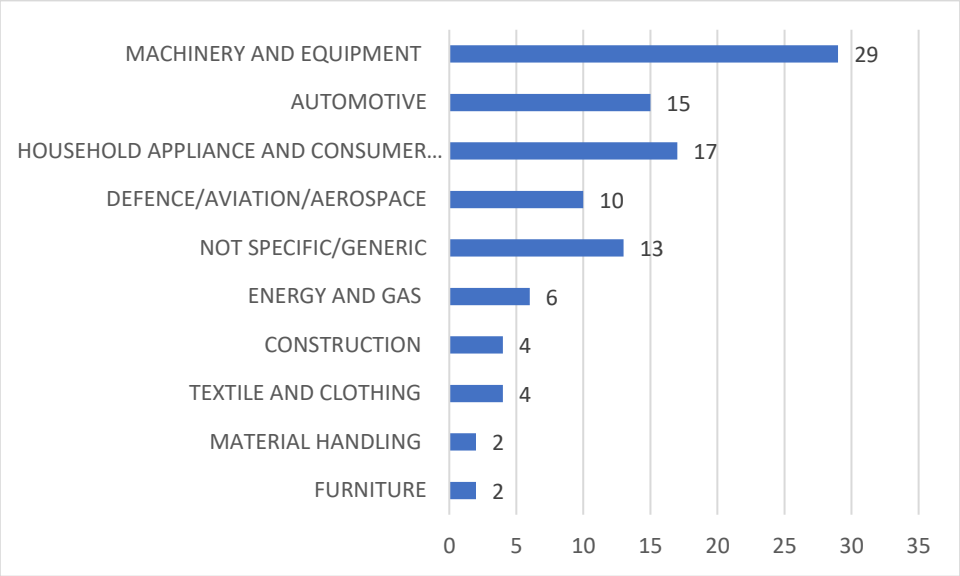


Figure 14 Sector distribution (empirical papers)

2.2.6 Actors, products and markets involved

The analysis of actor involvement across the empirical publications reveals three main categories: users, retailers/service providers, and manufacturers (Figure 15).

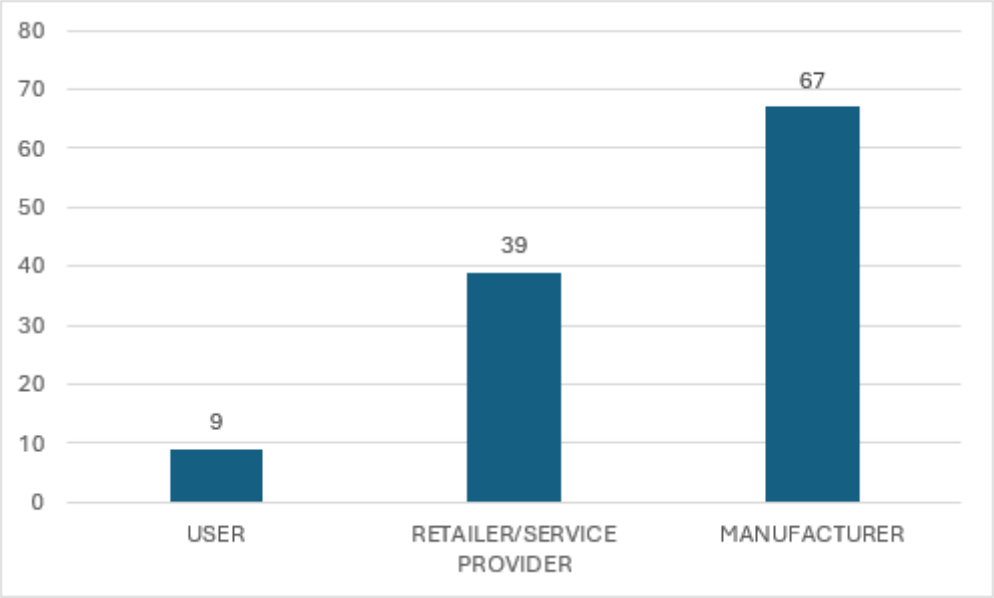


Figure 15 Distribution of actors involved in the analyzed empirical papers

Manufacturers appear in 67 papers, confirming their central role in the adoption and delivery of XaaS models. Retailers and service providers also represent a substantial share, being considered in 39

studies, while only 9 publications focus primarily on end-users. This distribution highlights a strong provider-centric perspective within the XaaS literature, where value creation, capability provision, and business model innovation are predominantly examined from the standpoint of organizations that design, integrate, or deliver the service rather than from the final customer's experience.

With respect to the type of offering (Figure 16), 42 publications analyse XaaS applied to finished goods, while 24 address generic or non-specified products, and 9 focus on components. This confirms the prevalence of OEMs and full-product manufacturers in XaaS-related research, as finished goods provide a clearer basis for studying product–service integration, ownership models, and pay-per-use strategies. Conversely, component-level XaaS models remain less explored, suggesting an opportunity for future studies to investigate modular, subsystem-based servitization.

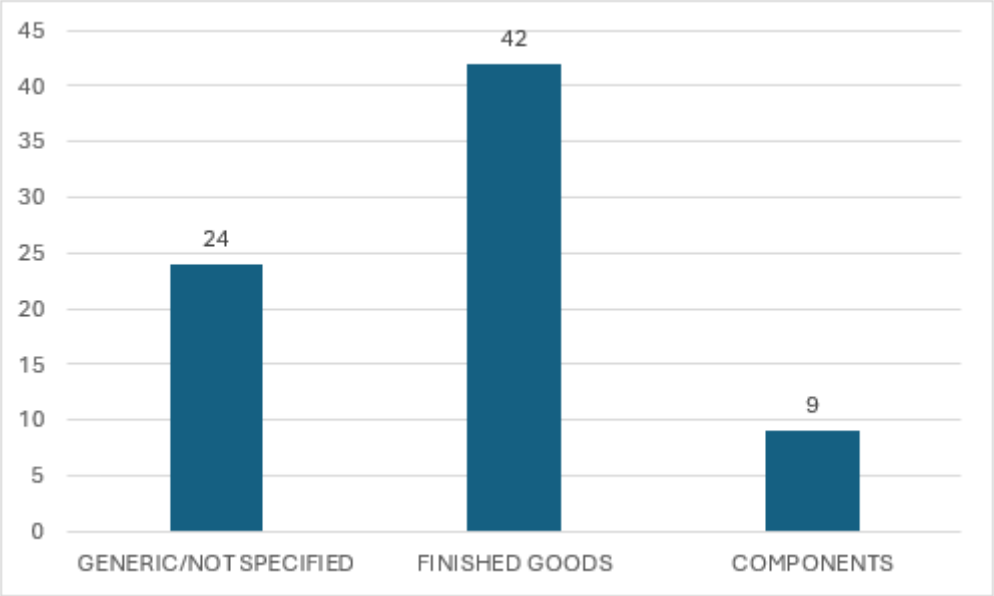


Figure 16 Product type described in the empirical papers

Regarding the targeted market (Figure 17), 45 papers examine B2B contexts, while 24 focus on B2C, and another 24 investigate hybrid or mixed configurations. This means that 46% of the papers are B2B, 25% B2C, and 25% mixed, indicating that although XaaS originated and is still strongly rooted in industrial settings, it has gained increasing relevance in consumer markets (e.g., mobility-as-a-service, appliances-as-a-service). The balanced distribution between B2C and hybrid studies also suggests a gradual democratization of XaaS models beyond traditional business environments.

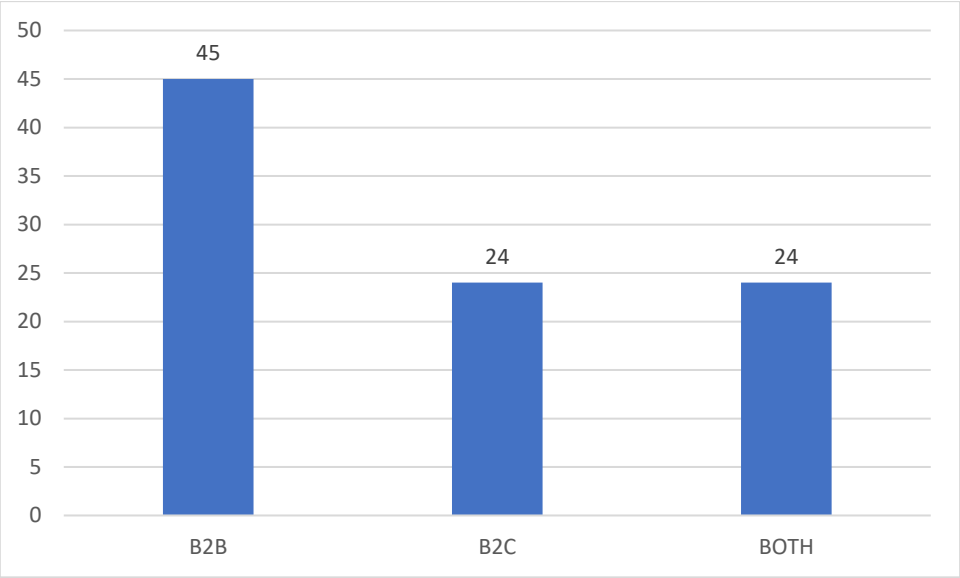


Figure 17 Market orientation of the analyzed papers

Overall, the combined evidence from these three dimensions (actors, product type, market type) demonstrates that the XaaS literature remains predominantly oriented toward manufacturers, finished goods, and B2B markets, yet it also reflects an ongoing diversification of the model. The emerging presence of service providers, component-level offerings, and consumer-oriented implementations highlights the progressive expansion and maturation of XaaS across different value chain positions and market configurations.

2.2.7 Tukker's classification

The analyzed articles were classified according to Tukker's (2004) three macro-categories of Product–Service Systems, Product-Oriented (PO), Use-Oriented (UO), and Result-Oriented (RO), as well as the seven specific subcategories included in Tukker's original framework. Because many papers describe multiple service configurations or hybrid models, each publication may fall into more than one category or macro-category. The distribution across the macro-categories (Figure 18) shows a clear predominance of Result-Oriented (RO) models, addressed in 59 papers. This category includes outcome-based, performance-based, and function-oriented services, and its prominence suggests that the academic literature increasingly associates XaaS models with performance delivery, guaranteed outcomes, and pay-for-results mechanisms, reflecting the shift from ownership to service-based value creation. Use-Oriented (UO) models represent the second largest group, with 45 papers. This confirms strong research interest in access-based models such as leasing, renting, sharing, and pay-per-use arrangements, configurations that align directly with XaaS logic and digital-enabled service delivery. Finally, Product-Oriented (PO) models appear in 14 papers, indicating that although traditional service additions (e.g., product-related services, maintenance, consultancy) remain part of

the servitization landscape, they represent a smaller share of XaaS-focused publications. Their presence highlights continuity with earlier servitization forms but also underscores the transformation toward more advanced service models.

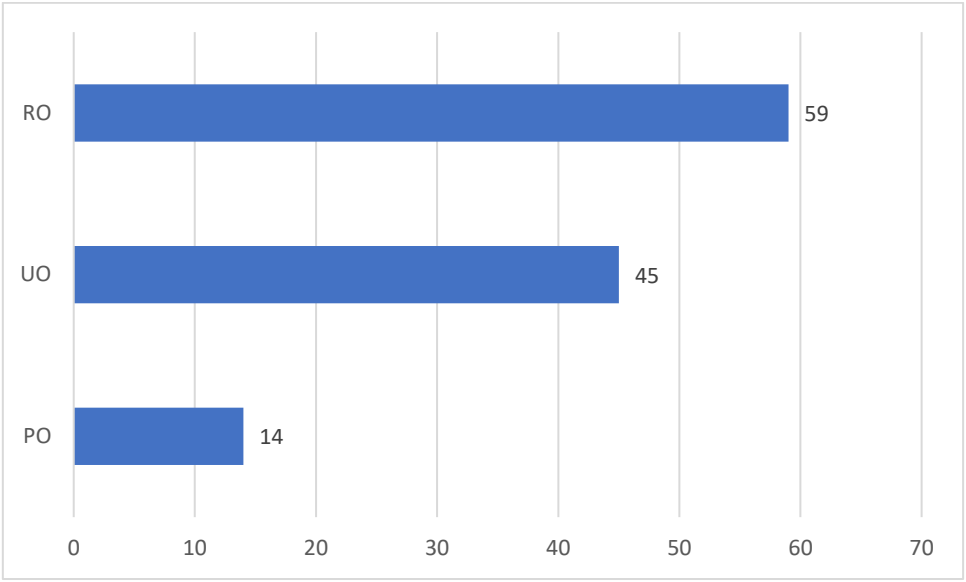


Figure 18 Distribution of papers across Tukker's (2004) three PSS macro-categories (multiple classifications per paper possible)

A more granular distribution (Figure 19) provides deeper insight into the typologies considered. Functional Result (45) and Product Lease (38) emerge as the most frequent subcategories, reinforcing the dominance of performance-based contracting and access-over-ownership models. Pay-per-service-unit follows closely with 35 occurrences, confirming the relevance of consumption-based or usage-based revenue models, core elements of the XaaS model. Other use-oriented services, product renting/sharing (17) and product pooling (4), are less represented yet still indicate growing interest in shared-access business models, particularly in sectors influenced by digital platforms.

On the product-oriented side, product-related services (13) remain relevant, whereas advice and consultancy (1) shows limited presence. The relatively low occurrence of activity management/outsourcing (6) in the sample is notable, suggesting that although outsourcing complex activities has long been associated with advanced PSS, it is less frequently framed explicitly as XaaS within the selected literature. Taken together, these findings reveal that scholarly attention overwhelmingly gravitates toward use-based and result-based service models, consistent with the evolution of digital servitization and the core logic of XaaS. This also indicates that XaaS research is predominantly positioned within outcomes-driven and access-driven frameworks rather than traditional service add-ons.

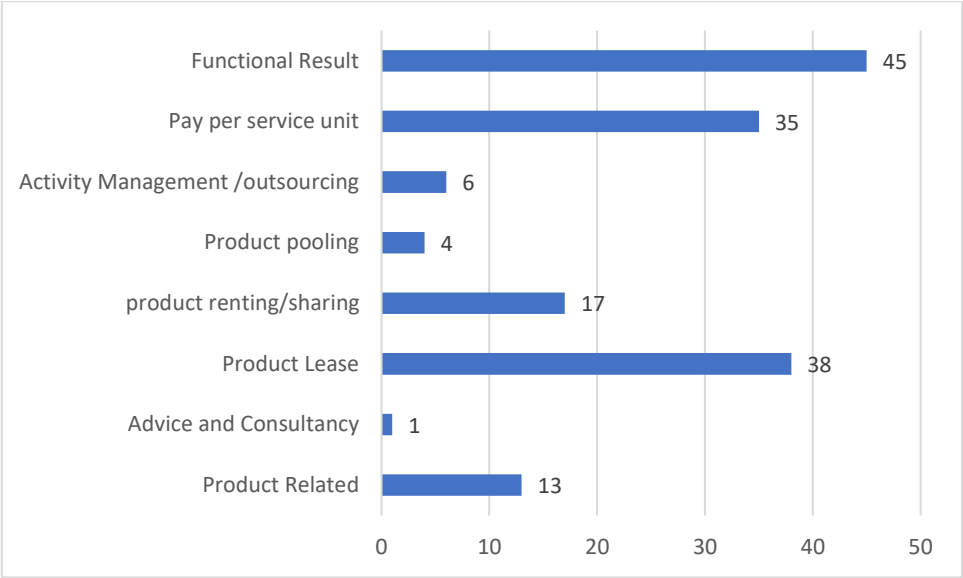


Figure 19 Distribution of papers across Tukker's (2004) seven PSS subcategories (multiple classifications per paper possible)

This chapter has provided a descriptive analysis of the papers identified through the literature review. The content of these studies is examined in the following chapter, with the aim of identifying existing research gaps and thereby establishing a clear justification for the research objectives of this dissertation.

3 CHAPTER III – GAPS, OBJECTIVES, AND RESEARCH QUESTIONS

3.1 Identification of research gaps emerging from the literature on XaaS in manufacturing

The systematic analysis of the selected body of literature reveals four primary research gaps that characterize the current state of knowledge on Everything-as-a-Service (XaaS) within manufacturing contexts. Although the model is increasingly discussed as a transformative model enabling servitization, digitalization, and sustainability transitions, the literature remains fragmented and unevenly developed. In particular, the review highlights (1) conceptual fragmentation and definition overlap in XaaS research, (2) lack of integrative frameworks for characterizing XaaS in manufacturing, (3) a lack of actionable guidelines and implementation roadmaps for XaaS adoption in manufacturing, and (4) the fact that the XaaS–sustainability relationship remains underexplored and under-evidenced. The four gaps identified are illustrated below:

- **Conceptual fragmentation and definitional overlap in XaaS research**

A first and consistently emerging gap concerns the fragmented conceptualization of Everything-as-a-Service (XaaS) within manufacturing research. Despite the growing adoption of the term, the literature does not converge toward a shared definition. Instead, XaaS is interpreted through multiple partially overlapping lenses, resulting in blurred conceptual boundaries and limited theoretical consistency. Rather than reflecting a lack of scholarly attention, this fragmentation stems from the proliferation of heterogeneous definitions that position XaaS in relation to adjacent constructs such as Product-Service Systems, digital servitization, outcome-based models, subscription offerings, and platform-based services. These concepts are frequently used interchangeably or treated as implicit equivalents, often without explicitly clarifying whether XaaS represents an evolution of existing paradigms or a distinct analytical category. Early research had already pointed to insufficient theoretical grounding in advanced service models (Azarenko et al., 2009), yet subsequent studies suggest that definitional divergence has persisted over time. Benedettini et al. (2015) note unresolved conceptual tensions within servitization research, while Batista et al. (2017) call for clearer conceptual delineation in service-oriented manufacturing transformations. Similarly, Annarelli et al. (2020) highlight uncertainty surrounding the defining characteristics of service-based competitive strategies, further indicating the absence of stable conceptual boundaries. The issue becomes particularly evident in digitally enabled contexts. Charro and Schaefer (2018) observe that the integration of digital technologies has expanded the interpretive scope of service models, often without corresponding conceptual refinement. Chun and Lee (2017) likewise emphasize definitional imprecision in advanced service offerings, suggesting that the increasing diversification of service logics may be outpacing theoretical consolidation. More recent empirical evidence also points to limited managerial

understanding of XaaS-type models, reinforcing the idea that conceptual ambiguity extends beyond academia (Arioli et al., 2022). Taken together, these observations indicate that the core challenge is not the absence of definitions but their multiplicity. The coexistence of competing interpretations prevents theoretical convergence and makes it difficult to determine what should legitimately be classified as XaaS. As a result, the construct remains analytically underbounded, constraining cumulative knowledge development and reducing comparability across studies.

- **Lack of Integrative Frameworks for Characterizing XaaS in Manufacturing**

A second major gap emerging from the literature concerns the absence of integrative analytical frameworks capable of systematically characterizing XaaS configurations within manufacturing contexts. While the growing diffusion of service-based business models has stimulated substantial scholarly attention, existing research predominantly focuses on isolated dimensions of XaaS rather than providing comprehensive structures through which the phenomenon can be consistently described and analyzed. Several studies explicitly call for more robust modeling approaches. Azarenko et al. (2009) already emphasized the limited understanding of the structural conditions underpinning advanced service models, highlighting the need for clearer analytical representations. More than a decade later, similar concerns persist. Bertoni and Bertoni (2019) underline the lack of structured methods to support the design and evaluation of integrated product–service offerings, while Bech et al. (2019) point to insufficient methodological support for assessing lifecycle implications in service-oriented solutions. Recent contributions reinforce this fragmentation. Hidalgo-Crespo et al. (2025) identify a shortage of performance indicators and design-oriented tools capable of supporting the transition toward Product-as-a-Service models. Likewise, Buerkle et al. (2023) note that although technological infrastructures increasingly enable service-based offerings, structured models to guide their configuration remain underdeveloped. In the specific context of Manufacturing-as-a-Service, Andersen and Bering (2023) further highlight the absence of consolidated methodologies for describing how such systems should be organized and operationalized. Importantly, the limitation does not appear confined to technological or design aspects. Batista et al. (2017) stress the need for frameworks that capture network-level value creation, suggesting that existing approaches struggle to represent the systemic nature of service ecosystems. Similarly, Bettoni et al. (2021) advocate for analytical models capable of reflecting the dynamic evolution of smart service systems rather than static configurations. Earlier servitization research also questioned the generalizability of available models across industries, pointing to their restricted explanatory power (Benedettini et al., 2015). Taken together, these studies indicate that the current body of knowledge lacks a cohesive framework through which XaaS can be holistically characterized. Existing approaches tend to isolate individual elements, such as design parameters, technological enablers, lifecycle considerations, or network

structures, without integrating them into a unified analytical perspective. As a result, scholars face difficulties in systematically comparing XaaS configurations, identifying their defining dimensions, and accumulating transferable knowledge across empirical settings. Developing integrative frameworks therefore represents a critical step toward advancing the analytical maturity of XaaS research.

- **Lack of actionable guidelines and implementation roadmaps for XaaS adoption in manufacturing**

A third major gap emerging from the reviewed literature concerns the limited availability of actionable guidance to support the organizational adoption and implementation of XaaS in manufacturing. While many studies discuss the strategic potential of shifting toward service-based and "as-a-service" models, they repeatedly acknowledge that firms lack concrete, prescriptive roadmaps translating XaaS principles into operational steps, governance routines, and implementation pathways. This gap is visible in contributions that explicitly call for structured transition guidance and readiness instruments. For example, Exner et al. (2017) note the insufficient development of maturity models for assessing organizational readiness and, crucially, the limited availability of actionable recommendations that connect assessment outcomes to transformation steps. In a similar vein, research on subscription-oriented service models in manufacturing emphasizes that adoption is hindered by the scarcity of documented "how-to" evidence: Arioli et al. (2022) report limited knowledge diffusion and a shortage of successful cases that firms can use as templates when implementing subscription-based XaaS-like solutions. Across industrial use-oriented and outcome-oriented contexts, the literature repeatedly stresses that implementation knowledge remains thin and context-bound. Baecker et al. (2021) highlight limited empirical evidence on implementation, an insufficient understanding of organizational conditions and capabilities required to operationalize such models, and the need for guidance, particularly tailored to SMEs. In technology-intensive XaaS variants, the same pattern reappears: Buerkle et al. (2023) describe an early-stage adoption landscape where technological availability outpaces industrial utilization, with usability, complexity, and lack of standardized plug-and-play architectures acting as practical adoption barriers, again implying a need for implementation-oriented principles rather than only conceptual discussions. Importantly, the lack of adoption guidance is not confined to a single industry setting. Evidence from complex engineered systems suggests that firms struggle to operationalize XaaS because real-world implementation remains underexplored. Azcárate-Aguerre et al. (2022) explicitly point to limited empirical evidence on implementation and real-world performance of XaaS models and emphasize the need for pilot projects and experiments to validate feasibility. Even in

contexts where technology is considered an enabler, barriers persist at the organizational and institutional level: Azcárate-Aguerre et al. (2022) underline a persistent gap between technological innovation and mainstream adoption, shaped by managerial and institutional constraints and by limited understanding of front-end organizational transformation when shifting from product sales to performance-based service delivery. Finally, the same adoption-oriented deficit is reflected in design-for-transition perspectives. Hidalgo-Crespo et al. (2025) identify a scarcity of performance indicators and design guidelines that firms can use during Product-as-a-Service transitions, reinforcing the idea that manufacturers often lack practical decision support across the phases of implementation. Taken together, these studies suggest that XaaS research in manufacturing is still disproportionately weighted toward describing opportunities and challenges, while offering insufficient operational guidance on how to adopt XaaS in practice. The dominant missing element is therefore not another conceptual argument in favor of XaaS, but prescriptive, empirically grounded implementation knowledge, e.g., staged roadmaps, capability-building pathways, maturity/self-assessment tools linked to concrete actions, and validated guidelines derived from pilots and longitudinal evidence.

- **The XaaS–sustainability relationship remains underexplored and under-evidenced**

A fourth major gap emerging from the reviewed literature concerns the still limited and uneven understanding of how XaaS contributes to sustainability in manufacturing. Although XaaS is frequently associated, sometimes implicitly, sometimes explicitly, with resource efficiency, circular economy strategies, and dematerialization, the sustainability argument is often articulated at a conceptual level, while rigorous empirical validation and standardized assessment approaches remain scarce. In other words, sustainability is widely invoked as a *promise* of XaaS, but far less frequently demonstrated through consistent metrics, lifecycle-based evaluations, or real-world evidence. Several studies emphasize this lack of robust assessment and validation. Bech et al. (2019) point to insufficient methodological guidance for evaluating environmental performance in integrated product–service solutions and highlight that lifecycle-oriented sustainability assessments are often not embedded into the design and decision-making process. Similar concerns are raised by Haber and Fargnoli (2021), who call for structured decision-support approaches capable of jointly capturing customer value and environmental outcomes—suggesting that sustainability and value logic are still not coherently operationalized in service-based models. From a broader PSS and sustainable transition perspective, Costa et al. (2015) stress the scarcity of real-world implementations of sustainable PSS and the limited integration of social dimensions, indicating that the sustainability discourse remains under-empiricized and incomplete. Pallaro et al. (2017) likewise highlight the need for integrated approaches linking outcome-based service logic with circular strategies and closed-loop thinking, implying that the mechanisms connecting “as-a-service” logics to circular outcomes

are still insufficiently theorized and tested. Beyond methods, the literature also signals conceptual and behavioral tensions that make sustainability impacts uncertain. Allais and Gobert (2016) warn that sustainability is often addressed without fully integrating environmental, social, and economic dimensions, and they highlight risks such as rebound effects that may offset expected benefits. Annarelli et al. (2020) reinforce this ambiguity by discussing a potential "dematerialization paradox," whereby service-based offers that are theoretically more sustainable may still face market resistance, thereby undermining their real-world impact. More recent work continues to suggest that evidence remains limited regarding whether sustainability gains materialize in practice, especially when considering full lifecycle effects and multi-stakeholder settings rather than narrow operational indicators (e.g., Smania et al., 2023). In parallel, the lack of practical sustainability-oriented indicators and guidelines during XaaS/PaaS transitions further points to an operational gap: firms may be unable to manage or even observe sustainability outcomes systematically while implementing such models (Hidalgo-Crespo et al., 2025). Overall, the literature indicates that the key limitation is not the absence of sustainability-related claims, but the lack of systematic, evidence-based validation of XaaS sustainability outcomes. This underexplored linkage constrains both theory development (because causal mechanisms remain unclear) and managerial practice (because firms lack reliable tools to evaluate trade-offs and verify benefits). Advancing the field therefore requires moving beyond normative expectations toward rigorous, comparable, and empirically grounded assessment of environmental and social impacts within real XaaS implementations (Bech et al., 2019; Costa et al., 2015).

To systematically address the research gaps identified in the previous section, the reviewed papers were classified according to their primary analytical contribution to the understanding of XaaS. Specifically, the literature was grouped into four categories: studies that provide or support a definition of XaaS, studies that propose frameworks or examine defining dimensions of the paradigm, studies that investigate practical challenges associated with implementation, and studies that explore the sustainability implications of adopting as-a-service models. The distribution presented in Figure 20 reveals a clear predominance of studies focusing on frameworks, defining aspects, or core dimensions of XaaS, with 62 papers contributing to the structural or conceptual characterization of the model. This concentration suggests that the academic community is still actively engaged in unpacking the architecture of XaaS, identifying its key components, and clarifying how such models should be interpreted within manufacturing contexts. In this sense, the literature appears to be progressing toward greater analytical sophistication, yet without fully reaching theoretical consolidation. The second most frequent research objective concerns the analysis of benefits and challenges, addressed in 48 papers. This emphasis reflects a growing scholarly effort to understand

the organizational, technological, and relational implications of transitioning from product-centric to service-oriented business models. At the same time, the prominence of this stream signals that firms continue to face significant uncertainties when operationalizing XaaS, thereby reinforcing the relevance of research aimed at translating theoretical insights into actionable guidance. A substantial number of contributions (45 papers) examine the sustainability implications associated with XaaS adoption, indicating an increasing alignment between service-based logic, servitization trajectories, and circular economy principles. These studies frequently discuss how usage-based models, extended product lifecycles, and alternative ownership structures may foster more resource-efficient practices. However, the variability of approaches and assessment methods suggests that the sustainability impact of XaaS remains an evolving area of inquiry rather than an empirically consolidated outcome. In contrast, only 19 papers explicitly attempt to define XaaS or significantly refine its conceptual boundaries. While the paradigm is widely invoked across the literature, its formal delineation remains comparatively underdeveloped. This imbalance reinforces the need for greater definitional convergence and supports the relevance of further conceptual work aimed at stabilizing the construct.

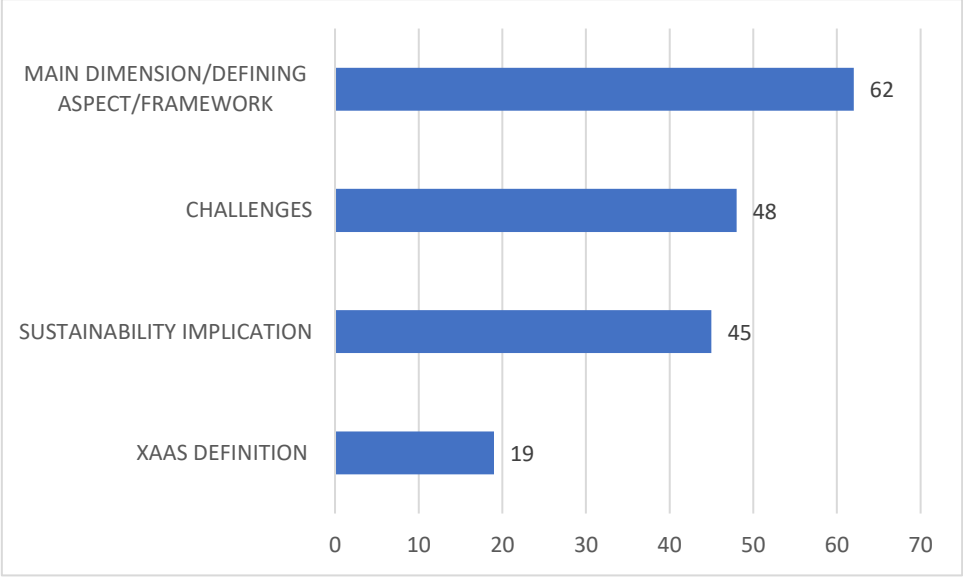


Figure 20 Paper classification

Overall, the distribution portrays a research landscape that is conceptually vibrant but still characterized by uneven development across thematic areas. The strong focus on structural dimensions, combined with the comparatively limited attention to definitional clarity and implementation guidance, highlights critical opportunities for advancing both theoretical understanding and managerial applicability. In particular, the findings point to the need for research that not only refines the conceptual foundations of XaaS but also facilitates their translation into operational insights.

The research gaps identified through this classification are further articulated in the research questions presented in the following subsection and are subsequently addressed in the chapters dedicated to each research question.

3.2 Research objectives and research questions

Building on the research gaps identified in the previous section, this PhD thesis aims to advance both the theoretical and practical understanding of the XaaS model. Over the last decade, XaaS has increasingly emerged as a strategic business model innovation, enabled by digital technologies, connectivity, and data-driven service architectures, and it is progressively reshaping how organizations design value propositions and capture value over time. Nevertheless, despite its growing relevance, the literature on XaaS remains dispersed across disciplines and streams that often adopt partially overlapping concepts (e.g., *Product-as-a-Service*, *Everything-as-a-Service*, outcome-based contracting), hindering cumulative theory development and limiting the possibility to compare findings across studies. Addressing this conceptual ambiguity represents a first key step for both scholars and practitioners, and it motivates the following research question:

- **RQ1:** *How can the XaaS model be defined across fragmented research streams and terminologies?*

Despite the increasing diffusion of XaaS models within manufacturing, the phenomenon remains conceptually fragmented. Prior research has predominantly examined isolated aspects, such as technological enablers, lifecycle implications, design approaches, or network structures, without integrating them into a cohesive analytical perspective. This fragmentation limits scholars' ability to systematically describe XaaS configurations, compare empirical manifestations, and accumulate transferable knowledge across industrial contexts. Addressing this limitation requires moving beyond descriptive accounts of individual implementations toward the development of integrative analytical structures capable of capturing the multidimensional nature of XaaS. In particular, manufacturing provides a critical empirical setting, as the sector is currently experimenting with heterogeneous service-based configurations that remain insufficiently conceptualized in the literature. Therefore, this thesis aims to identify the key aspects that characterize XaaS configurations in manufacturing and to integrate them into a structured analytical framework that supports their systematic description and comparison:

- **RQ2:** *What are the key aspects that characterize XaaS configurations in manufacturing, and how can they be integrated into an analytical framework that enables their systematic description and comparison?*

Beyond adoption dynamics, the operationalization of as-a-service models typically exposes firms to recurring managerial and technical challenges, such as contractual complexity, governance and responsibility allocation, data ownership and cybersecurity concerns, interoperability constraints, and internal organizational resistance. At the same time, firms may develop emerging solutions, practices, and organizational arrangements that can facilitate implementation and increase the likelihood of success. Systematically identifying these patterns is essential to move from anecdotal evidence to actionable and generalizable insights. For this reason, this thesis aims to consolidate evidence from real-world manufacturing cases in order to derive practical suggestions, tools, and guidelines that managers can use to approach the XaaS transformation more effectively:

- **RQ3:** *What best practices emerge from real-world XaaS implementations in the manufacturing sector, and how can such evidence be translated into managerial guidelines to support the transformation?*

Finally, although XaaS is often associated with sustainability-related narratives, the relationship between as-a-service models and environmental sustainability remains conceptually underdeveloped and empirically under-investigated. Existing research has not yet provided a systematic understanding of which environmental value drivers are most directly influenced by XaaS (e.g., resource efficiency, energy consumption, product lifetime extension, circularity and end-of-life management) and through which mechanisms such impacts materialize across the lifecycle of offerings. Moreover, there is still limited clarity on whether and how the adoption of XaaS models affects sustainability performance, and how firms can intentionally design and manage XaaS offerings to achieve measurable environmental outcomes. To address this gap, the thesis explores the connections between XaaS and environmental sustainability by focusing on the environmental impacts of XaaS models, identifying which environmental sustainability aspects are affected and through which mechanisms these effects materialize:

- **RQ4:** *Which environmental sustainability aspects are affected by XaaS models and how?*

Overall, by addressing these questions, the thesis seeks to consolidate the conceptual foundations of XaaS research and provide practical guidance for manufacturing firms navigating the transition toward service- and outcome-oriented business models.

In line with the research questions presented above, this PhD thesis is expected to generate both conceptual and empirical outcomes that contribute to consolidating the XaaS research domain and supporting manufacturing firms in approaching the transition toward as-a-service business models. Specifically, the expected outcomes of the study are the following:

- **(O1)** Provide a structured and up-to-date state-of-the-art of the academic literature on *X-as-a-Service (XaaS)* in the manufacturing context.
- **(O2)** Develop a comprehensive definition of XaaS in the manufacturing context, providing a conceptual foundation that also supports the clarification of its boundaries
- **(O3)** Propose an integrative framework that characterizes XaaS models through a set of key dimensions and variables, serving both as an analytical tool for academic classification and as a practical instrument to guide XaaS adoption and implementation in manufacturing firms
- **(O4)** Deliver an empirically grounded mapping of XaaS adoption in the manufacturing sector, based on real-world case studies and systematically structured through the proposed framework. The outcome includes a cross-case synthesis of recurring adoption patterns and the development of a set of XaaS archetypes, each characterized by a coherent configuration of key implementation elements..
- **(O5)** Identify the main challenges and best practices related to the transition toward XaaS models and translate the evidence into actionable guidelines that managers can use to approach this transformation in a more structured and informed way.
- **(O6)** Explore the relationship between XaaS adoption and environmental sustainability in manufacturing by developing an assessment perspective that clarifies which environmental sustainability aspects are most affected (e.g., resource efficiency, energy consumption, product lifetime extension, circularity, and end-of-life management), and through which mechanisms such impacts occur across the lifecycle.

Overall, these outcomes are expected to contribute to the literature by providing a clearer conceptual foundation for XaaS research and by enabling more robust cross-study comparisons across fragmented streams. From a managerial perspective, the thesis aims to generate actionable knowledge and guidance to support manufacturing firms in designing, implementing, and governing XaaS transformations. Finally, by explicitly addressing the environmental sustainability dimension, the study seeks to extend the debate beyond purely economic and operational considerations, offering insights into how XaaS can be aligned with sustainability objectives and performance measurement (Figure 21).

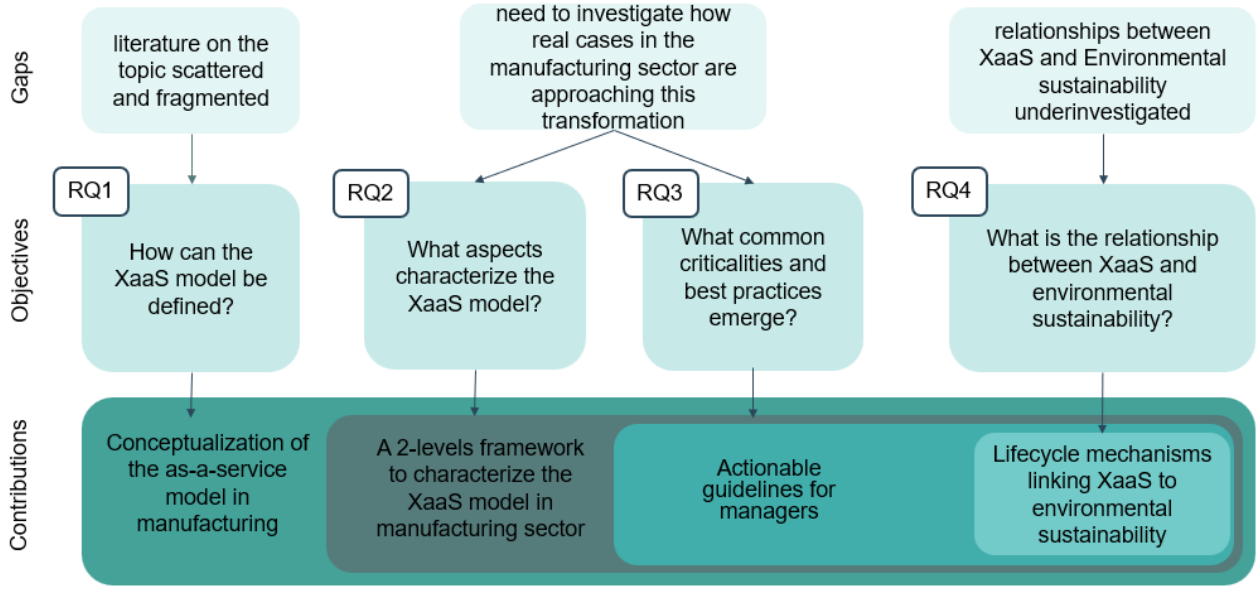


Figure 21 Research gaps, objectives, and contributions

3.3 Methodology

This research adopts a two-stage methodological approach that integrates conceptual development and empirical application, as illustrated in Figure 22. The combination of these two complementary components allows the study to both advance the theoretical understanding of XaaS and to examine its practical manifestations within manufacturing contexts. The overall design is explicitly driven by the research gaps identified in the literature and described in the previous paragraph, and aims to ensure coherence between theoretical development and empirical validation.

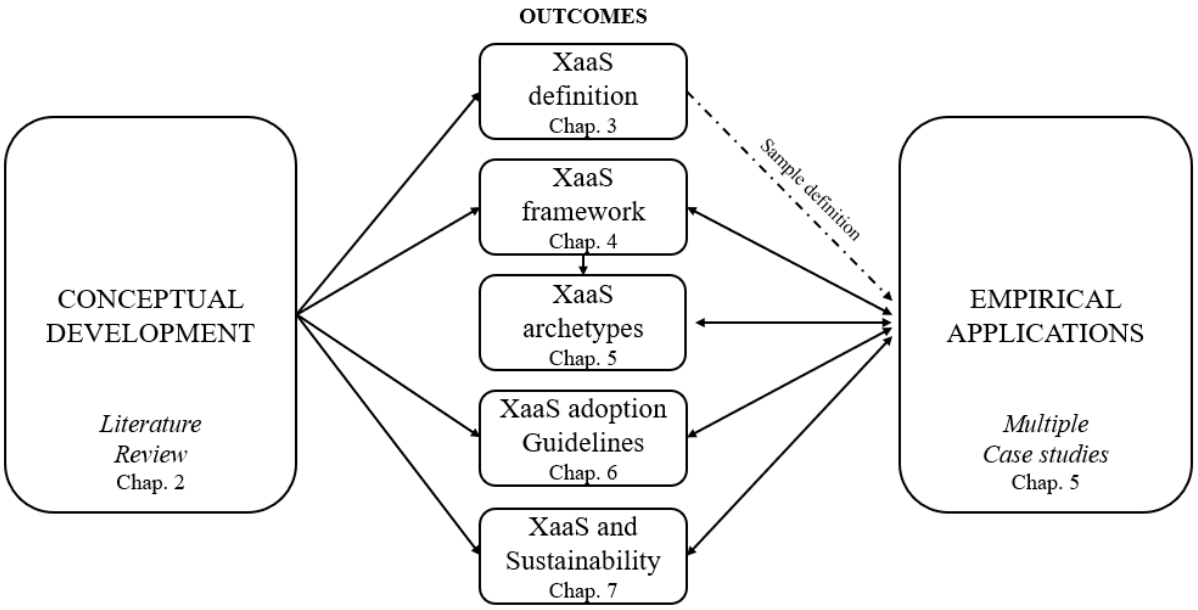


Figure 22 Methodological approach

- **Conceptual Development**

The first part of the research focuses on conceptual development and is grounded in a systematic literature review conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Moher et al., 2009; Page et al., 2021), as described in Chapter 2. The PRISMA-based review ensures transparency, replicability, and rigor in the identification, screening, and selection of relevant academic contributions on XaaS and related service-oriented business models. The systematic literature review constitutes the primary methodological foundation for the theoretical outcomes of the thesis. Specifically, insights derived from the literature were used to address the key gaps highlighted in the preceding section and to produce the following conceptual outcomes:

- the development of a clear and explicit definition of XaaS (Chapter 3), aimed at reducing the conceptual ambiguity observed in prior research;
- the construction of an analytical framework for characterizing XaaS business models (Chapter 4), designed to integrate the fragmented dimensions identified in the literature;
- the identification of key challenges related to the implementation and adoption of XaaS, as reported in existing studies (Chapter 6);
- the investigation of the relationship between XaaS and sustainability, synthesizing insights on environmental and systemic implications emerging from prior research (Chapter 7).

Through this structured conceptual development, the literature review does not serve merely a descriptive function but acts as a theory-building mechanism that directly informs the analytical tools and research questions guiding the empirical phase.

- **Empirical Application**

The second part of the research consists of an empirical application based on a multiple case study methodology, following the principles outlined by Yin (2018). This approach is particularly suited to the exploratory and theory-elaborative nature of the study, as it enables in-depth investigation of contemporary phenomena within their real-life contexts. The empirical design, data collection procedures, and case selection criteria are described in detail in Chapter 5. The empirical phase is tightly connected to the conceptual outcomes developed in the first part of the thesis. In particular, the empirical analysis benefits from and builds upon the conceptual work in several ways. First, the XaaS definition developed in Chapter 3 is used to delimit the empirical domain and to define the sample of firms and initiatives included in the analysis. Second, the XaaS framework developed in Chapter 4 is applied as an analytical tool to systematically characterize XaaS offerings in the

manufacturing sector and to identify recurring adoption configurations, referred to as XaaS archetypes (Chapter 5). Beyond framework application, the empirical analysis also serves a theory-refining function. The multiple case studies enable the assessment of whether the challenges identified in the literature are observable in practice, while also allowing the identification of additional challenges that emerge from real-world implementations. Furthermore, cross-case comparison supports the identification of best practices and managerial insights, which are synthesized into actionable XaaS adoption guidelines (Chapter 6). Finally, the empirical findings reinforce and extend the analysis of the XaaS–sustainability relationship by providing practice-based evidence on how XaaS models influence resource utilization, lifecycle management, and systemic sustainability outcomes (Chapter 7).

- **Integration of Conceptual and Empirical Phases**

Overall, the methodological approach is characterized by a strong iterative linkage between theory and empirics. The conceptual development phase informs the empirical design and analysis, while empirical findings are used to validate, refine, and extend the conceptual contributions of the thesis. This integration ensures methodological coherence and strengthens the analytical robustness of the research, allowing the study to contribute both to the theoretical advancement of XaaS research and to its practical understanding within manufacturing contexts.

The detailed methodological choices and analytical procedures associated with each section are reported in the respective dedicated chapters.

4 CHAPTER IV –XAAS CONCEPTUALIZATION AND CONCEPTUAL DEVELOPMENT

4.1 Scope and approach

This chapter advances the conceptualization of XaaS within manufacturing by addressing two interrelated objectives. First, it develops a clear and explicit definition of XaaS in response to the conceptual ambiguity that characterizes the existing literature. To this end, a structured analysis of established service-oriented concepts is conducted to identify the foundational characteristics of service-based value creation and to clarify which elements are inherited, adapted, or uniquely emphasized in XaaS models. Second, building on this conceptual grounding, the chapter critically examines the existing literature for capturing the distinctive structural and operational mechanisms of XaaS. The limitations that emerge from this review motivate the development of an integrative analytical framework designed to support the systematic characterization of the XaaS model in manufacturing contexts. Together, these steps provide the theoretical foundation necessary to enhance the analytical clarity of the phenomenon and to guide subsequent investigation.

4.2 XaaS Definition

This chapter establishes the conceptual basis for understanding XaaS by developing a clear and explicit definition of the model. Given the absence of a shared interpretation in the literature, the definition is derived through a structured comparative analysis of established service-oriented concepts, including Product–Service Systems, servitization, and advanced service models, in order to identify the foundational characteristics that underpin service-based value creation. Building on this first step, the chapter examines XaaS-specific contributions to assess the extent to which these features are inherited, transformed, or extended within the XaaS logic. The synthesis of these insights enables the identification of the key attributes that distinguish XaaS from related approaches and supports the formulation of a dedicated definition, which then provides the conceptual grounding for the framework developed in the remainder of the chapter.

4.2.1 Conceptual analysis of established product-service-oriented concepts and definitions

The literature addressing service-oriented business models is characterized by a wide range of established concepts, such as Product–Service Systems (PSS), servitization, advanced services, subscription models, and use- or result-oriented offerings, that describe different ways of shifting from product-based to service-based value creation. While these concepts are extensively discussed and relatively well defined within their respective research streams, the literature lacks a clear and shared definition of XaaS, despite the increasing use of this term in both academic and managerial contexts. As a consequence, XaaS is often implicitly associated with existing service-oriented models,

without a systematic clarification of which characteristics are inherited from prior concepts and which elements distinguish XaaS as a specific business model. To address this gap, the objective of this first analytical step is to examine the existing definitions to identify the common characteristics that underpin service-oriented business models, as well as the features that differentiate these foundational concepts from XaaS. This comparative analysis provides the necessary conceptual grounding to clarify the distinctive nature of XaaS and to support the development of a dedicated and explicit definition of the model. To this end, a broad set of definitions drawn from the relevant literature streams was analysed and mapped, focusing on the attributes explicitly used to describe the nature of the offering, the value proposition, and the underlying business logic. Through an iterative coding and comparison process, recurring attributes mentioned across the analysed definitions were identified, grouped into conceptually related categories, and consolidated into a set of eight core characteristics recurrently associated with service-oriented business models. These characteristics represent the common building blocks underlying service-oriented business models and provide the basis for the subsequent conceptualization of XaaS. The analysis revealed that existing definitions consistently refer to a transition from product-centric offerings toward **integrated solutions**, where products and services are combined to deliver value beyond the physical artefact (Martinez et al., 2010; Visnjic et al., 2017; Tukker and Tischner, 2006). A recurrent element is the presence of **added-value services**, typically based on the provider's in-house expertise and capabilities, which complement the core product and enhance its utility for the customer (Boehm and Thomas, 2013; Baines et al., 2007; Vandermerwe and Rada, 1988). Several definitions also emphasize changes in **revenue streams**, highlighting a shift away from traditional one-time sales toward alternative pricing mechanisms, such as usage-based or performance-related payments (Neely, 2008; Costa et al., 2015). Closely related to this aspect is the identification of new **revenue drivers**, which are no longer linked to product ownership but to outputs, functionality, performance, or availability, often expressed through "pay-per-x" logics (Chiarot et al., 2022; Ng et al., 2013). Another central theme concerns **ownership transfer and risk assumption**. Many service-oriented models imply that ownership of the physical asset is retained by the provider, who consequently assumes a greater share of operational, financial, and performance-related risks (Datta & Roy, 2011; Maisenbacher et al., 2014; Bocken et al., 2014; Rathmann et al., 2014). This redistribution of risk is frequently associated with increased **customer involvement**, where offerings are customized to specific needs and developed through closer interaction between provider and user (Schaefers et al., 2021; Hou and Neely, 2018). Finally, several definitions stress the importance of **partnerships and relational arrangements**, reflecting a shift from transactional exchanges to longer-term collaborations. In this perspective, value creation emerges from continuous interaction among multiple actors rather than from isolated

product exchanges (Ceschin, 2013; Wood & Godsiff, 2021). These features, summarized and mapped across the analysed definitions in the Table 4, demonstrate that, while the terminology varies, the underlying logic of service-oriented models is largely built upon a shared set of characteristics. At the same time, the variability in how these elements are combined and emphasized contributes to the conceptual ambiguity observed in the literature. This structured analysis therefore provides the basis for comparing these foundational concepts with XaaS and for identifying which elements are inherited, transformed, or extended in XaaS-specific interpretations.

object	definitions + ref.	integrated solution	added value services	revenues streams	ownership transfer	revenue driver	risk assumption	customer involvement	partnership
PSS	Goedkoop et al. (1999) - Mont (2004) - Manzini and Vezzoli (2002) - Hockerts and Weaver (2002) - Tukker and Tischner (2006) - Boehm and Thomas (2013) - Peruzzini et al. (2013) - Brandsotter (2003) - Wong (2004) - ELIMA (2005) - Baines et al. (2007) - Centre for Sustainable Design (2002) - Morelli (2002) - Komoto et al. (2005) - Cook et al. (2006) - Tan et al. (2007) - Evans et al. (2007) - Aurich et al. (2007) - Maussang et al. (2009) - Aurich et al. (2009) - Geng et al. (2010) - Meyer et al. (2010) - Becker et al. (2010) - Meier et al. (2011) - Cavalieri & Pezzotta (2012) - Ceschin (2013) - Boehm & Thomas (2013) - Schenkl et al. (2014) - Cook (2014) - Exner et al. (2014) - Kimita & Shimomura (2014) - Berkovich et al. (2014) - Peruzzini & Germani (2014) - Maisenbacher et al. (2014) - Song et al. (2015) - Armstrong et al. (2015) - Gelbmann & Hammerl (2015) - Reim et al. (2015) - Chou et al. (2015) - Joore & Brezet (2015) - Azcárate-Aguerre et al. (2018) - Karaca et al. (2018) - Kamal et al. (2020) - Bocken et al. (2014) - Webb & Bil (2011) - Rabe et al. (2018) - Baxter et al. (2009)	**X**	**X**		**X**	**X**		**X**	**X**
Servitization	Martinez et al. (2010) - Baxter et al. (2009) - Vandermerwe and Rada (1988) - Desmet et al. (2003) - Tellus institute (1999) - Verstrepen and Van Den Berg (1999) - Robinson et al. (2002) - Lewis et al. (2004) - Ward and graves (2005) - Ren and Gregory (2007) - Buerkle et al. (2023)	**X**	**X**		**X**	**X**			
Advanced Service	Schroeder et al. (2022) - Wood & Godsiff (2021) - Wood & Godsiff (2021) - Baines & Lightfoot (2013) - Rönnberg Sjödin et al. (2016)	**X**		**X**		**X**		**X**	**X**
Subscription Models	Riesener et al. (2020) - Hansen (2014) - Smania et al. (2023) - Häckel et al. (2022)	**X**		**X**		**X**		**X**	**X**

Use-oriented (PSS - business model - system)	Häckel et al. (2022) - Neely (2008) - Chiarot et al. (2022) - Tukker (2004) - Bech et al. (2019) - Kernschmid et al. (2016) - Costa et al. (2015)	**X**	**X**	**X**	**X**	**X**			
Result-oriented (PSS - business model - contact)	Neely (2008) - Chiarot et al. (2022) - Rathmann et al. (2014) - Kernschmid et al. (2016) - Costa et al. (2015)	**X**	**X**		**X**	**X**	**X**	**X**	
outcome-based contracts	Ng et al. (2009) - Batista et al. (2017) - Hou & Neely (2018) - Schaefers et al. (2021) - Visnjic et al. (2017) - Grubic & Jennions (2018) - Alonso-Rasgado et al. (2004) - Kim et al. (2007) - Ng et al. (2009) - Kim et al. (2010) - Hypko et al. (2010a) - Ng and Nudurupati (2010) - Priya Datta and Roy (2011) - Guajardo et al. (2012) - Kleemann and Essig (2013) - Ng et al. (2013) - Van Ostaeyen et al. (2013) - Holmbom et al. (2014) - Selviaridis and Wynstra (2015) - Böhm et al. (2016) - Essig et al. (2016) - Liinamaa et al. (2016) - Batista et al. (2017) - Batista et al. (2017) - Visnjic et al. (2017) - Hou and Neely (2018) - Visnjic et al. (2018) - Ziaee Bigdeli et al. (2018) - Visnjic et al. (2017) - Visnjic et al. (2018)	**X**	**X**	**X**	**X**	**X**	**X**	**X**	

Table 4 Main product-service-oriented definitions

A complete version of the table, including full definitions and corresponding references, is available in Appendix A.

4.2.2 Towards a definition of XaaS: identification of key characteristics

Building on the main features identified through the analysis of foundational service-oriented concepts, the XaaS literature was subsequently examined to assess the presence and relevance of these characteristics within XaaS-specific contributions. In particular, we analyzed the papers that provided an initial definition of the phenomenon, investigating the key common features. To this initial analysis, which covered 19 of the initially selected papers, additional seminal articles reporting common examples of XaaS, but not specifically related to the manufacturing sector, and therefore excluded from the review, were then added to confirm the characteristics identified in the first phase. Mourtzis et al. (2021, p. 332) define Manufacturing-as-a-Service as "an integrated set of products and services offering added value to industrial applications (..) requires an example shift towards selling functionality rather than selling products" while Mustonen et al. (2019, p. 1) assert that the Product-as-a Service (PaaS) is a business model where "a physical product is transformed into a means of production." Wasserbaur et al. (2023, p. 2), illustrate the example of Heat-as-a-Service (HaaS), which emphasizes the transition from the "transactional sale of boilers to offering integrated solutions that deliver heat and comfort to domestic households" while Buerkle et al. (2023, p. 2) described the Robot-as-a-service (RaaS) asserting how "Similar to other "as-a-service" theorems, the characteristic

of RaaS is to rent software or computing hardware, rather than acquiring it". Thus, these definitions encompass the **integrated solution** characteristic of the servitized models, wherein the product, in this case, is conceptualized and promoted as a service. Furthermore, the focus of the offer shifts towards delivering a **value-added service** that gives the customer exactly what they want, thereby fulfilling their requirements. In the XaaS concept, therefore, X can represent either a product (such as Tires-as-a-Service), a service (such as Heat-as-a-Service), or a functionality (such as mobility-as-a-service). Duan et al. (2015) introduce the notion of XaaS specifically within the context of Information Technology and in particular of the Cloud Computing model. The enabling factor in this definition is therefore technology, and in particular cloud computing that offers **on-demand access** (Monetti & Maffei, 2023). According to Duan et al. (2015), cloud computing is recognized as an as-a-service model: Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS), and Infrastructure-as-a-Service (IaaS) are typical examples. Vandermerwe & Erixon (2023, p. 484) highlight how "thanks to everything being in the cloud, customers can get exactly what they want, without having to own content or infrastructure". Therefore, in this definition, we discover an extra characteristic of the XaaS model, which is the provider's **retention of ownership** over the asset, software, and infrastructure necessary to provide the service, as well as the **assumption of risks** that were traditionally borne by the customers (Gebauer et al., 2017). By examining the most common definitions in the literature about PSS, Servitization, and related concepts in this topic it emerges that while the aspects of integrated solution and value-added can also be found in the more common definitions of Servitization and PSS (Tukker and Tischner, 2006; Baines et al., 2007; Vandermerwe & Rada, 1988), the on-demand aspect is a defining factor of the model, enabling both a change of mindset regarding the concept of asset ownership and the possibility of establishing a **relation-based approach** to the customer. Many of the benefits associated with XaaS model adoption for the customer and the company, as well as for the environment, illustrated previously, are related in fact to the ability to establish trust between the parties. The technology behind the XaaS model makes it possible to analyze the customer's choices, tastes, and needs and provide targeted and personalized service (Kowalkowski & Ulaga, 2024). In addition, it enables timely and preventive intervention in case of failures and provides necessary assistance at all times (Monetti & Maffei, 2023). The aaS model is commonly linked to several pricing systems, including subscription, fixed fee, and pay-per-x, which are determined based on the agreement between the consumer and the company. However, at its core, the frequency remains, setting it apart from one-time transaction models that do not facilitate the establishment of client relationships. Based on the above consideration, we have defined the as-a-service model as "*an integrated solution, available on demand, that, through a value-added offering,*

provides the customer with exactly what they want when they need it". The mapping of XaaS papers onto the identified main features is illustrated in Table 5.

Main features	References
Integrated solution	Azcárate-Aguerre et al. (2022); Bettoni et al. (2018); Buerkle et al. (2023); Chiarot et al. (2022); Mustonen et al. (2019); Opresnik & Taisch (2015); Perruzzini & Germani (2014); Peruzzini et al. (2013b); Pulkkinen et al. (2019); Sanchez et al. (2022); Wasserbaur et al. (2023); Yang et al. (2009)
Value-added service	Bettoni et al. (2018); Perruzzini & Germani (2014); Peruzzini et al. (2013b); Sanchez et al. (2022)
On-demand access	Buerkle et al. (2023); Mourtzis et al. (2021); Peruzzini & Germani (2014); Peruzzini et al. (2013a); Webb & Bil (2011); Yang et al. (2009)
Ownership retention and risk assumption	Buerkle et al. (2023); Huang et al. (2020); Opresnik & Taisch (2015); Pulkkinen et al. (2019)
Relation-based approach	Mourtzis et al. (2021); Opresnik & Taisch (2015); Peruzzini & Germani (2014); Peruzzini et al. (2013a); Pulkkinen et al. (2019); Webb & Bil (2011); Weking et al. (2018); Yang et al. (2009)

Table 5 XaaS main features

4.2.3 Synthesis of common and distinctive XaaS characteristics

The analysis highlights that XaaS shares several foundational characteristics with established service-oriented concepts, including the provision of integrated solutions, the delivery of added-value services, the retention of ownership and risk by the provider, and a strong relational orientation between actors. These elements confirm that XaaS builds upon the core logic of servitization and product–service integration rather than representing a completely disconnected model. However, the analysis also reveals that XaaS introduces **distinctive features** that are not systematically present in earlier concepts. Most notably, the role of **technology as an enabling infrastructure** emerges as a defining element. In XaaS models, digital technologies, such as cloud computing, data analytics, and connectivity, are not merely supportive tools but constitute the backbone that enables **on-demand access**, scalability, continuous service provision, and real-time monitoring. This technological foundation allows XaaS offerings to be dynamically activated, adapted, and priced according to actual usage or performance, reinforcing the shift from ownership-based transactions to access- and outcome-based value creation. Beyond the technological dimension, XaaS also differs from traditional service-oriented models in terms of **temporal structure and operational logic**. While PSS and servitization often involve long-term, predefined contractual arrangements, XaaS is characterized by higher flexibility, recurrent interactions, and continuous value delivery. Furthermore, XaaS places greater emphasis on **frequency, modularity, and scalability of access**, enabling customers to consume services exactly when needed and to adjust the level of service over time. Taken together, these elements suggest that XaaS should not be interpreted as a mere extension of existing service-oriented concepts, but rather as a **technology-enabled evolution** of them, in which on-demand logic, continuous interaction, and digital infrastructure play a central role. This distinction provides the conceptual basis for the definition of XaaS proposed in this chapter.

4.3 XaaS Framework

4.3.1 A business model approach for characterizing the XaaS business model

Although several frameworks have been proposed to analyse service-oriented business models, digital services, and servitization strategies, none of them is explicitly designed to capture the specific structural mechanisms underlying XaaS business models. Existing approaches typically focus on isolated dimensions, such as technology adoption, revenue models, or customer–provider interactions, without providing an integrated perspective that reflects the distinctive combination of ownership, digital enablement, value creation, and value capture that characterizes XaaS. For this reason, the following section critically reviews the most relevant frameworks adopted in the literature, with the aim of identifying their main limitations and motivating the need for a dedicated XaaS-oriented framework.

In the Information Technology sector, where the concept was originated, the Technological-Organizational-Environmental (TOE) framework, established by Tornatzky and Fleischer in 1990 has been used both to Rahman and Subriadi (2022) and Kim et al. (2017) to examine the determinants affecting Software-as-a-Service adoption, emphasizing organizational, networking, external expertise, IT resources, and top management support elements. However, the TOE framework does not explicitly delineate how a company generates or creates value via a business model; instead, it focuses on contextual factors influencing technology adoption. Ibrahim et al. (2023) delineate the challenges associated with adopting Software-as-a-Service within a comprehensive framework of sixteen factors, primarily emphasizing data-related aspects such as security, data privacy, confidentiality, governance, transparency, quality of service, and finance. Consequently, these contributions remain fragmented and lack a broader strategic and organizational perspective.

In the manufacturing sector, the literature primarily concentrates on single aspects of the XaaS, especially revenue models. For example, Landscheidt et al (2018) discuss how the leasing and pay-per-use business models should be designed and what components and features are needed for successful implementation in a robot manufacturing company. In their study, Menon et al. (2021) define the systematic steps that help equipment manufacturing companies in the concept design of Pay-per-X models. Lastly, Bulut et al. (2021) introduce a guideline for small and medium-sized firms to effectively adopt Manufacturing-as-a-Service by strategically aligning their business models. The business model in this case refers to the provision of physical manufacturing resources and capabilities, and for this reason, the authors focus on the interactions between customers and firms.

In the servitization of manufacturing context, a framework-based approach has been used to delineate the essential elements necessary for designing, evaluating, and managing a Product-Service System Business model (Adrodegari et al., 2017). Existing literature dealing with this topic used Business Model Canvas (Osterwalder and Pigneur, 2010), composed of 9 dimensions (customer segments, value propositions, distribution channels, customer relationships, revenue streams, key resources, key activities, key partners, and cost structure), to this end. As an example, Adrodegari et al. (2017) present a two-level hierarchical business model framework based on BM Canvas that describes PSS business models and their development in the industrial sector. However, BM Canvas does not consider the dimension of environmental sustainability, although it is fundamental in the XaaS perspective (Kolling et al., 2022). Moreover, its level of abstraction remains high and does not specifically address the distinctive features of XaaS (Adrodegari et al., 2017). For this reason, we propose to use its dimensions as a starting point, adapting them to offer a more targeted and accessible interpretation of XaaS-specific aspects.

Similarly, Barquet et al. (2013) propose a framework that assists in the adoption of PSS using the notion of business models. Nonetheless, these frameworks fail to address the distinctive elements of the XaaS, including the internal organization and connections among the involved parties, as well as the aspect of risk management. Thus, there is a lack of a framework dedicated to implementing the XaaS business model in manufacturing that captures all the different aspects involved. The characteristics and dimensions of the main frameworks mentioned are shown in Table 6.

References	Used model	Purpose	Dimensions	Limits
Rahman and Subriadi (2022)	TOE	Identify and analyze the factors influencing the adoption of cloud computing, particularly for SaaS	Technological Factors Organizational Factors Environmental Factors	Does not explicitly address how a company creates or captures value through its business model. Focuses mainly on contextual factors influencing technology adoption rather than business model dynamics
Kim et al. (2017)	TOE	Provides practical strategies for small firms adopting SaaS and for SaaS providers	Control variables Technological Risks Technological Benefits Environmental Context Organizational Context	Does not explicitly address how a company creates or captures value through its business model. Focuses mainly on contextual factors influencing technology adoption rather than business model dynamics
Ibrahim et al. (2023)	framework proposed	Find and evaluate previous studies on the challenges of	Security; Privacy; Data Confidentiality; Governance; Interoperability; Financial	Focuses primarily on data-related aspects (e.g., security, privacy,

References	Used model	Purpose	Dimensions	Limits
	by the author	adopting SaaS cloud computing and identify any gaps	resistance; Quality Assurance; Transparency; Regulatory Requirement; Proficient users; Data confidentiality; Managing multiple; Clouds; Performance; Service Level of Agreement (SLA); Confirmation; Quality of service; App rating and Free Alternative to paid apps	confidentiality, governance), lacking a broader perspective that includes strategic, organizational, and value creation dimensions
Landscheidt et al (2018)	Business Model Canvas	To identify how the robotics business is currently structured and to explore how new business models for industrial robots could be designed in the future	Value proposition Customer segments Customer relationships Channels Revenue flows Key activities Key resources Key partners Cost structure	Focuses on isolated aspects of XaaS lacking a holistic view of business model design and integration
Menon et al. (2021)	framework proposed by the author	identifies a comprehensive systematic process and the main steps for the preliminary conceptual design of Pay-per-X (PPX) business models for equipment manufacturing companies (EMIs)	9 Steps	Focuses on isolated aspects of XaaS, particularly revenue models, lacking a holistic view of business model design and integration
Bulut et al. (2021)	framework proposed by the author	proposes guidelines on how SMEs can position their business models to prepare for the future of MaaS	Market Drivers Technology Drivers	Emphasizes customer-firm interactions while potentially overlooking other value creation aspects
Barquet et al. (2013)	Business Model Canvas	To offer a practical framework that helps companies explore PSS scenarios, identify challenges, and plan business transformation after PSS implementation.	Value proposition Customer segments Customer relationships Channels Revenue flows Key activities Key resources Key partners Cost structure	Fails to address distinctive elements of XaaS such as internal organization, stakeholder interactions, and risk management
Adrodegari et al. (2017)	Adaptation of the Business Model Canvas	Helps industrial companies, particularly SMEs, design their future business models and plan the necessary steps for implementation.	Value proposition Customer Key resources Key activities Key partners Channels Cost Revenue	Does not consider the dimension of environmental sustainability

Table 6 Existing models

The analysis of the most relevant contributions reveals a set of recurring conceptual and operational gaps that limit the ability of existing frameworks to capture the specific mechanisms underlying XaaS business models. In particular, the reviewed approaches exhibit the following limitations:

- **Marginal role of digitalization and data**: digital technologies and data are generally treated as auxiliary or contextual elements, with limited explicit consideration of continuous data acquisition, real-time monitoring, and analytics, despite their central role in enabling on-demand access, performance measurement, and value creation in XaaS models.
- **Lack of recognition of provider ownership as a strategic driver**: prior frameworks do not conceptualize ownership retention as a core mechanism shaping incentives for maintenance, durability, cost allocation, and lifecycle management, thereby underestimating its impact on both operational and economic outcomes.
- **Separation of value creation and revenue generation**: value creation and value capture are typically represented as independent components, failing to account for their structural interdependence in usage- or performance-based pricing schemes, where operational efficiency directly influences revenue streams.
- **Limited integration of environmental sustainability**: when sustainability is addressed, it is often framed through generic circular economy or PSS principles, without explicitly linking environmental outcomes to the specific mechanisms enabled by XaaS, such as extended product lifecycles, optimized utilization, and reduced resource intensity.
- **Predominantly descriptive orientation**: existing frameworks mainly provide taxonomies or classification schemes and lack diagnostic or analytical capabilities to identify misalignments, trade-offs, or capability gaps across dimensions, thereby limiting their effectiveness in guiding XaaS design and transformation processes.

Taken together, these limitations highlight the absence of a framework specifically designed to capture the integrated, technology-enabled, and outcome-oriented logic of XaaS business models, thus motivating the need for the framework proposed in the following section. In fact, unlike existing PSS and pay-per-X frameworks, the proposed framework explicitly captures the structural mechanisms that characterize XaaS business models in manufacturing. In particular, it highlights retained ownership as a central incentive and risk-allocation mechanism, the role of continuous data acquisition in enabling usage- and performance-based pricing, and the intrinsic coupling between value creation and value capture. These mechanisms jointly distinguish XaaS from traditional servitized business models and motivate the dimension-level configuration of the framework.

4.3.2 XaaS framework dimensions

In this section, we present a novel two-level framework that encompasses the elements to be assessed and defined for characterizing an XaaS model. The development of the framework was guided by the need to provide a structured and comprehensive representation of the key dimensions characterizing the XaaS transformation in manufacturing. As highlighted in previous studies on PSS and servitization, framework-based approaches are particularly effective in supporting the understanding of complex business model transformations by systematizing the relevant elements and their interrelations (Adrodegari & Saccani, 2020). In line with this rationale, the framework developed in this study integrates the main dimensions emerging from prior conceptualizations with the XaaS-specific insights identified through the systematic literature review, offering a coherent foundation to analyse and guide the adoption of XaaS models.

. Specifically, the first level (Dimensions) comprises eight aspects that encompass the primary features of the XaaS concept. These dimensions were identified through a comparative analysis of the frameworks discussed in Section 4.3.1 and summarized in Table 6. The Business Model Canvas and its adaptation to Product-Service Systems (Adrodegari et al., 2017) were used as the primary structural foundation of the framework, as they provide a comprehensive representation of business model elements. The original dimensions were then adapted and reorganized to better capture the specific characteristics of XaaS identified in the literature review. In particular, conceptually related elements were consolidated into broader dimensions, while environmental sustainability was introduced as an additional dimension due to its growing relevance in manufacturing-oriented XaaS models. The resulting eight dimensions therefore reflect both established business model theory and the specific requirements emerging from the XaaS literature.

The dimensions of the framework are described below.

- **Value Proposition**

  The value proposition dimension captures the fundamental shift from product ownership to the delivery of functional value in XaaS business models. Rather than focusing on the sale of a physical asset, this dimension reflects how manufacturers redefine what is offered to customers in terms of outcomes, availability, and performance. In XaaS, value is created through the integration of products and services into a coherent solution that responds dynamically to customer needs, emphasizing value-in-use over value-in-exchange.

- **Customers**

  The customer dimension addresses how XaaS reshapes the relationship between providers and users. Unlike traditional transactional models, XaaS is characterized by long-term, continuous interactions that require a deeper understanding of customer operations, usage

patterns, and expectations. This dimension reflects the active role of customers in value co-creation, as well as the importance of sustained engagement, trust, and collaboration throughout the service lifecycle.

- **Ecosystem**

  The ecosystem dimension captures the networked nature of XaaS business models. Delivering XaaS offerings typically requires the coordination of multiple actors, such as technology providers, financial partners, service intermediaries, and logistics operators, whose roles extend beyond traditional supply chain relationships. This dimension highlights how value creation in XaaS emerges from interdependent partnerships, shared responsibilities, and aligned incentives within a broader system.

- **Organizational Structure and Culture**

  This dimension reflects the internal transformation required to support XaaS adoption. XaaS business models challenge traditional product-centric organizational logics, requiring new roles, decision-making structures, and cultural orientations. The organizational structure and culture dimension captures how companies must realign internal processes, responsibilities, and mindsets to support service orientation, cross-functional collaboration, and continuous customer engagement.

- **Economic and Financial**

  The economic and financial dimension represents the mechanisms through which value is captured and risks are managed in XaaS models. Unlike one-time sales, XaaS relies on recurrent and performance-linked revenue streams, which fundamentally alter cash-flow dynamics, cost structures, and financial exposure. This dimension emphasizes the tight coupling between operational performance and economic outcomes, as well as the strategic implications of pricing, risk allocation, and long-term contractual arrangements.

- **Resources**

  The resources dimension addresses the tangible and intangible assets required to enable XaaS offerings. In XaaS, value generation is strongly dependent on digital technologies, data, and service infrastructures that support monitoring, control, and continuous service delivery. This dimension highlights how resources extend beyond physical products to include data, digital platforms, and service-related assets that sustain the XaaS logic over time.

- **Capabilities**

  The capabilities dimension captures the firm’s ability to effectively deploy resources and manage the complexity inherent in XaaS models. XaaS adoption requires new analytical, technical, and relational capabilities that go beyond traditional manufacturing competencies.

This dimension reflects the firm's capacity to design service-oriented offerings, manage risks, interpret data, and coordinate activities across organizational and ecosystem boundaries.

- **Environmental Sustainability**

  The environmental sustainability dimension reflects how XaaS business models can align economic objectives with environmental outcomes. Rather than treating sustainability as an external or add-on concern, this dimension captures how retained ownership, data-enabled monitoring, and performance-based logics create incentives for resource efficiency, product life extension, and circular practices. In XaaS, environmental sustainability emerges as a consequence of the underlying value-generation mechanisms rather than as a separate objective.

Table 7 summarizes how the proposed framework explicitly addresses the conceptual and operational gaps identified in existing approaches, highlighting the role of each dimension in overcoming current limitations.

Identified gap in existing frameworks	Framework dimensions addressing the gap	How the framework addresses the gap
Marginal role of digitalization and data	Resources; Capabilities; Value Proposition	Digital technologies, data, and service infrastructures are explicitly embedded as core resources enabling continuous service delivery, real-time monitoring, and on-demand access. Capabilities related to data interpretation and analytics support performance-based value propositions.
Lack of recognition of provider ownership as a strategic driver	Economic and Financial; Value Proposition; Environmental Sustainability	Ownership retention is treated as a central mechanism shaping risk allocation, incentives for maintenance and durability, and lifecycle optimization, directly influencing value creation, revenue logic, and environmental outcomes.
Separation of value creation and revenue generation	Value Proposition; Economic and Financial; Capabilities	The framework explicitly links delivered outcomes to pricing and revenue mechanisms, capturing the interdependence between operational performance, cost structures, and economic returns in usage- or performance-based models.
Limited integration of environmental sustainability	Environmental Sustainability; Resources; Economic and Financial	Environmental sustainability is embedded as an endogenous dimension, connected to data-enabled monitoring, optimized utilization, extended product lifecycles, and incentive-aligned revenue mechanisms.
Predominantly descriptive orientation	All dimensions; Capabilities; Organizational Structure and Culture	The integrated structure of the framework enables diagnostic use by highlighting interdependencies and potential misalignments. Organizational and capability dimensions support the identification of readiness gaps and transformation challenges

Table 7 Framework gaps and proposed solutions

Taken together, this explicit alignment between identified gaps and framework dimensions demonstrates that the proposed framework is not a generic extension of existing models, but a purpose-built analytical tool designed to capture the distinctive, technology-enabled, and outcome-oriented logic of XaaS business models.

4.3.3 XaaS framework variables

To ensure a higher degree of specificity and practical applicability, each dimension was further detailed in a second level of analysis through a set of variables. For each paper included in the literature review, the variables associated with the previously identified dimensions were extracted and classified. These variables were then mapped onto the eight dimensions of the framework, and only those recurring across multiple studies were retained in the final model. The mapping process was supported by a structured Excel-based matrix, which allowed a systematic qualitative and quantitative comparison of how each dimension was addressed across the reviewed studies. It should be noted that the second-level variables presented in Figure 23 are not intended to provide an exhaustive representation of all possible attributes associated with each framework dimension. Rather, they represent a parsimonious set of variables selected from the literature based on their relevance, recurrence, and suitability for the operationalization and empirical analysis of XaaS business models. Consequently, broader dimensions such as ecosystem, organizational structure, or capabilities may encompass additional characteristics that were not explicitly included in the framework. Figure 23 illustrates the two-level framework with the associated variables, which are discussed below.

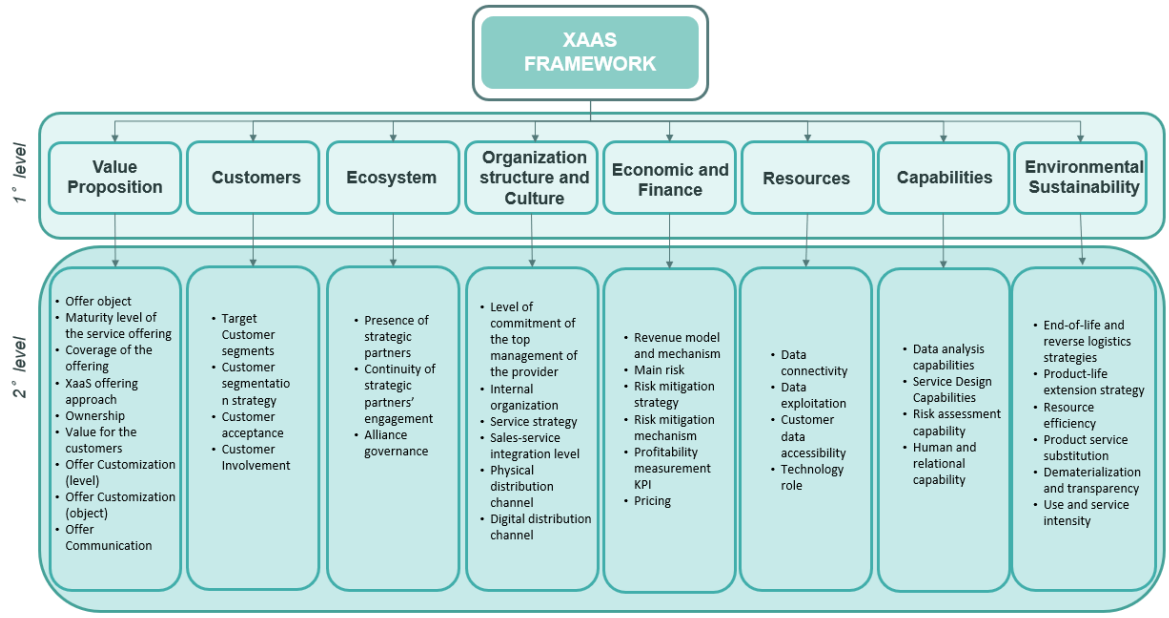


Figure 23 XaaS framework

- **Value proposition**

The XaaS concept is grounded in the idea that customers increasingly seek access to capabilities, functionalities, and outcomes rather than ownership of physical products (Yang et al., 2009). In this

perspective, the value proposition defines how the provider designs, positions, and delivers value through an integrated combination of products, services, and digital resources. Within the proposed framework, the value proposition dimension is articulated through the variables **offer object**, **maturity level of the service offering**, **coverage of the offering**, **XaaS offering approach**, **value for the customers**, **offer customization (level and object)**, **offer communication**, and **ownership**. The **offer object** refers to the core focus of the XaaS offering, capturing whether value creation is primarily centered on the product, the service, the payment logic, or the sales channel. In XaaS models, the offer often combines technological components, such as data collection, monitoring, and analytics, with service elements aimed at ensuring availability, reliability, and performance of the underlying system (Grubic & Jennions, 2018a; Grubic & Jennions, 2018b; Rathmann et al., 2014; Karaca et al., 2018). Intangible elements, including customer experience, reputation, and perceived reliability, further contribute to the overall value delivered through the offering. The **maturity level of the service offering** captures the extent to which the XaaS solution is institutionalized within the provider organization. Following the servitization and pay-per-X literature, XaaS offerings may range from pilot solutions, often experimental, customized, and limited in scope, to consolidated offerings that are fully integrated, standardized or configurable, and supported by established organizational processes and data-driven monitoring systems (Schroeder et al., 2022; Annarelli et al., 2021). This variable reflects the stability and scalability of the value proposition over time. The **coverage of the offering** describes the scope of the XaaS proposition in terms of the provider's product and service portfolio. XaaS models may be applied to a single product or service line, or extended across a broader portfolio, requiring the alignment of tangible and intangible assets to support consistent performance and lifecycle management (Karaca et al., 2018). The definition of coverage influences the complexity of the value proposition and the provider's ability to ensure long-term reliability, flexibility, and upgradeability of the offering (Allais & Gobert, 2016; Grubic & Jennions, 2018b). The **XaaS offering approach** reflects the strategic posture adopted by the firm in developing the offering, distinguishing between solutions proactively designed as part of a structured service strategy and those reactively introduced in response to specific customer requests or market pressures (Annarelli et al., 2016; Arioli et al., 2022; Andersen & Bering, 2023). This variable captures whether XaaS is positioned as a core strategic initiative or as a tactical extension of existing offerings. The **value for the customers** refers to the specific benefits generated through the XaaS model, which may include cost reduction, risk minimization, guaranteed access to functionality, process optimization, simplicity, or the achievement of predefined outcomes. In XaaS, value is increasingly delivered through pay-per-use or pay-per-outcome mechanisms rather than through product ownership, aligning provider incentives with customer performance and results (Gebauer et al., 2017; Sousa-Zomer et al., 2017). **Offer**

customization is examined through two complementary variables: **customization level** and **customization object**. The customization level captures whether the offering is standardized, configurable, or fully customized, reflecting the balance between scalability and the fulfillment of individual customer requirements (Nordin et al., 2011; Kowalkowski et al., 2021). The customization object specifies which elements of the offering are subject to customization, such as the product, service components, payment structure, or sales channel (Alix & Zacharewicz, 2021). Modularity plays a key role in enabling this balance by allowing predefined structures to be adapted without compromising efficiency. **Offer communication** concerns how the value proposition is conveyed to customers and how expected benefits are articulated. Effective communication is essential in XaaS contexts, as customers must understand the shift from ownership-based models to service-based value logics and the implications for cost, risk, and performance (Moro et al., 2022). Decisions regarding communication and sales channels, as well as the form of customer relationship, directly influence customer acceptance and perceived value (Rathmann et al., 2014). Finally, **ownership** represents a defining element of the XaaS value proposition. In XaaS models, customers acquire the right to use the product without transferring ownership, while the provider retains ownership and responsibility for the asset throughout its lifecycle (Adrodegari et al., 2017). Ownership retention expands the provider's accountability in terms of maintenance, upgrades, and end-of-use management, reinforcing long-term engagement and aligning value creation with lifecycle performance (Sousa-Zomer et al., 2017; Guzzo et al., 2022).

- **Customers**

The XaaS model helps to increase customer satisfaction and, as a result, the overall value of the service delivered (Karaca et al., 2018). In the proposed framework, the customer dimension is analyzed through a set of variables that capture how XaaS offerings are targeted to specific customers, how broadly they are positioned across different clients, how customers perceive and accept service-based solutions, and the extent to which they are actively involved in the service provision and value creation process. **Target customer segment** refers to the individuals or companies that a firm aims to serve and for whom it generates value through the XaaS offering (Charro & Schaefer, 2018; Kim et al., 2022). In this context, defining the target segment allows firms to align the offering with customers' operational conditions and usage contexts, supporting the development of appropriate service configurations and pricing models (Sousa-Zomer et al., 2018). Closely related to this, **customer segmentation strategy** describes whether the XaaS offering is developed to meet the needs of a specific customer or customer group, often in response to particular requirements, or designed to address multiple customers through more standardized or configurable solutions (Annarelli et al.,

2020). These choices influence the balance between customization and scalability that characterizes XaaS business models. **Customer acceptance** is a critical factor in the adoption of XaaS offerings, as it reflects customers' willingness to move away from traditional ownership-based solutions and embrace service- and usage-oriented models (Charro & Schaefer, 2018). Acceptance is influenced by customers' evaluation of the service in terms of perceived value, pricing logic, and risk reduction, particularly in long-term arrangements where service performance is continuously assessed rather than evaluated at the point of sale (Batista et al., 2017; Schaefers et al., 2021). A systematic approach to addressing customer acceptance contributes to the stability and sustainability of XaaS offerings over time (Donner & Steep, 2021). Finally, **customer involvement** represents a defining characteristic of XaaS business models. Users actively contribute to service delivery by providing operational input and usage-related data that support monitoring, adaptation, and continuous improvement of the offering (Rabe et al., 2018). XaaS solutions are often collaboratively developed by providers and customers from the outset and continuously adjusted to accommodate changes in usage conditions, ensuring significant value creation for both parties (Alix & Zacharewicz, 2021). Customers can actively tailor service configurations to their specific use conditions (Kowalkowski & Ulaga, 2024), and in some cases, direct customer input may be as important as, or even more important than, sensor-based monitoring data in improving service effectiveness and responsiveness (Huang et al., 2020).

- **Ecosystem**

A XaaS offering requires the adoption of an ecosystem-based approach, as value creation increasingly depends on the coordinated contribution of multiple actors rather than on a single firm (Vaskelainen et al., 2022). An ecosystem can be described as a dynamic environment characterized by collaboration and interdependence among stakeholders involved in different phases of the offering lifecycle, where each actor contributes specific resources, capabilities, or knowledge (Yang & Evans, 2019; Allais & Gobert, 2016; Rathmann et al., 2014). Within the proposed framework, the ecosystem dimension is analyzed by focusing on the **presence of strategic partners**, the **continuity of their engagement**, and the **governance mechanisms regulating collaboration**. The **presence of strategic partners** refers to the involvement of key actors that support the development and delivery of the XaaS offering by contributing complementary resources, capabilities, or assets (Charro & Schaefer, 2018). Strategic partners play a critical role in XaaS models, which are often built on advanced technological infrastructures and service capabilities that cannot be fully developed internally. In particular, partners may provide technological expertise, operational support, or financial resources, helping firms mitigate risks associated with the transition from product sales to service-based revenue models

(Parida & Jovanovic, 2022). The availability and suitability of partners are especially important in contexts where customers or local actors may lack the readiness or capabilities required to support advanced XaaS solutions. Beyond their mere presence, the **continuity of strategic partners' engagement** captures the extent to which partners are involved in a stable and ongoing manner throughout the lifecycle of the XaaS offering, rather than being engaged only in specific phases or activities. Sustained partner involvement supports long-term alignment, capability co-development, and adaptability within the ecosystem, while discontinuous or ad hoc engagement may limit partners' ability to contribute effectively to service performance and innovation (Allais & Gobert, 2016). Finally, **alliance governance** describes how collaboration with strategic partners is structured and managed within the XaaS ecosystem. Governance mechanisms define roles, responsibilities, decision rights, and incentive structures, shaping how value is created, shared, and controlled among participants (Kowalkowski & Ulaga, 2024; Parida & Jovanovic, 2022). Effective governance is particularly relevant in XaaS settings, where partners are required to share operational and financial risks and where poorly defined or overly rigid arrangements may restrict collaboration and reduce partners' ability to contribute to service improvement and innovation (Allais & Gobert, 2016).

- **Organization Structure and Culture**

Organization structure and culture encompass the set of norms, rules, and shared practices that define how activities are coordinated, responsibilities are allocated, and decisions are made within an organization (Schroeder et al., 2022). Given that organizational culture is often reflected in structural arrangements and routines, both elements are considered within the same dimension, in line with prior methodological approaches (Wikström et al., 2009; West et al., 2022). In the context of XaaS, organizational structure and culture play a critical role in enabling collaboration, knowledge sharing, and openness toward service-based logics, particularly in organizations transitioning from product-centric models (Annarelli et al., 2020; Schroeder et al., 2022). Within the proposed framework, this dimension is examined through variables capturing the **level of commitment of the top management**, **internal organization**, **service strategy**, **sales–service integration level**, and the configuration of **physical and digital distribution channels**. The **level of commitment of the top management of the provider** is a foundational condition for the implementation of XaaS models, as leadership must actively embrace a service-oriented approach and support the transformation through strategic guidance and resource allocation (Grubic & Jennions, 2018b; Aziz et al., 2020). Top management commitment is also essential to address internal resistance and to promote cultural change as employees adapt to new service-oriented roles and processes (Karatzas et al., 2022). **Internal organization** refers to the degree of coordination and coherence among organizational units

involved in the design, commercialization, and delivery of XaaS offerings. Effective internal organization supports collaboration between functions such as operations, research and development, and sales, facilitating knowledge exchange and reducing internal frictions that may hinder service performance (Sousa-Zomer et al., 2018; Karatzas et al., 2022). Closely related, **service strategy** reflects the organization's capability to design and manage an integrated service offering that aligns tangible and intangible resources, such as technology, data infrastructures, and organizational know-how, to ensure consistent performance and customer satisfaction over time (Karaca et al., 2018; Annarelli et al., 2020). A critical organizational challenge in XaaS models concerns the **sales–service integration level**, which captures how sales activities related to XaaS contracting are aligned with service delivery and execution. Higher levels of integration support continuity across the contract lifecycle, from offering definition to service provision, ensuring aligned objectives, consistent execution, and a unified customer interface (Priya Datta & Roy, 2011; Exner et al., 2017; Tukker, 2015). Conversely, fragmented organizational arrangements may generate coordination issues and undermine the sustainability of XaaS offerings. Finally, organizational structure and culture also influence the configuration of the **physical distribution channel** and the **digital distribution channel**. The physical distribution channel defines how XaaS offerings are sold and delivered to customers, shaping the degree of direct control over customer relationships and dependence on intermediaries. In parallel, the digital distribution channel captures the role of digital interfaces in supporting or enabling customer interaction, service activation, and ongoing management of XaaS offerings. Together, these channels reflect the organization's ability to adapt traditional go-to-market structures to service-based and digitally enabled business models, supporting scalability, efficiency, and responsiveness in XaaS delivery (Exner et al., 2017; Tukker, 2015).

- **Economic and Finance**

The economic and financial dimension is combined with value capture following the approach proposed by Moro et al. (2022), reflecting one of the defining characteristics of XaaS business models, namely the tight interdependence between revenue generation and customer value creation. In XaaS offerings, economic viability depends not only on cost recovery but also on the ability to align pricing and revenue mechanisms with service usage, performance, and outcomes delivered to customers. Accordingly, this dimension is examined through variables capturing **revenue model mechanisms**, **pricing**, **main risks**, **risk mitigation strategies and mechanisms**, and **profitability measurement through KPIs**. **Revenue model mechanisms** refer to the ways in which firms generate revenues from XaaS offerings and define how customers are charged for service usage and outcomes (Charro & Schaefer, 2018). XaaS models enable a shift from traditional transaction-based revenues toward mechanisms based on usage or time (usage-based, time-based), as well as on

achieved outcomes, performance levels, value delivered, or guaranteed availability (Rabe et al., 2018; Exner et al., 2017; Priya Datta & Roy, 2011; Buerkle et al., 2023). Firms must carefully assess the economic viability of these mechanisms by identifying the key drivers of service charges and ensuring that revenue streams are aligned with the value delivered over the lifecycle of the offering (Buerkle et al., 2023). Closely related, **pricing** captures how the monetary value of the XaaS offering is determined and reflects the logic through which revenues are captured. In XaaS contexts, pricing increasingly relies on value-based approaches that account for the benefits generated for the customer's business, rather than solely on cost recovery or market benchmarks (Huang et al., 2020; Annarelli et al., 2016; Arioli et al., 2022; Alix & Zacharewicz, 2021). Pricing decisions must therefore incorporate information on service usage, performance, and lifecycle considerations to ensure alignment between value creation and value capture (Guzzo et al., 2022). The provision of XaaS offerings is associated with several **main risks**, which are widely recognized as a significant challenge in the literature (Karaca et al., 2018; Chakrabarti et al., 2022). These risks include commercial, operational, financial, and behavioral components, as firms retain ownership of assets and assume responsibility for service performance over extended periods (Schroeder et al., 2022). Additionally, XaaS models may generate risks of market cannibalization, requiring firms to differentiate service-based offerings from traditional product sales to avoid internal competition (Sousa-Zomer et al., 2018). To address these challenges, firms adopt specific **risk mitigation strategies**, which define the overall approach used to manage uncertainty and exposure in XaaS models. Such strategies often include the design of long-term contractual arrangements, the allocation of responsibilities among involved actors, and the alignment of incentives to reduce opportunistic behavior and financial volatility (Sousa-Zomer et al., 2018; Tabares et al., 2023). Complementing these approaches, **risk mitigation mechanisms** refer to the concrete tools and practices used to operationalize risk management, such as initial assessments of operating conditions, customization of service configurations, and monitoring systems aimed at preventing failures and reducing performance deviations (Guzzo et al., 2022; Sousa-Zomer et al., 2018). Finally, the economic sustainability of XaaS offerings requires systematic **profitability measurement through KPIs**, which allow firms to evaluate both financial and operational performance during service delivery. Relevant indicators include parameters related to usage intensity (e.g., duration, frequency), service performance (e.g., availability, quality), and economic outcomes (e.g., revenues, costs), as well as customer satisfaction (Rabe et al., 2018; Priya Datta & Roy, 2011; Wilberg et al., 2015). The definition and continuous monitoring of these KPIs are essential to assess the economic viability of XaaS offerings and to support informed decision-making throughout the service lifecycle.

- **Resources**

In XaaS models, value creation is inherently linked to the availability and effective use of resources. These resources include both tangible assets, such as physical products and infrastructure, and intangible assets, such as data, digital technologies, human competencies, and organizational capabilities (Alix & Zacharewicz, 2021; Annarelli et al., 2020; Karatzas et al., 2022). Unlike traditional product-centric models, XaaS places particular emphasis on digitally enabled resources that allow providers to monitor, manage, and continuously adapt service performance throughout the lifecycle of the offering. Within the proposed framework, the resources dimension is examined through **data connectivity**, **data exploitation**, **customer data accessibility**, and the **role of technology**. **Data connectivity** refers to the degree of technical integration between the physical product, the service layer, and the digital infrastructure that enables data collection and transmission. Connectivity may be absent, partial, or continuous and automated, and it determines the provider's ability to monitor product performance, support preventive and predictive maintenance, and enable outcome-based XaaS offerings through connected and smart products (Rabe et al., 2018; Huang et al., 2020; Kim et al., 2022). Building on connectivity, **data exploitation** captures how collected data are used to generate value within the XaaS offering. This ranges from basic operational monitoring to advanced analysis of performance, behavior, and integrated system and customer data. The ability to exploit data supports service optimization, contract management, risk reduction, and the development of usage- or outcome-based business models (Exner et al., 2017; Grubic & Jennions, 2018a; Donner & Steep, 2021). Historical data and their reprocessing are particularly relevant in availability- and performance-based contracts, where they contribute to mitigating risks and ensuring service continuity for customers (Exner et al., 2017). **Customer data accessibility** refers to the extent to which the XaaS provider can access, use, and analyze data generated during service delivery. Access may be full, limited by contractual or regulatory constraints, or restricted to aggregated or anonymized information, reflecting trade-offs between data-driven service optimization, privacy requirements, security concerns, and customer digital readiness (Allais & Gobert, 2016; Mourtzis et al., 2021; Schroeder et al., 2022; Tabares et al., 2023). The level of accessibility directly affects the provider's ability to refine the service offering and to support continuous improvement and personalization. Finally, the **role of technology** captures how digital technologies enable and shape XaaS offerings. Advanced digital solutions, such as remote monitoring systems, analytics platforms, and digitally supported service tools, allow manufacturers to deliver maintenance, monitoring, and support services in a scalable and responsive manner (Kim et al., 2022; Huang et al., 2020). These technologies support outcome-based contracting by improving transparency, reducing reporting inaccuracies, and enabling the precise attribution of service outcomes (Grubic & Jennions, 2018b; Donner & Steep, 2021). At the same time, their effectiveness remains closely tied to organizational

capabilities and human expertise, highlighting the complementary role of technology within the broader XaaS resource configuration (Grubic & Jennions, 2018a).

- **Capabilities**

According to Kindstrom and Kowalowski (2014), a firm's capabilities are its ability to consistently produce a given operational output. In our model (as well as in the model of Kimita et al. 2022 and Moraes and Cunha 2022) the capability dimension interacts with the other dimensions previously mentioned. Specifically, the framework explores the capabilities critical to the acceptance of the XaaS business model, namely **data analysis capability, service design capability, risk assessment capability, and human and relational capabilities**. **Data analysis capabilities** refer to using structured data management and integration procedures together with analytical capabilities (Tabares et al., 2023). Specifically, the ability to examine and understand data is recognized as a crucial strategic skill for manufacturing companies transitioning to services (Grubic and Jennions, 2018a), and data obtained through remote monitoring are identified as a critical strategic asset (Sjödin et al., 2016). The crucial factors in this context are the competencies, expertise, and understanding possessed by the individual analysts required to interpret the gathered data, referred to as digitalization capabilities (Sjödin et al., 2016). The **service design capabilities** encompass designing for standardization, disassembly, adaptability, and modularity and the expertise to promote sustainable practices (Kimita et al., 2022). Moreover, they involve the creation of innovative methods to engage and motivate customers to utilize products correctly (Sousa-Zomer et al., 2018). The XaaS model requires a company to retain ownership of the asset and bear all associated risks, making risk assessment and mitigation capabilities (**Risk assessment capability**) highly significant. To fulfill this objective, he must determine the origins of responsibility, oversee and control them. Additionally, it is important to possess new skills in financial and legal domains, such as the ability to assess the financial consequences of pay-per-use services (Sousa-Zomer et al., 2018). To implement an XaaS business model, it is necessary to acquire new technical and relational skills (**Human and relational capability**). Specifically, companies must establish an operational structure to oversee subscriptions and improve relationships with consumers (Kimita et al., 2022; Allais & Gobert, 2016). Therefore, employees must undergo targeted training and adapt their behaviors according to the requirements and competencies of the current team (Sousa-Zomer et al., 2018).

- **Environmental Sustainability**

In XaaS business models, environmental sustainability is not an ancillary objective but emerges as a consequence of specific value-generation mechanisms. Retained ownership, data-enabled monitoring, and performance-based revenues create incentives for providers to intensify asset use,

extend product lifetimes, and systematically manage end-of-life flows. Accordingly, the sustainability variables included in this framework are interpreted through the lens of these XaaS-specific mechanisms, rather than as generic circular economy practices.

XaaS models provide for a reduction in resource consumption and address difficulties related to the entire lifespan and disposal of assets, while the provider maintains ownership (Pigosso and McAloone, 2016; Despeisse et al., 2012). Companies have complete authority over the entire product lifetime, enabling a reduction in the physical components of the offering (Bech et al., 2019; Holgado and Macchi, 2023). Additionally, they are motivated to incorporate high product quality (Sousa-Zomer et al., 2017; Pallaro et al., 2017). The XaaS solution has a positive impact on extending the lifespan of products (Matschewsky, 2019; Bech et al., 2019), enhancing the efficiency of resources and energy, and decreasing carbon emissions (Chiarot et al., 2022; Yang and Evans, 2019). The primary variables include **end-of-life and reverse logistics strategies, product life extension strategy, resource efficiency, product system substitution, use and service intensity and dematerialization and transparency. The product-life extension strategy,** particularly during the design phase, is a crucial component of the XaaS business model. This is because companies owning the product and earning profits based on its performance have an advantage in creating more durable products. In an XaaS context, then, the providers are economically incentivized to prioritize durability and lifetime extension as means to simultaneously enhance service value and reduce environmental impacts. In fact, this strategy results in reduced production and consumption of natural resources (Kanatlı and Karaer, 2022; Allais & Gobert, 2016) while ensuring greater value and quality (Ræbild and Bang, 2017; Pieroni et al., 2019). The primary objective is to combat waste resulting from poor design, including rapid obsolescence, inefficient processes, or irresponsible behavior by consumers, such as excessive consumption or improper usage of items (Pieroni et al., 2019). The XaaS model promotes the use of circular methods, such as recycling, remanufacturing, and reuse, to effectively close the material loop (**End-of-life and reverse logistics strategies**). This approach optimizes take-back and end-of-use strategies, leading to more efficient resource utilization. (Bech et al., 2019; Holgado and Macchi, 2023). Within XaaS business models, retained ownership and continuous customer relationships enable providers to systematically manage take-back, remanufacturing, and reuse activities, transforming end-of-life and reverse logistics from isolated circular practices into integral, economically viable components of the service offering (Sousa-Zomer et al., 2017; Kühl et al., 2023; Pigosso and McAloone, 2016). Furthermore, the integration of remanufacturing with the XaaS business model enhances customer receptiveness towards remanufactured items, as customers are primarily concerned with the product's functionality (Kazakova and Lee, 2022). **Resource efficiency** refers to the provider’s ability to optimize the use of materials, energy, and consumables

across the entire product lifecycle. In XaaS models, resource efficiency is strengthened by data-enabled service delivery and performance-based revenues, which incentivize providers to continuously optimize material, energy, and consumable use throughout the asset lifecycle in order to maintain service performance while reducing operational and environmental costs. Continuous monitoring of product condition, usage, and location enables more efficient maintenance and repair (Kühl et al., 2022). This data-driven approach encourages the use of durable materials, preventive maintenance, and timely upgrades, all aimed at extending product life and reducing resource input (Yang & Evans, 2019). Additionally, providers are incentivized to minimize energy and consumable use during the operational phase by adopting efficient design and service strategies that help close resource loops (Reim et al., 2015; Korkeamäki et al., 2021). **Product system substitution** refers to the ability of XaaS models to replace traditional product ownership with service-based solutions that fulfill the same functional needs. As highlighted by Cusumano et al. (2015), these substituting services challenge the conventional view of services as mere complements to products, positioning them instead as full alternatives. In an XaaS context, product system substitution is enabled by usage- and outcome-based service logics, which allow providers to deliver the required functionality through shared or optimized assets, thereby reducing the total number of products needed while maintaining customer value and service performance. (Käjer et al., 2019). Moreover, the XaaS model enhances efficiency by employing sharing and pooling models (Bech et al., 2019), and it educates customers on proper usage and saves energy costs (Peruzzini et al., 2013c; Chun and Lee, 2017; Pallaro et al., 2017) (**Use and service intensity**). Through sharing and pooling, the As-a-service model reduces the number of products being offered instead of creating individual products for each need (Kanatlı and Karaer, 2022; Despeisse, 2022). In XaaS models, sharing and pooling logics are reinforced by provider-controlled asset management and data-enabled usage optimization, allowing the same product to serve multiple users more intensively while reducing idle time, overall asset proliferation, and the environmental impacts associated with underutilization. Thus, the XaaS service diminishes environmental consequences by distributing the impacts across multiple users during the usage stages (Tukker, 2015) and by optimizing resource utilization (Chiarot et al., 2022). **Dematerialization** refers to the reduction in the quantity of physical materials required to deliver a given function, achieved by shifting from product ownership to service provision. By offering functional results instead of physical goods, providers can significantly decrease material throughput across the product lifecycle (Beuren et al., 2013). In XaaS models, dematerialization is enabled by outcome-oriented service logics and digital mediation, which allow providers to deliver the required functionality without transferring physical ownership, thereby reducing material intensity while maintaining or enhancing customer value. This is complemented by

transparency, enabled by digital technologies that allow for real-time monitoring and traceability of product-related data, including location, condition, usage, and maintenance history (Alcayaga et al., 2019; Ries et al., 2023). In XaaS contexts, such transparency is intrinsically linked to continuous service provision. In fact, enhanced data visibility across the value chain, enabled by real-time monitoring and traceability, supports proactive asset management, more informed and efficient resource use, and predictive or preventive interventions, thereby reducing redundant processes such as unnecessary transportation or excess inventory while aligning service performance with lower environmental impacts. From a social perspective, the primary advantage is in the augmentation of employment opportunities (Yang and Evans, 2019; Chiarot et al., 2022; Pallaro et al. 2017) and to allow users to access costly products (Sousa-Zomer et al., 2017). The variables are also defined more specifically in Table 8.

Dimensions	Variables	Definitions
Value Proposition	Offer object	In the XaaS model, the offer object concerns the company's strategic decision to focus its as-a-service proposition primarily on the product or the service. To deliver value, the firm must manage both intangible assets, such as technology, databases, reputation, and networks, and tangible assets, including the physical resources required for service delivery (Karaca et al., 2018). Whether emphasizing product functionality or service performance, the offering must align with product architecture and strategy and exhibit key attributes such as durability, upgradability, ease of use, quality maintenance service, and responsive technical support (Allais & Gobert, 2016; Haber & Fargnoli, 2021; Holgado & Macchi, 2021; Grubic & Jennions, 2018b; Kernschmidt et al., 2016).
	Maturity Level of the Service Offering	The maturity level of the service offering captures the extent to which an XaaS solution is developed and institutionalized within the provider organization. Following maturity-based perspectives in the pay-per-X and servitization literature, service offerings can be distinguished between pilot configurations, characterized by experimental and non-standardized implementations, and consolidated configurations, in which the offering is fully implemented, standardized, and supported by established organizational processes and data-driven monitoring (Schroderus et al., 2022)
	Coverage of the Offering	Coverage of the offering refers to the breadth of a company's XaaS proposition, indicating whether the as-a-service model is applied to the entire product portfolio or limited to a specific subset. Implementing this approach requires managing the necessary intangible and tangible assets to support the chosen scope (Karaca et al., 2018) and ensuring that all included products and services meet critical criteria such as long-life cycle, flexibility, upgradability, and reliable technical support. Alignment with overall product architecture and business strategy is essential to guarantee consistency and performance across the selected range of offerings (Allais & Gobert, 2016; Haber & Fargnoli, 2021; Holgado & Macchi, 2021; Grubic & Jennions, 2018b; Kernschmidt et al., 2016).
	XaaS Offering Approach	The XaaS offering approach describes the strategic posture of the firm toward XaaS, distinguishing between offerings that are proactively designed as part of a structured service strategy and those that are reactively introduced in response to specific customer requests or

		market pressures (Annarelli et al., 2016; Arioli et al., 2022; Andersen & Bering, 2023)
	Ownership	The value proposition also encompasses the concept of product ownership (Adrodegari et al., 2017), which is one of the key elements of the XaaS model definition (Gebauer et al., 2017). Customers acquire the right to use the product without transferring ownership. On the other hand, the company retains product ownership and expands its engagement and accountability across the complete lifecycle (Sousa-Zomer et al. 2017).
	Value for the customers	Value for customers refers to the set of benefits delivered by an XaaS offering. In XaaS models, customer value is primarily created through value-in-use and value-in-outcome mechanisms rather than through product ownership (Gebauer et al., 2017).
	Offer costumization (level)	The offer customization level refers to the extent to which an XaaS offering is tailored to individual customer needs, ranging from fully standardized solutions to configurable or highly customized offerings (Nordin et al., 2011; Kim et al., 2022). This dimension captures how providers balance customization requirements with scalability and standardization across multiple customers.
	Offer Customization (object)	The offer customization object describes which elements of the XaaS offering are subject to customization, such as the product, service, payment structure, or sales channel (Alix & Zacharewicz, 2021).
	Offer communication	Effective communication plays a crucial role in the XaaS context since value propositions need to clearly convey the positive changes in value that customers may expect by adopting this kind of model, such as the reduction of responsibilities and the emergence of economic advantages (Moro et al. 2022a). Companies must make decisions regarding the selection of communication and sales channels, as well as the specific form of client relationship to establish (Rathmann et al., 2014).
Customers	Target Customer segments	Customer maturity refers to the stage of development of the relationship between a company and its clients, ranging from newly acquired to consolidated customers. Understanding this maturity is essential for tailoring engagement approaches and aligning the offering with the specific needs of the client lifecycle (Charro & Schaefer, 2018; Kim et al., 2022). By distinguishing between new and established customers, firms can better adapt pricing models, design targeted strategies, and enhance value propositions in line with the evolution of their customer base (Sousa-Zomer et al., 2018; Annarelli et al., 2020).
	Customer segmentation strategy	Customer category mapping refers to whether an offering is targeted to a specific type of client—such as a certain industry, company size, or geographical market—or whether it is addressed to all customers without distinction (Charro & Schaefer, 2018; Kim et al., 2022). Identifying client categories supports the development of value propositions and strategies that are either specialized for particular segments, designed upon customer request to meet unique needs, or conceived to address the requirements of multiple markets broadly (Sousa-Zomer et al., 2018; Annarelli et al., 2020).
	Customer acceptance	Customer perception refers to how customers interpret and evaluate an organization's service-based offerings, shaping their willingness to adopt an XaaS model (Charro & Schaefer, 2018). While users possess deep knowledge of their own needs arising from product use, producers contribute technological expertise developed through systematic research and development (Kernschmidt et al., 2016). The perceived quality of service and the extent to which it meets customer expectations are central to influencing acceptance of XaaS solutions. In rental contexts, for instance, customers may be particularly sensitive to factors such as service pricing and the convenience of rental and return locations, which strongly affect their overall perception (Allais & Gobert, 2016). Building a structured approach to understanding and shaping these perceptions enhances the long-term sustainability of the

		offering and encourages a more comprehensive evaluation of costs beyond initial expenses (Batista et al., 2017; Schaefers et al., 2021).
	Customer involvement	User interaction is a crucial component since users can contribute valuable data that forms the foundation of services (Rabe et al., 2018). XaaS models exhibit a significant level of manufacturer-customer integration as they are tailored to meet the specific requirements and procedures of customers while manufacturers assume a substantial amount of responsibility (Kühl et al., 2022). A tailored solution, collaboratively built by the user and the provider from the beginning and adjusted to accommodate changes in usage guarantees a solution with significant added value for both parties (Alix & Zacharewicz 2021). Clients have the ability to actively tailor offers to their own use conditions (Kowalkowski and Ulaga 2024). Furthermore, consumer engagement enhances the information gathered by sensors, and at times, customer input holds greater significance than monitoring data (Huang et al., 2020).
Ecosystem	Presence of strategic partners	Strategic partners are partners who can help in maximizing the benefits of the XaaS service (Charro and Schaefer, 2018). The involvement of strategic partners in delivering the XaaS offering is crucial due to the implementation of a servitization strategy that heavily relies on technology, specifically the XaaS model. This approach necessitates a well-coordinated collaboration among all parties involved (Sklyar et al., 2019). Furthermore, it is crucial to have a strategic partner who can provide financial support to mitigate the financial risk arising from the lack of product sales (Parida and Jovanovic, 2022).
	Continuity of strategic partners' engagement	Continuity of strategic partners' engagement refers to the degree to which key partners are involved in a stable and ongoing collaboration throughout the lifecycle of the XaaS offering. This variable captures whether partner involvement is continuous and sustained over time or limited to specific phases, influencing long-term alignment, capability co-development, and adaptability within the XaaS ecosystem (Allais & Gobert, 2016; Annarelli et al., 2016; Arioli et al., 2022)
	Alliance governance	Alliance governance describes how collaboration with strategic partners is structured and managed, distinguishing between coordinated arrangements based on clearly defined roles, responsibilities, and rules, and collaborative arrangements characterized by flexibility, shared decision-making, and joint problem-solving. This variable reflects the governance logic through which value creation, control, and coordination are managed within the XaaS ecosystem (Allais & Gobert, 2016; Annarelli et al., 2016)
Organization structure and Culture	Level of commitment of the top management of the provider	To implement an XaaS model, leadership must actively embrace a service-oriented approach (Grubic and Jennions, 2018b). Obtaining support from top-level executives is vital to promote the acceptance of XaaS offerings and ensure the provision of sufficient resources, including new technology (Aziz et al., 2020). In addition, management must resolve the internal friction arising from current employees' resistance to adopting an XaaS offering. (Karatzas et al., 2022).
	Internal organization	An effective provision of a Xaas offering can be ensured by promoting intra-organizational cooperation between operations, research and development, and sales teams through organizational design and culture (Karatzas et al., 2022; Sousa-Zomer et al., 2018). In light of this, employees must modify their behavior and actions, particularly those related to sales and direct interaction with clients, to better conform to the new strategy (Sousa-Zomer et al., 2018). For effective integration of product and service development, it is crucial to utilize certain approaches and tools (Exner et al., 2017) while avoiding any conflicts (Rathmann et al., 2014). The company has to effectively manage the conflicts, especially the ones between front-end and back-end employees. These conflicts primarily arise from a lack of comprehension and communication between different departments

		(Raja et al., 2018). Furthermore, the presence of a dedicated department is crucial for the development and marketing of the new XaaS product.
	Service strategy	Within the XaaS model, service strategy represents the organization's capability to design and coordinate an integrated service vision that supports both product and service innovation. It involves aligning tangible resources and intangible assets, such as technology, data infrastructures, and reputation, to guarantee consistent performance and customer satisfaction (Karaca et al., 2018). A successful strategy encourages collaboration across operations, R&D, and sales, fostering an organizational culture that supports shared goals and smooth communication (Karatzas et al., 2022; Sousa-Zomer et al., 2018). To deliver value, companies must ensure that offerings feature durability, flexibility, ease of use, and reliable maintenance and technical support (Allais & Gobert, 2016; Haber & Fargnoli, 2021; Holgado & Macchi, 2021; Grubic & Jennions, 2018b). Dedicated processes and departments help integrate product and service development, while structured tools and conflict-management practices prevent misalignment between customer-facing and back-end teams (Exner et al., 2017; Rathmann et al., 2014; Raja et al., 2018). By embedding these elements, the service strategy becomes a central driver of sustainable and scalable XaaS delivery.
	Sales–Service Integration level	Sales–service integration level refers to the degree of organizational alignment and coordination between sales functions responsible for selling and contracting XaaS offerings and service functions responsible for service delivery and execution. This variable captures whether sales and service activities are managed by separate units, partially coordinated through interface roles, or fully integrated under unified responsibilities across the entire XaaS contract lifecycle, ensuring continuity of the customer experience and long-term service sustainability (Priya Datta & Roy, 2011; Exner et al., 2017; Tukker, 2015).
	Physical distribution channel	The physical distribution channel describes how the XaaS offering is sold and delivered to the end customer, distinguishing between intermediary-based, hybrid, and direct configurations. This variable captures the degree of direct control the manufacturer retains over the customer relationship and the level of dependence on traditional intermediaries, enabling the analysis of disintermediation dynamics in the go-to-market strategy of manufacturing XaaS models (Arioli et al., 2022; Annarelli et al., 2016)
	Digital Distribution channel	The digital distribution channel describes the presence and role of digital interfaces in the distribution and management of XaaS offerings, capturing whether digital tools are absent, used to support intermediary-based models, or enable direct interaction with the end customer (Andersen & Bering, 2023; Arioli et al., 2022)
Economic and Finance	Revenue model and mechanism	Revenue streams refer to the methods of setting prices in order to obtain value (Charro and Schaefer, 2018). Companies need to modify their revenue models in order to maximize the benefits of a XaaS model. This involves identifying the crucial elements that determine the service charge and assessing the economic viability of the model (Buerkle et al., 2023; Häckel et al., 2022). To effectively price XaaS solutions and address the associated risks and uncertainties, it is also crucial to utilize costing systems that take into account the life cycle costs and incorporate usage data (Guzzo et al., 2022). Customers have the option to pay based on their usage or the duration of their use of the product/service (usage-based or time-based), or based on the outcome or value they derive from it (results-based, performance-based, value-based) (Rabe et al., 2018; Buerkle et al., 2023; Exner et al., 2017). Additionally, customers can also choose to pay based on the availability of the product/service (availability-based) (Priya Datta and Roy, 2011).
	Main Risk	The identification and evaluation of potential risks is widely acknowledged as a significant challenge in the provision of XaaS

		(Karaca et al., 2018; Chakrabarti et al., 2022). Specifically, firms must recognize and reduce the risk linked to the commercial, operational, financial, and behavioral components (Schroderus et al., 2023; Hou and Neely, 2018). Furthermore, an XaaS offering has the potential risk of cannibalization, necessitating the establishment of a distinct business division and autonomous business plan that does not target the same specific consumer market (Sousa-Zomer et al. 2018).
	Risk mitigation strategy	The utilization of risk mitigation and controversy management tools, as well as the presence of a risk detection measurement system, are fundamental (Sousa-Zomer et al., 2018; Guzzo et al., 2022)
	Risk mitigation mechanisms	To mitigate the financial risk that comes with renting the product, it is highly beneficial to implement a long-term contract structure (Tabares et al., 2023; Sousa-Zomer et al., 2018). Additionally, conducting an initial evaluation of the technical conditions of the location and customizing the product accordingly can also minimize the likelihood of operational failures (Sousa-Zomer et al., 2017).
	Profitability Measurement KPI	The profitability measurement KPI dimension reflects how the company monitors and evaluates the economic and service performance of its XaaS offering. An XaaS model involves substantial changes in both risk-taking and revenue logic; therefore, it becomes essential to establish a structured system to track parameters such as usage intensity (duration, frequency), service performance (availability, quality), and resulting economic outcomes (revenue, cost) (Rabe et al., 2018; Tabares et al., 2023). To ensure that the delivered value aligns with customer expectations, companies must define and monitor key performance indicators (KPIs) that capture both financial and operational results (Wilberg et al., 2015). KPIs thus represent a critical mechanism for evaluating performance during the utilization phase of the XaaS offering (Priya Datta and Roy, 2011).
	Pricing	Pricing describes the logic through which the monetary value of an XaaS offering is determined, distinguishing between cost-plus, market-based, and value-based approaches. This variable captures how pricing reflects cost structures, market conditions, or the value perceived by the customer, shaping revenue models and the alignment between service performance and value capture in XaaS business models (Annarelli et al., 2016; Arioli et al., 2022; Alix & Zacharewicz, 2021)
Resources	Data connectivity	Data connectivity refers to the degree of technical integration between the physical product, the service layer, and the digital infrastructure enabling data collection and transmission. It captures whether data flows are absent, partial, or continuous and automated, determining the provider's ability to monitor product performance, support predictive maintenance, and enable outcome-based XaaS offerings through connected and smart products (Rabe et al., 2018; Huang et al., 2020; Kim et al., 2022).
	Data Exploitation	Data exploitation describes how collected data are used to generate value within the XaaS offering, ranging from basic operational monitoring to advanced analysis of performance, behavior, and integrated system data. This variable captures the firm's ability to leverage data for service optimization, contract management, risk reduction, and the development of usage- or outcome-based business models (Exner et al., 2017; Grubic & Jennions, 2018a; Donner & Steep, 2021; Chiarot et al., 2022).
	Customer Data accessibility	Customer data accessibility refers to the extent to which the XaaS provider can access, use, and analyze customer-generated data within the service relationship. It captures whether access is full, limited by contractual or regulatory constraints, or restricted to aggregated or anonymized data, reflecting trade-offs between data-driven service optimization, privacy, security requirements, and customer digital readiness (Exner et al., 2017; Mourtzis et al., 2021; Schroderus et al., 2023; Tabares et al., 2023).

	Technology role	Technology plays a pivotal role in enabling XaaS offerings. Advanced digital services—such as online monitoring and predictive maintenance—open new opportunities for real-time maintenance, repair, and field operations (Kim et al., 2022; Schroeder et al., 2022; Huang et al., 2020). Smart products equipped with sensors and connectivity features facilitate continuous data collection (Rabe et al., 2018), thereby supporting performance monitoring, predictive maintenance, and effective spare parts management throughout the product life cycle. These technological capabilities also underpin outcome-based contracting by reducing reporting inaccuracies and enabling the precise attribution of damages to specific instances of consumer behavior (Matschewsky, 2019; Grubic and Jennions, 2018b; Donner and Steep, 2021). Remote monitoring technologies, widely recognized as a key component of XaaS, provide remote access to machine control systems for assessing health conditions, diagnosing errors, and supporting informed decision-making. Their effectiveness, however, continues to depend heavily on the expertise, knowledge, and support of human operators (Grubic and Jennions, 2018a). Complementary tools for field service development further enhance the model by facilitating the rapid and seamless delivery of services (Bulut et al., 2021). Manufacturers adopting product-as-a-service models primarily leverage digital capabilities to deliver value through digitally enabled maintenance and monitoring, as well as online platforms that support their products and services (Kim et al., 2022). Remote assistance technologies extend these capabilities by enabling firms to provide helpdesk support via telephone or video-streaming, as well as guided repairs through integrated diagnostic systems requiring human intervention (Arioli et al., 2022; Chiarot et al., 2022). Moreover, remote specialists and on-site technicians can collaborate in real time using audio-video streams enriched with augmented reality (AR), further improving efficiency and responsiveness (Müller et al., 2020). Tthe framework aims to investigate the purposes for which technologies are used.
Capabilities	Data-analysis capabilities	Data integration and analytics refer to using structured data management and integration procedures together with analytical capabilities (Tabares et al., 2023). The collecting and processing of data is considered important for providing as-a-service offerings. Specifically, the ability to examine and understand data is recognized as a crucial strategic skill for manufacturing companies transitioning to services (Grubic and Jennions, 2018a; Cimini et al., 2021), and data obtained through remote monitoring are identified as a critical strategic asset (Sjödin et al., 2016). The crucial factors in this context are the competencies, expertise, and understanding possessed by the individual analysts required to interpret the gathered data, referred to as digitalization capabilities (Sjödin et al., 2016).
	Service design capabilities	The design capabilities are fundamental for the XaaS model. They encompass designing for standardization, disassembly, adaptability, and modularity (Azcarate-Aguerre et al., 2022), and the expertise to promote sustainable practices (Kimita et al., 2022). Moreover, they involve the creation of innovative methods to engage and motivate customers to utilize products correctly (Sousa-Zomer et al., 2018). The design capabilities can be compared to the service development capabilities (SDCs), which include the capacity to generate new service offerings that bring value to customers, as well as the establishment of frameworks, procedures, and actions to foster the creation and advancement of new product services (Sjödin et al., 2016).
	Risk assessment capabilities	The XaaS model requires a company to retain ownership of the asset and bear all associated risks, making risk assessment and mitigation capabilities highly significant (Visnjic et al., 2017). The provider is assuming also the risk associated with the product's performance. To fulfill this objective, he must determine the origins of responsibility,

		oversee and control them (Visnjic et al., 2018). Additionally, it is important to possess new skills in financial and legal domains, such as the ability to assess the financial consequences of pay-per-use services (Sousa-Zomer et al., 2018). Furthermore, the provider must develop the capability to effectively handle the potential risks in the supply chain that arise from the participation of many actors in the delivery of an XaaS offering (Karatzas et al., 2022).
	Human and relational capabilities	To implement an XaaS model, it is necessary to acquire new technical and relational skills. Specifically, companies must establish an operational structure to oversee subscriptions and improve relationships with consumers (Kimita et al., 2022; Smania et al., 2023; Allais & Gobert, 2016). The service provider's relationship capabilities are crucial and hold greater significance than their contractual capabilities (Holgado and Macchi, 2023). Companies must possess a highly skilled sales team that is competent in selling product-service solutions (Costa et al., 2015), and has extensive practical knowledge and expertise (Exner et al., 2017). Specifically, companies must carefully consider how their salespeople engage with potential clients in the initial stages, ensuring that the implications of the agreement are clear and that both technical and commercial aspects are discussed (Schaefers et al., 2021). Therefore, it is imperative for employees to undergo targeted training and adapt their behaviors according to the requirements and competencies of the current team (Sousa-Zomer et al., 2018).
Environmental Sustainability	End-of-life and reverse logistics strategies	In the manufacturing sector, the XaaS model is closely linked to the concepts of reverse logistics and remanufacturing (Paricio et al., 2019; Kazakova and Lee, 2022; Sallerström et al., 2022; Pallaro et al., 2017). The concept of retained ownership in PSS allows for the efficient return of old products to the original producer (Sousa-Zomer et al., 2017; Kühl et al., 2022; Kühl et al., 2023). Indeed, the XaaS mode allows for the possibility of returning the goods at the end of the contract, which may then be refurbished and utilized for future contracts, even those with shorter durations (Pigosso and McAloone, 2016). Furthermore, the integration of remanufacturing with the XaaS model enhances customer receptiveness towards remanufactured items, as customers are primarily concerned with the product's functionality (Kazakova and Lee, 2022). Finally, take-back systems or rental or leasing systems enable customers to evade waste responsibilities and diminish resource consumption. (Bech et al., 2019).
	Product-life extension strategy	The product-life extension strategy, particularly during the design phase, is a crucial component of the XaaS model. This is because companies owning the product and earning profits based on its performance have an advantage in creating more durable products. These characteristics result in reduced production and consumption of natural resources (Kanatlı and Karaer, 2022; Nishino et al., 2022; Allais & Gobert, 2016) while ensuring greater value and quality (Ræbild and Bang, 2017; Pieroni et al., 2019). The primary objective is to combat waste resulting from poor design, including rapid obsolescence, inefficient processes, or irresponsible behavior by consumers, such as excessive consumption or improper usage of items (Pieroni et al., 2019).
	Resource efficiency	Resource efficiency refers to the provider's ability to optimize the use of materials, energy, and consumables across the entire product lifecycle. Continuous monitoring of product condition, usage, and location enables more efficient maintenance and repair (Kühl et al., 2022). This data-driven approach encourages the use of durable materials, preventive maintenance, and timely upgrades, all aimed at extending product life and reducing resource input (Yang & Evans, 2019). Additionally, providers are incentivized to minimize energy and consumable use during the operational phase by adopting efficient design and service strategies that help close resource loops (Reim et al., 2015; Korkeamäki et al., 2021).

	Product service substitution	Product system substitution refers to the ability of XaaS models to replace traditional product ownership with service-based solutions that fulfill the same functional needs. As highlighted by Cusumano et al. (2015), these substituting services challenge the conventional view of services as mere complements to products, positioning them instead as full alternatives. By shifting from product acquisition to service consumption, companies can offer solutions that reduce the overall number of products in use, thus contributing to a net reduction in resource consumption (Käjer et al., 2019).
	Dematerialization and transparency	Dematerialization refers to the reduction in the quantity of physical materials required to deliver a given function, achieved by shifting from product ownership to service provision. By offering functional results instead of physical goods, providers can significantly decrease material throughput across the product lifecycle (Beuren et al., 2013). This is complemented by transparency, enabled by digital technologies that allow for real-time monitoring and traceability of product-related data, including location, condition, usage, and maintenance history (Alcayaga et al., 2019; Ries et al., 2023). Enhanced data visibility across the value chain supports more informed and efficient resource management, helping to avoid redundant processes (e.g., unnecessary transportation or excess inventory) and enabling predictive or preventive interventions.
	Use and service intensity	Through sharing and pooling, the As-a-service model reduces the number of products being offered instead of creating individual products for each need (Kanatlı and Karaer, 2022; Despeisse, 2022). Companies develop use-intensive products and services, to maximize their usefulness for a larger number of consumers. Moreover, these products are intended to be reused over their lifespan and are designed to be durable, with a focus on maintenance, repair, and longevity (Chiarot et al., 2022; Sallerström et al., 2022). Therefore, the XaaS service diminishes environmental consequences by distributing the impacts across multiple users during the usage stages (Tukker, 2015) and by optimizing resource utilization (Chiarot et al., 2022).

Table 8 XaaS variables description

4.3.4 Coding of XaaS framework variables

To operationalize the framework and enable its use as a configuration tool, each predefined variable was systematically coded following the Constant Comparative Method (CCM) (Boeije, 2002). This qualitative coding technique is based on iterative comparison across empirical materials and supports the transparent and rigorous refinement of analytical categories and their boundaries. In this study, the CCM was used exclusively to define the configurations (i.e., fixed states) associated with each variable, while framework dimensions and variables, defined in the preceding section, have been established conceptually prior to the empirical analysis.

The methodology was applied to a set of 17 semi-structured interviews conducted with key informants involved in XaaS offerings. Details regarding the selection of the analyzed companies, the interview protocol, and the overall empirical research design are presented in Chapter 5.

The coding process followed a stepwise constant comparative procedure, articulated as follows:

- **Step 1 - Within-interview comparison**: interview excerpts related to each predefined variable were coded and compared within individual interviews to identify provisional interpretations and eliminate internal inconsistencies.
- **Step 2 - Between-interview comparison**: provisional codes were compared across interviews to refine configuration boundaries and clarify the distinguishing attributes associated with each variable.
- **Step 3 - Cross-case comparison**: for each variable, recurring differences observed across cases were consolidated into discrete configurations, which were retained only when empirically recurrent and conceptually coherent with the predefined framework logic.
- **Step 4 - Iterative recoding and consistency checks**: previously coded interviews were revisited using the refined configuration scheme to ensure interpretability, mutual exclusivity where intended, and clear assignment rules.
- **Step 5 - Stabilization and saturation**: the configuration set was considered stable when additional interviews did not lead to the identification of new configurations or substantive revisions of existing ones.

The outcome of this process is a transparent and empirically grounded set of variable configurations, supported by explicit definitions and coding rules, which enables the consistent application of the framework across cases. The results of the empirical application of the framework are discussed in Chapter 5, while the final coding schemes are summarized in Table 9, providing an overview of the variables, their configurations, and associated definitions.

Dimensions	Variables	Coding	Definitions
Value Proposition	Offer object	Product	The offer covers both the product and the services included in the offer.
		Service	The aaS offer concerns services. The asset has already been purchased by the customer, who retains ownership of it.
	Maturity Level of the Service Offering	Pilot	The service is in the experimental phase. It has been launched on a small scale, with a limited number of customers, products, or markets, often with learning and validation objectives.
		Consolidated	The service is an integral part of the company's offering. It is offered regularly on key products, supported by dedicated processes and internal resources, and recognized by the market. It is part of the standard value proposition.
	Coverage of the Offering	Entire product range	The service offering is applied across the entire company portfolio
		Specific category	The service offering is limited to one or more well-defined product categories
		Specific product type	The application concerns an even more restricted and targeted set of products, often linked to a very specific use or pilot project (e.g., a single model, an experimental line, a particular type of component). This could indicate an experimental phase of the offering
	XaaS Offering Approach	Reactive (Upon request)	The offer is potentially available to all customers but is only activated for those who expressly request it.
		Proactive	The offer is systematically proposed to customers as part of the standard commercial process, regardless of an explicit request.
	Ownership	Customer	The customer purchases and owns the asset. The asset therefore remains under the control and responsibility of the customer.
		Offer Provider	The supplier retains ownership of the asset, which is made available to the customer through formulas such as pay-per-use, rental, etc.
		Third parties	An external party, other than the supplier or customer, holds ownership of the asset. This may be a finance company, a leasing company, or a technology partner. The company orchestrating the service coordinates delivery without owning the asset.
	Value for the customers	The reduction in initial investment	The company aims to eliminate or contain the costs incurred by the customer when purchasing the product, favoring the adoption of recurring revenue streams.
		The content and methods of service delivery (a fast and efficient service)	The company aims to differentiate the value of its offering through the functionality, quality, and flexibility of its service, creating a competitive advantage (i.e., fast and rapid service).
		Minimization of operating costs	The offer is designed to minimize management costs for the customer, increasing efficiency and convenience in continuous use.
		Risk minimization	The goal is to transfer or reduce technical, financial, or operational risks for the customer, offering greater security in adopting the service.
		Optimization of usage processes	The offer aims to simplify and improve the customer's operational activities, increasing productivity and reducing complexity.
		Guaranteed access to the product at a cost known in advance	The offer guarantees economic predictability, establishing a fixed or transparent cost for the entire duration of the contract.

		Guarantee of functionality	The goal is to ensure that customers can always count on the service/product functioning correctly, without interruptions or unexpected events.
		The achievement of an expected result	The value of the offer is based on the achievement of a concrete and measurable outcome for the customer (e.g., efficiency, performance, savings).
		Simplicity (removal of complications)	The company aims to simplify the customer experience by reducing complexity in the selection, use, and management of the service.
		The reduction in initial investment	The company aims to eliminate or contain the costs incurred by the customer when purchasing the product, favoring the adoption of recurring revenue streams.
	Offer customization (level)	Customizable offer	The offer is co-developed or heavily customized for the customer.
		Configurable offer	The offer is customized in certain aspects (e.g., service level, contract duration), but is based on a standard structure. It starts from a modular or predefined offer, with room for adjustment.
		No customization	The service is offered in a predefined form, the same for everyone, without variations.
	Offer Customization (object)	Product	the offer is characterized from a product perspective (different products have different possibilities for customization/configuration of the offer)
		Service	the offer is characterized from a service perspective (based on service characteristics, complexity, etc.)
		Payment	the offer is characterized in terms of payment methods (e.g., choice between different types of payment, from the customer's point of view)
		sales channel	The offer differs based on the sales channel (e.g., whether through a distribution channel or direct sales)
	Offer communication	New dedicated channels	The company has activated new specific communication tools or formats to promote the servitized offering. These channels are designed to support the cultural and commercial change associated with servitization.
		Integration into existing channels	The servitized offering is communicated through the same tools used for the product, without creating new channels. Communication takes place within existing flows, as part of the overall offering.
		Limited or absent communication	No structured channel has been set up to communicate the offering. The service is offered only on request or in individual negotiations, without visible material or messages.
Customers	Target Customer segments	consolidated customers	Long-standing or regular customers with whom the company has long-term relationships, often based on trust, mutual knowledge, and previous collaboration. Typical of: personalized service contracts, tailor-made solutions, shared pilot projects.
		New Customers	Recently acquired or potential customers who do not yet have a solid relationship with the company. The service offering can be used as a lever to attract new customers or lower the entry threshold. Typical of: standardized offers, “entry-level” models, commercial experimentation.
		No distinction	The offer is aimed at all customers, without distinction
	Customer segmentation strategy	Segment-Oriented	The offering is designed for specific customer segments selected based on shared characteristics (e.g., industry, usage profile, digital maturity).
		Specific customer-oriented	The offering is tailored for a very limited group of customers, typically key accounts or strategic partners with distinctive needs or dedicated initiatives.

		Undifferentiated	The offering is conceived as a standard, cross-market solution intended for the entire customer base, without significant segmentation or customization.
	Customer acceptance	High interest	Customers show enthusiasm or strong openness towards the servitized offering. The proposal generates curiosity and a high number of active requests. It is seen as a valuable solution.
		Moderate interest	Customers are interested but have reservations. The offering is perceived as promising but requires clarification, testing, or adaptation. Adoption is not automatic.
		Limited interest	Customers are skeptical or uninterested. They may see the offer as risky, unnecessary, or less convenient than the traditional model.
		N/A	not detected
	Customer involvement	Passive	The customer primarily receives the service; the offering is defined and managed almost entirely by the provider, with minimal customer involvement.
		Collaborative	The customer contributes in a limited yet structured way, for example by providing data, feedback, or participating in the definition of certain service requirements.
		Co-creative	The customer acts as an active partner in the design, customization, and continuous improvement of the XaaS offering.
Ecosystem	Presence of strategic partners	Financial	Provides funding, investment, or financial support to enable the XaaS offering, including risk sharing and revenue models.
		Technical	Offers technical expertise and operational support for implementing and maintaining the XaaS solution, ensuring reliability and service quality.
		Technological	Supplies or integrates technology components, platforms, or tools essential for delivering the XaaS service.
		Consultancy & research	Provides advisory services, market insights, or academic research to inform strategy, design, and value creation for the XaaS offering.
		Service delivery	Supports the execution and management of the service, including installation, maintenance, and customer support for the XaaS solution.
	Continuity of strategic partners' engagement	Financial _development	Partner involved in the financial structuring and planning of the XaaS offering.
		Financial _delivery	Partner providing financial support during the execution and operation of the XaaS service.
		Financial _both	Partner engaged in both financial planning and ongoing support throughout the XaaS offering lifecycle.
		Technical _development	Partner contributing technical expertise to the design and development of the XaaS solution.
		Technical _delivery	Partner supporting the implementation, maintenance, and operational execution of the XaaS service.
		Technical _both	Partner involved in both technical design and operational delivery of the XaaS offering.
		Technological _development	Partner providing technology components or platforms during the development of the XaaS offering.
		Technological _delivery	Partner supplying or managing technology infrastructure during the service delivery phase.
		Technological _both	Partner contributing technological solutions across both development and delivery stages of the XaaS service.
		Consultancy & research_development	Partner offering advisory or research input to guide the design and strategy of the XaaS offering.

		Consultancy & research_delivery	Partner providing guidance, monitoring, or feedback to optimize service delivery and outcomes.
		Consultancy & research_both	Partner engaged in both strategic guidance during development and support during service execution.
		Service delivery_development	Partner assisting in planning service processes and delivery workflows for the XaaS offering.
		Service delivery_delivery	Partner responsible for executing, managing, and supporting the XaaS service.
		Service delivery_both	Partner involved in designing the service delivery model and executing it throughout the XaaS lifecycle.
	Alliance governance	Financial_coordinated	The alliance is managed with clearly defined rules and responsibilities; roles, tasks, value distribution, and incentives are established and shared.
		Financial_collaborative	The alliance favors a flexible and dynamic management approach; the partner actively participates in defining tasks and responsibilities, with autonomy to adapt to context or needs.
		Technical _coordinated	Roles, tasks, and responsibilities are clearly defined; the partner follows a structured approach to technical support and execution.
		Technical _collaborative	The partner engages dynamically in co-design and problem-solving, contributing expertise while adapting responsibilities as needed.
		Technological _coordinated	esponsibilities for technology provision and integration are clearly established, with defined tasks and performance expectations.
		Technological _collaborative	The partner participates in joint technology decisions and adapts solutions flexibly based on evolving service requirements.
		Consultancy & research_coordinated	Advisory and research tasks are predefined; roles, deliverables, and value contributions are structured and agreed upon.
		Consultancy & research_collaborative	The partner co-defines activities and recommendations, adapting insights and guidance according to project needs.
		Service delivery_coordinated	Service execution tasks, roles, and responsibilities are clearly defined; processes, KPIs, and incentives are established upfront.
		Service delivery_collaborative	The partner actively contributes to co-designing delivery processes, adapting tasks and methods dynamically to optimize service outcomes.
Organization structure and Culture	Level of commitment of the top management of the provider	Widespread and strategic commitment	The XaaS offering is fully integrated into the company's strategy; it involves multiple functions (marketing, operations, finance, IT) and is supported by long-term investments and objectives.
		Partial or localized commitment	Commitment to the XaaS offering is limited to specific functions or business units; full strategic alignment is still lacking.
		Weak commitment or absent	The XaaS offering is in an initial or experimental phase; it is not yet a strategic priority and lacks strong organizational support.
	Internal organization	New, dedicated business unit or team	The company has created an internal structure/team of people dedicated exclusively to managing the service offering. This unit has autonomous responsibilities and often plays a cross-functional role with respect to other functions.
		Existing functions or business units	The XaaS offering is managed using existing organizational structures, without the creation of new dedicated units.

	Service strategy	Absent / Not aligned	No specific strategic objectives exist for XaaS. XaaS initiatives are tactical, isolated, or experimental, with no clear connection to the company's broader strategic direction
		Partially aligned / Integrated	Specific strategic objectives for XaaS are defined, but primarily as extensions or enablers of general corporate goals. XaaS is considered an integral part of the strategy, yet still operates within its own perimeter.
		Fully integrated / Strategically driven	XaaS objectives are embedded within the company's overarching strategic priorities. XaaS is not a sub-strategy but one of the main drivers of the company's transformation.
	Sales–Service Integration level	Separated	Sales and service delivery functions operate independently, with uncoordinated responsibilities and objectives. The contract is sold by one unit (e.g., Sales) and managed by another (e.g., Service), with no single organizational owner overseeing the entire lifecycle.
		Partially integrated	Sales and service delivery functions collaborate or share some objectives but remain organizationally separate. Coordination mechanisms may exist, such as a liaison role (e.g., account manager, contract owner) or functional alignment, yet full integration is not achieved.
		Integrated / Unified	Sales and XaaS contract management are fully integrated. A single responsible role (or cross-functional team) oversees the entire contract lifecycle, from offering to delivery, ensuring aligned objectives, consistent execution, and a unified customer relationship.
	Physical distribution channel	Intermediated	Sales and service delivery for the XaaS offering are managed through partners or intermediaries (e.g., dealers, system integrators, distributors). The manufacturer has no direct relationship with the end customer.
		hybrid/intermediate	Direct and indirect channels coexist. The manufacturer may manage certain customers directly—typically strategic accounts—while others are served through intermediaries.
		Disintermediated	The manufacturer sells and delivers the XaaS offering directly to the end customer, without involvement from intermediaries. All commercial and contractual interactions are managed in-house.
	Digital Distribution channel	Absent	No digital channel exists for the sale or management of the XaaS offering. Processes are traditional, relying on offline or manual workflows.
		Intermediated	A digital channel (platform or portal) is in place and used within an intermediated model—for example, to support dealers or to manage orders and contracts through partners.
		Disintermediated	A digital channel enables a fully disintermediated model, such as an online platform or customer portal through which the end customer can directly activate, monitor, or manage the XaaS offering.
Economic and Finance	Revenue model and mechanism	One-off sale	Traditional sales
		Fixed period / subscription (payment per period)	The customer pays a fixed amount at regular intervals (monthly, quarterly, annually) to access the service, regardless of actual usage.
		Pay-per-use	The customer pays based on actual use of the service, such as hours of use.
		Payment per performance / per availability	The customer pays based on actual results achieved (performance) or guaranteed service availability.
		Payment per result	The customer only pays based on the achievement of specific and measurable results (outcomes) defined in the contract.

	Main Risk	Financial risk	Represented by the dilution of revenues over time and the initial failure to sell, as well as the customer's creditworthiness.
		Technological risk	Represented by dependence on infrastructure and digital partners, with problems related to downtime, technological obsolescence, and IT vulnerabilities.
		Operational risk	Represented by inefficiencies in processes, errors in systems, or shortcomings in customer support, which can compromise the continuous and reliable delivery of the service.
		Cannibalization risk	When the new service model replaces or reduces sales of traditional products, resulting in discontent and competition within the organization
		Data security risk	This concerns the protection of sensitive customer data, with possible breaches, unauthorized access, or losses that can cause reputational, legal, and financial damage.
		Reputational risk	Represented by damage to brand and customer trust from service failures, unmet SLAs, or poor as-a-service delivery, affecting renewals and future adoption.
		N/A	The company claims that it does not encounter any particular risks.
	Risk mitigation strategy	Formalized risk management model	The company has a defined model or procedure for identifying, assessing, and mitigating XaaS risks (e.g., policies, dedicated roles).
		No formal strategy	The company lacks a formal model; risk management is reactive or handled on a case-by-case basis.
	Risk mitigation mechanisms	Contractual clauses	The company mitigates risk through contractual clauses, sometimes involving the legal department (where present).
		Financial company	The company relies on an internal/external financial institution to which it sells the asset.
		Customer and/or portfolio diversification	The company diversifies risk by entering into contracts with multiple customers in order to cover any individual defaults or protect itself from the risk of cannibalization.
		Third-party instruments involvements (insurers..)	The company relies on other entities to cover risk (insurance policies, involvement of third parties other than financial institutions, etc.).
		Maintenance or monitoring programs	The company has scheduled maintenance programs in place to prevent breakdowns, outside of the customer offering.
		Digitals risk monitoring tools	The company uses digital tools and platforms to continuously monitor and mitigate XaaS risks, ensuring service reliability and proactive issue resolution.
	Profitability Measurement KPI	financial economics KPI	The company uses traditional financial indicators (e.g., ROI) to monitor profitability, but does not integrate service or usage performance metrics.
		operational performance KPI	KPIs combine financial metrics with service performance indicators (e.g., uptime, utilization rate, SLA compliance).
		life cycle KPI	The company uses a comprehensive measurement system, with KPIs tied to outcomes and customer value (e.g., TCO).
	Pricing	Cost-plus	The price is determined by adding a profit margin to the costs incurred.
		Market-based	The price is determined based on market prices.
		Value-based	The price is determined based on the value perceived by the customer and the benefits obtained from the offer.
Resources	Data connectivity	Disconnected product	No connectivity or only manual data collection; the product is not connected or not connectable.

		Partially connected system	Partial connectivity, with data accessible only to certain functions; the product is connectable but used by few, and not in real time.
		Fully connected system	Continuous connectivity with automatic data transmission and integration across the system.
	Data Exploitation	Basic operational data	Collection of fundamental data (e.g., machine status, alarms) for basic monitoring and maintenance.
		Performance and behavioral data	Collection of performance metrics and customer usage behavior to optimize service and understand usage patterns.
		Integrated system & customer data	Combined use of product, process, and customer data to drive value creation, improve outcomes, and support decision-making.
	Customer Data accessibility	Full access	The provider has unrestricted access to customer data, enabling comprehensive analysis and service optimization.
		Limited/conditional access	Access is partial or subject to agreements (e.g., NDA, specific data types, or timing restrictions).
		No specific data	The provider cannot directly access customer data; only aggregated or anonymized information is shared.
	Technology role	Maintenance automation and/or operational continuity	The company uses digital technologies to automate maintenance activities and ensure uninterrupted operation of the XaaS solution.
		Real-time monitoring and/or analysis	The company leverages technologies to continuously collect and analyze data in real time, enabling immediate insights and rapid decision-making
		Safety guarantee	The company employs digital tools to ensure equipment and process safety, reducing risks and supporting compliance with safety standards.
		Functional monitoring for pricing definition	The company monitors an aspect that contributes to the pricing of the offer (e.g., monitoring parts in a pay-per-part offer)
		Interoperability and/or modularity	The company wants to ensure the possibility of establishing interaction with the customer's existing system
		High level of customization	The company wants to guarantee a highly personalized service (including the use of AI)
Capabilities	Data-analysis capabilities	Basic	Data is collected but rarely analyzed or used to support XaaS solution design.
		Intermediate	The company is able to process and interpret service-related data to support XaaS offering development.
		Advanced	The company demonstrates a mature ability to integrate and leverage digital technologies (e.g., IoT, cloud, AI, platforms) to enhance XaaS solution design.
	Service design capabilities	Basic design:	Ability to develop value-added services, without structured integration with the product or customer co-creation.
		Continuous innovation:	Structured processes for the continuous improvement and innovation of service offerings.
		Integrated PSS design	Integrated product–service design, developed through close collaboration and co-creation with the customer.
	Risk assessment capabilities	Base risk control	Qualitative and reactive risk assessments with limited structure.
		Structured risk management	Formalized processes for systematic risk evaluation and mitigation.
		Financial & operational integration	Integrated management of financial and operational risks within the XaaS model.

	Human and relational capabilities	Basic Skills	Individual communication and sales capabilities with limited cross-functional integration.
		Managerial & organizational skills	Cross-functional coordination and managerial competencies supporting structured service-related activities.
		Hybrid selling & distribution skills	Ability to sell and distribute integrated product–service offerings within XaaS business models.
Environmental Sustainability	End-of-life and reverse logistics strategies	End-of-life/contract product collection	The company manages the collection of products at the end of life or at contract expiration to enable responsible recovery and circular processes.
		Remanufacturing services offered	The company provides remanufacturing services to restore products or components to like-new condition, reducing waste and material consumption.
		No structured end-of-life management	The company does not have a formalized approach for product end-of-life handling or recovery.
	Product-life extension strategy	Preventive and predictive maintenance programs	The company adopts preventive or predictive maintenance programs that reduce failures, extend asset life, and optimize resource usage.
		development of a durable product	The company designs products to ensure long service life, minimizing replacements and environmental impact.
		Modular upgrade or component replacement	The company enables modular upgrades or component-level replacements to extend product life and reduce material waste.
		Reuse or lifetime extension throught refurbishment	The company supports refurbishment activities to recover used products and extend their operational lifetime.
		No structured life extension policy	The company lacks a defined strategy to extend product lifetime through maintenance, refurbishment, or upgrades.
	Resource efficiency	Measurements and optimization of resource, consumption (energy, materials..)	The company measures and optimizes resource use (e.g., energy, materials) within the XaaS offering to reduce environmental impact.
		Implementation of eco-efficient design or processes	The company adopts eco-efficient product design or operational processes to minimize waste, emissions, and resource consumption.
		No specific initiatives for resource efficiency	The company has no structured actions targeting energy, material, or resource efficiency improvements.
	Product service substitution	Full substitution	The XaaS offering fully replaces other product ownership; the customer purchases less or no alternative products as the service provides a complete solution.
		Partial substitution	A hybrid offering is available, where the XaaS service partially substitutes product ownership while traditional products are still used.
		No substitution	The XaaS offering complements traditional product sales without replacing existing ownership.
	Dematerialization and transparency	Monitoring and reporting of environmental data to customers	The company tracks environmental performance (e.g., energy, emissions, materials) and shares relevant data with customers to increase transparency.

		Digital platforms supporting traceability and reporting	The company leverages digital platforms to enable traceability, reporting, and communication of environmental and sustainability-related data
		No structured transparency or dematerialization	The company lacks formal processes or tools for reporting, traceability, or dematerialization of environmental information.
	Use and service intensity	Asset sharing among multiple users	The company enables multiple customers to access and use the same physical asset, increasing utilization and reducing environmental impact.
		Optimization of asset use (maximized uptime, performance-based logic)	The company optimizes asset usage through high uptime, performance-based monitoring, and operational efficiency to maximize value and reduce waste.
		Multi-contract asset utilization	The company allows a single asset to serve multiple contracts or customers over time, enhancing efficiency and sustainability.
		Single-use or customer-specific asset	Assets are dedicated to a single customer or contract, limiting sharing and reuse opportunities.
		Inclusion of second-hand products in the aaS offering	The company incorporates refurbished or second-hand products in its XaaS offering to extend product life and promote circularity.

Table 9 Dimensions, variables, and codin

Beyond its analytical purpose, the proposed framework also provides practical support for the design and structuring of XaaS business models in manufacturing contexts. By organizing XaaS configurations across interconnected dimensions, variables, and implementation choices, the framework enables firms to systematically assess how different business model elements interact and influence the overall coherence of the offering. In particular, the framework can support managers in identifying suitable combinations of value proposition, revenue logic, lifecycle involvement, digital infrastructure, ecosystem configuration, and governance mechanisms according to the characteristics of the target market and operational context.

Rather than prescribing a single optimal XaaS configuration, the framework highlights the configurational nature of XaaS adoption and emphasizes the need to align strategic, organizational, technological, and financial dimensions within a coherent business model architecture. In this sense, the framework may serve both as a diagnostic tool for evaluating existing XaaS initiatives and as a decision-support structure for designing and progressively developing new service-oriented and outcome-oriented offerings. Furthermore, the operationalization of the framework through variables and coding categories facilitates its applicability in empirical analyses and managerial assessment processes, supporting comparability across different XaaS implementations and industrial settings.

5 CHAPTER V – EMPIRICAL APPLICATION

5.1 Scope and approach

This chapter aims to identify and theoretically interpret recurring configurations of XaaS business models within manufacturing contexts. Building on the analytical framework developed in the previous chapter, the objective is to examine how different dimensions of XaaS offerings combine in practice, thereby revealing internally coherent patterns that enhance the understanding of how such models are structured and enacted. Rather than seeking statistical generalization, the analysis adopts a theory-driven perspective focused on pattern recognition and conceptual refinement. Methodologically, the chapter employs a qualitative cross-case analysis in which firms are treated as empirical instances through which recurring configurations can be identified and compared. Cases are systematically examined across the framework dimensions to detect similarities, contrasts, and meaningful combinations of attributes, following a pattern-matching logic consistent with multiple-case study research. This approach enables the derivation of ideal-typical configurations that capture dominant adoption patterns while remaining closely grounded in empirical evidence. To support structured comparison, cases are first grouped according to the type of XaaS offering, distinguishing between integrated product–service solutions and service-only configurations. A maturity lens, differentiating pilot from consolidated initiatives, is then applied as a transversal interpretative dimension to capture the evolutionary character of XaaS business models. The resulting cross-case comparison provides the basis for identifying analytically distinct groups and for discussing the mechanisms that shape alternative pathways of XaaS adoption in manufacturing

5.2 XaaS framework application – Multiple Case Studies

This chapter presents the empirical application of the conceptual framework for XaaS business models in the manufacturing context developed in the previous chapters. The primary aim is to assess the applicability and descriptive capability of the proposed framework by mapping a set of manufacturing firms according to the key dimensions, variables, and configurations of the XaaS framework.

The framework is furthermore employed as an analytical lens to systematically examine and compare heterogeneous firms, enabling the identification of similarities and differences, as well as the strategic, organizational, and operational choices underlying the transition towards XaaS solutions.

The empirical analysis is conducted using a multiple case study methodology (Yin, 2009), which is particularly suitable for investigating complex and still-emerging phenomena, such as XaaS business models in the manufacturing domain. The multiple case study is an all-encompassing method, including both design logic and data collection techniques, but also approaches for analyzing the

results. Case research involves several phases, from the case study design to the development of the empirical investigation for data collection and analysis. The main steps adopted in this research are summarized in Figure 24 and briefly described below.

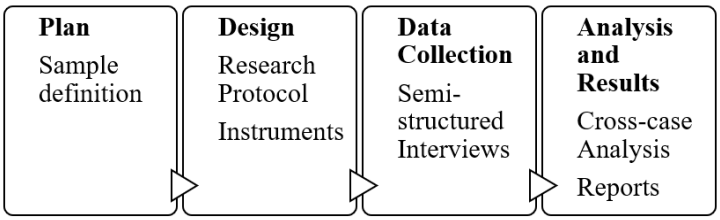


Figure 24 Multiple case studies research steps

- **Plan**

This work adopts a judgmental technique to select the cases as already done by similar works (Cimini et al., 2021). The multiple case study is based on a purposive sample of 13 manufacturing companies, selected according to three main criteria. First, the companies were required to offer a more or less established XaaS solution. Second, they had to demonstrate willingness to participate in the study and provide access to relevant informants. Third, the companies were required to operate within the manufacturing domain, as the research specifically investigates the adoption and implementation of XaaS business models in manufacturing contexts. This selection approach is consistent with the exploratory and theory-building objectives of the research and with the adoption of a multiple case study design. The sampled companies operate across different industrial sectors and exhibit heterogeneous organizational sizes, ranging from medium-sized enterprises to large multinational corporations (Table 10). Such heterogeneity was intentionally sought in order to capture a broad range of XaaS implementations and to increase the analytical richness of the empirical analysis.

Company	Industry / Sector	Firm Size
Turboden	Energy systems and industrial solutions	Medium
Toyota Handling Material	Material handling and logistics equipment	Large
Kaer	Industrial cooling and energy efficiency	Medium
KUKA Robotics	Industrial robotics and automation	Large
Prima Industrie	Machine tools and industrial automation	Large
ABB Robotics	Electrification and industrial automation	Large
W&H	Packaging and converting machinery	Large
SEW-Eurodrive	Industrial drives and automation	Large
CGT	Construction equipment and industrial services	Large
Stulz	Precision cooling and air conditioning systems	Medium
Sandvik Coromant	Cutting tools and manufacturing solutions	Large
Cavanna	Packaging machinery	Medium
Henkelhausen GmbH & Co	Industrial machinery and systems	Medium

Table 10 Overview of the Sampled Firms

While the firm represents the organizational context of the study, the unit of analysis is defined at the level of the object of the XaaS offering, which is operationalized as one of the variables within the proposed framework. Accordingly, cases are identified and analyzed based on the specific configuration of this variable. In particular, two units of analysis are considered:

1. **Product-based offering**, intended as an integrated solution combining a physical product with associated services and delivered according to an as-a-service logic;
2. **Service offering**, where the XaaS logic applies exclusively to the service component, whereas the physical product is sold separately through a conventional ownership-product-based model.

Several firms in the sample offer both types of XaaS solutions simultaneously. In these cases, each offering is treated as a distinct unit of analysis and analyzed as a separate case. As a result, although the empirical sample consists of 13 firms, the overall analysis encompasses 17 cases, corresponding to the distinct XaaS offerings identified (Table 11).

Company	Unit of Analysis	XaaS Offering Description
Turboden	Service	Monitoring- and performance-based service for ORC plants
Toyota Handling Material	Product-based solution	Material handling equipment rental with integrated lifecycle services
Toyota Handling Material	Service	Training-as-a-service and Diagnostic-as-a-service
Kaer	Product-based solution	Cooling-as-a-service
KUKA Robotics	Product-based solution	Industrial robots rental with integrated services
KUKA Robotics	Service	Maintenance and availability services for customer-owned robots
Prima Industrie	Service	Maintenance and lifecycle service contracts for machine tools
ABB Robotics	Product-based solution	Robot-as-a-service
W&H	Service	Digital monitoring and compliance services for medical equipment
SEW-Eurodrive	Product-based solution	Predictive maintenance and installed-base management as-a-service
CGT	Product-based solution	Pay-per-performance equipment-as-a-service (euro per ton model)
Stulz	Product-based solution	Precision cooling equipment rental for temporary and transitional applications
Stulz	Product-based solution	Cooling-as-a-Service solution with provider-owned systems and availability-based delivery
Sandvik Coromant	Service	Pay-on-withdrawal cutting tools solution
Sandvik Coromant	Product-based solution	Pay-per-part cutting tools solution
Cavanna	Product-based solution	Packaging machinery rental for temporary production needs
Henkelhausen	Service	Engine-as-a-service

Table 11 Units of Analysis and XaaS Offerings

- **Design**

To conduct the investigation in the selected cases, a well-designed research protocol for the interviews has been defined. The definition of a research protocol is crucial in the case of opting for a multiple-case study in order to increase the reliability of case study research and to guide the researcher in collecting data (Yin, 2009). The protocol follows the XaaS framework proposed in the previous chapter. The dimensions have been investigated in the companies using 2 different instruments: the first is a preliminary questionnaire that has been submitted before the interview to gain preliminary insight. The second is an interview guideline made of 22 open questions, which have been used to guide the interviews. According to the designed protocol, the preliminary questionnaire was used to gather general information about the level of organization, skills, process management, and technology already existing in the companies, while the semi-structured interviews were then used to gather other specific data related to the challenges, obstacles, and steps taken at the organizational level (pathway) as well as the results of the offer and possible causes of infeasibility and the strategies adopted by companies to overcome them. Both tools are detailed in the appendix.

- **Data Collection**

Data collection relied on qualitative evidence gathered through semi-structured interviews conducted both online and on-site, involving multiple organizational roles and managerial functions within each firm. This approach allowed for the integration of diverse perspectives and contributed to the development of a comprehensive and nuanced understanding of the phenomenon under investigation. The selection of the respondents was made in each company on the basis of reliability and knowledge of all aspects covered during the interview. These interviews lasted between 2 and 4 hours and have been recorded and later on rescripted to avoid bias in the analyses and to increase the internal reliability of the study. Data and other company materials (brochures, reports, internal presentations, Excel, …) were also collected to integrate the interview. Moreover, a synthesis of what emerged during the interview was shared with the interviewees to enhance the validity of the data collected. The respondents and the number of interviews are shown in Table 12.

Company	**Respondents**	**Nr. of interviews**
Turboden	General Manager of the after-sales service division	6
Toyota Handling Material	Operations Director	5
Kaer	Director	1
KUKA Robotics	Head of Business Development	1
Prima Industrie	Chief Product and Sales Officer (CPSO) and Chief After Sales Officer (CASO))	1
ABB Robotics	Global Cobot Sales & Marketing Manager - Collaborative Robot Product Manager	1
W&H	Product Manager	1

SEW-Eurodrive	Regional Manager - Servitization Business Developer - Chief Business Officer	1
CGT	Marketing Director and Digital Business Development	2
Stulz	Sales and Marketing Director - Production Testing Specialist /Industrial Engineering	3
Sandvik Coromant	Vending Tool Logistics Global Manager	2
Cavanna	Senior Manager Sales Business Development - SW/EL Designing Manager - Service Director	4
Henkelhausen GmbH & Co	Head of Customer Service	1

Table 12 Respondents and number of interviews

- **Analysis**

All data has been collected and organized in a database for data documentation and analysis. The collected data has been therefore analyzed according to the framework dimensions through cross-case analysis, in order to draw cross-case conclusions. The results (illustrated in the next section) were returned to the participating companies in the form of a report. A general report was also prepared and presented at a public event.

A detailed description of each unit of analysis, structured according to the dimensions of the adopted framework, is provided in the Appendix. The Appendix also includes the framework table, reporting dimensions, variables, and their respective coding for each unit of analysis.

5.3 XaaS adoption configuration

Building on the XaaS framework developed in Chapter 4, this section advances the empirical analysis by examining how the identified dimensions and variables are instantiated across the selected cases. The empirical sample consists of 13 companies, articulated into 17 units of analysis, particularly distinguishing between integrated product–service solutions and service-only offerings where the physical product is traditionally purchased by the customer. Before proceeding to the identification of clusters, this section adopts a preliminary descriptive and exploratory approach aimed at uncovering dominant patterns across the sample. Specifically, the analysis focuses on identifying, for each framework dimension, the most recurrent variable observed among the 17 units of analysis. This step serves a dual purpose. First, it provides an aggregated overview of how XaaS business models are most commonly configured within the observed sample, highlighting the prevailing strategic, organizational, economic, and technological choices adopted by firms. Second, it establishes a reference baseline against which heterogeneity, deviations, and alternative configurations can later be assessed in the clustering phase.

It is important to clarify that this analysis does not aim to describe a “typical” or representative firm, nor does it imply that the most recurrent variables across different dimensions co-occur within the

same company. Rather, the objective is to identify dominant tendencies within each dimension independently, thereby revealing which aspects of the XaaS framework exhibit greater convergence across cases and which, conversely, display higher variability. As such, this analysis should be interpreted as a dimension-level exploration of patterns, rather than as a configurational or firm-level synthesis.

From a methodological perspective, this approach is particularly suited to the qualitative and categorical nature of the framework variables. By examining the frequency distribution of variables within each dimension, the analysis allows for the identification of structural features that are widely shared across XaaS offerings, such as ownership arrangements, revenue mechanisms or data exploitation practices, as well as dimensions where strategic choices are more dispersed. These insights are essential for informing the subsequent cluster analysis, as dimensions characterized by limited variability are expected to play a marginal role in discriminating between clusters, while dimensions exhibiting higher dispersion are more likely to act as key drivers of differentiation.

Accordingly, the results of this chapter are presented dimension by dimension. For each dimension, the most recurrent variable is identified and discussed in light of the XaaS conceptualization developed in Chapter 4. Where relevant, the degree of concentration or dispersion across alternative variables is also considered to support interpretation. This structured analysis provides a theoretically grounded and empirically informed foundation for the identification of XaaS clusters in the following section, ensuring continuity between the conceptual framework, the descriptive evidence, and the subsequent configurational analysis.

5.3.1 Descriptive analysis of XaaS framework dimensions across the sample

- **Value proposition**

The analysis of the *Value Proposition* dimension highlights how XaaS offerings are predominantly configured across the sample, shedding light on the core logics through which value is defined and delivered to customers. With respect to the **offer object**, the results show a prevalence of **product-based XaaS offerings** (10 out of 17 units of analysis), compared to service-only solutions. This indicates that, within the observed cases, XaaS is more frequently implemented as an integrated product–service proposition in which the physical asset remains central to value creation, even though value is increasingly delivered through service-based logics. Service-only offerings are nonetheless well represented, confirming the coexistence of different XaaS configurations within the sample.

The **maturity level of the service offering** further reflects this heterogeneity. A majority of the analyzed units are classified as **pilot offerings** (10 cases), while **consolidated offerings** account for the remaining 7 cases. This distribution suggests that many XaaS initiatives are still in a development

or experimentation phase, even though a significant subset of firms has already institutionalized XaaS as a stable and recurring component of their value proposition.

Looking at the **coverage of the offering**, the most recurrent configuration corresponds to XaaS solutions applied to the **entire product range** (9 cases), followed by offerings limited to a **specific category** (6 cases) and, to a lesser extent, to a **specific product type** (2 cases). This result indicates that, in several cases, XaaS is not confined to isolated pilots on individual products, but is instead extended across broader portions of the portfolio, suggesting a more systemic integration of the XaaS logic within the firm's offering structure.

In terms of the **XaaS offering approach**, the results reveal a very strong predominance of **proactively proposed offerings** (16 out of 17 units of analysis). This indicates that, in most cases, XaaS is not activated only upon explicit customer request, but is instead deliberately positioned and promoted by the provider as part of its standard commercial strategy. This finding points to a clear strategic intent behind the adoption of XaaS models in the sample, even when offerings are still at a pilot stage.

A core element of the Value Proposition dimension is represented by **ownership**. The analysis shows that **ownership retention by the offer provider** is the most recurrent configuration (10 occurrences), followed by customer ownership and, in a smaller number of cases, ownership by third parties. Although multiple ownership arrangements may coexist within the same firm, the predominance of provider ownership confirms its central role in XaaS business models, consistent with the idea that retaining ownership enables providers to control asset usage, manage performance, and align incentives over the service lifecycle.

Regarding **value for the customer**, the results do not point to a single dominant value driver, but rather to a set of recurring value dimensions. In particular, **minimization of operating costs**, **optimization of usage processes**, and **guarantee of functionality** emerge as the most frequently cited benefits (each observed in five cases). These results suggest that XaaS offerings are primarily positioned around operational efficiency and reliability, rather than focusing exclusively on reducing upfront investments or simplifying access. Risk minimization and outcome achievement also appear as relevant, though less dominant, value elements, reinforcing the view of XaaS as a model aimed at reducing uncertainty and ensuring continuous performance.

Concerning **offer customization**, the analysis highlights a predominance of **configurable offerings** (10 cases), compared to fully customized solutions and standardized offers. This indicates that most XaaS propositions are based on modular structures that allow adaptation to customer needs without sacrificing scalability. When examining the **object of customization**, service-related elements clearly prevail (11 occurrences), while product features, payment structures, and sales channels play a

secondary role. This finding underscores the importance of service design and service management as key levers for differentiation within XaaS value propositions.

Finally, the analysis of **offer communication** shows that XaaS offerings are most frequently communicated through **existing commercial channels** (10 cases), rather than through newly created, dedicated channels. This suggests that XaaS is often embedded within established sales and communication practices, instead of being positioned as a radically separate or standalone offering. Limited or absent communication strategies are still observed in a substantial number of cases, indicating that the articulation and visibility of XaaS value propositions remain uneven across the sample.

Overall, the descriptive analysis of the Value Proposition dimension reveals a configuration characterized by integrated product–service offerings, proactive commercialization, provider ownership, and a strong focus on operational efficiency and service reliability. At the same time, the distribution of variables across several aspects of the dimension highlights meaningful heterogeneity, suggesting that the Value Proposition is likely to contribute to differentiating XaaS business models in the subsequent analysis (Figure 25).

DIMENSIONS	VARIABLES	CODING	TOT
Value proposition	Offer object	Product	10
		Service	7
	Maturity Level of the Service Offering	Pilot	10
		Consolidated	7
	Coverage of the Offering	Entire product range	9
		Specific category	6
		Specific product type	2
	XaaS Offering Approach	reactive (Upon request)	1
		proactive	16
	Ownership	Customer	6
		Offer Provider	10
		Third parties	4
	Value for the customers	the reduction in initial investment	2
		the content and methods of service delivery (a fast and efficient service)	3
		minimization of operating costs	5
		risk minimization	4
		optimization of usage processes	5
		guaranteed access to the product at a cost known in advance	2
		guarantee of functionality	5
		the achievement of an expected result	3
		simplicity (removal of complications)	1
	Offer costumization (level)	Customizable offer	6
		Configurable offer	10
		No customization	1
	Offer Customization (object)	Product	6
		Service	11
		Payment	4
		sales channel	1
	Offer communication	New dedicated channels	0
		Integration into existing channels	10
		Limited or absent communication	7

Figure 25 Coding results for value proposition variables

- **Customers**

The analysis of the *Customers* dimension sheds light on how XaaS offerings are targeted, perceived, and co-developed with users across the sample, highlighting the nature of customer relationships underlying XaaS business models.

Starting from the **target customer segments**, the results show a very strong predominance of offerings addressed to **customers without explicit differentiation** (14 out of 17 units of analysis). In contrast, XaaS offerings explicitly targeting **consolidated customers** are observed in only 2 cases, while offerings aimed at **new customers** appear in a single case. This distribution suggests that, in most instances, XaaS solutions are conceived as broadly applicable offerings rather than as propositions tailored to specific customer categories. As such, XaaS is frequently positioned as a transversal model applicable across the customer base, rather than as a selectively targeted or relationship-specific initiative.

A similar pattern emerges when examining the **customer segmentation strategy**. The most recurrent configuration corresponds to a **segment-oriented approach** (9 cases), followed closely by **undifferentiated strategies** (8 cases), while **specific customer-oriented strategies** are not observed in the sample. This result indicates that, although XaaS offerings are often designed with reference to shared characteristics such as industry or usage profile, they are rarely developed as highly bespoke solutions for individual customers. Instead, firms appear to favor segmentation logics that balance differentiation with scalability, aligning with the modular and configurable nature of many XaaS offerings observed in the Value Proposition dimension.

The analysis of **customer acceptance** reveals a more heterogeneous picture. **Moderate interest** represents the most frequent level of acceptance (7 cases), followed by **high interest** (5 cases) and **limited interest** (4 cases), with one unit of analysis where acceptance was not detected. This distribution suggests that, while XaaS offerings generally attract attention and engagement from customers, full enthusiasm and immediate adoption are not universal. The prevalence of moderate acceptance indicates that customers often perceive XaaS as promising but still associated with uncertainties, learning requirements, or perceived risks, particularly in comparison to traditional ownership-based models.

With respect to **customer involvement**, the results show that **passive involvement** is the most recurrent configuration (10 cases), followed by **collaborative involvement** (4 cases) and **co-creative involvement** (3 cases). This indicates that, despite the relational and service-oriented nature of XaaS, most offerings are still primarily designed and managed by providers, with limited active participation from customers. Nevertheless, the presence of collaborative and co-creative arrangements in a subset of cases highlights that deeper forms of customer engagement are already emerging, especially in contexts where service customization, data sharing, or continuous adaptation are required.

Overall, the descriptive analysis of the Customers dimension highlights a configuration in which XaaS offerings are largely conceived as broadly applicable solutions, supported by segment-based rather than customer-specific strategies, and characterized by intermediate levels of customer

acceptance. While customer involvement remains predominantly passive, the coexistence of collaborative and co-creative modes suggests a gradual transition toward more interactive and relational forms of engagement. The observed heterogeneity across several variables indicates that the Customers dimension is likely to contribute meaningfully to differentiating XaaS business models in the subsequent analysis (Figure 26).

DIMENSIONS	VARIABLES	CODING	TOT
Customers	Traget Customer segments	consolidated customers	2
		New Customers	1
		No distinction	14
	Customer segmentation strategy	Segment-Oriented	9
		Specific customer-oriented	0
		Undifferentiated	8
	Customer acceptance	High interest	5
		Moderate interest	7
		Limited interest	4
		N/A	1
	Customer involvement	Passive	10
		Collaborative	4
		Co-creative	3

Figure 26 Coding results for customers variables

- **Ecosystem**

The analysis of the *Ecosystem* dimension highlights the extent to which XaaS offerings rely on inter-organizational collaboration and the structured involvement of external actors to support value creation and delivery.

Starting from the **presence of strategic partners**, the results show that **technological partners** represent the most recurrent category within the sample (7 occurrences), followed by **financial partners** and **service delivery partners** (both observed in 6 cases), and **technical partners** (5 cases). **Consultancy and research partners** appear only marginally, with a single occurrence. This distribution indicates that XaaS ecosystems are primarily built around actors that enable the technological infrastructure, financial structuring, and operational execution of the service, while knowledge-oriented or advisory partners play a limited role. The prominence of technological partners is consistent with the centrality of digital infrastructures and data-enabled capabilities in supporting XaaS offerings.

The analysis of the **continuity of strategic partners' engagement** provides further insight into how these collaborations are structured over time. Financial partners are most frequently involved across **both development and delivery phases** (5 cases), while technological partners are predominantly engaged during the **delivery phase** (5 cases), with only limited involvement in development or across both phases. Technical partners show a more fragmented pattern, with involvement mainly concentrated in the **development phase** (4 cases) and only occasional continuity across the lifecycle. Service delivery partners are largely engaged during the **delivery phase** (5 cases), with very limited participation in the development stage. Overall, these results suggest that partner involvement in XaaS

ecosystems is often phase-specific, with different actors contributing at distinct stages of the offering lifecycle rather than maintaining continuous engagement throughout.

Turning to **alliance governance**, the results reveal differentiated governance logics depending on the type of partner involved. For **technological partnerships**, a **coordinated governance structure** is predominant (7 cases), indicating clearly defined roles, responsibilities, and expectations in the provision and integration of digital infrastructures. In contrast, **financial partnerships** are more frequently governed through **collaborative arrangements** (5 cases), suggesting a higher degree of flexibility and shared decision-making in managing financial risks and revenue mechanisms. A similar pattern emerges for **service delivery partners**, where **collaborative governance** is also prevalent (5 cases), reflecting the need for adaptability and joint problem-solving during service execution. Technical partnerships, by comparison, are more often managed through **coordinated governance mechanisms** (4 cases), consistent with the more bounded and task-specific nature of their contributions.

Taken together, the descriptive analysis of the Ecosystem dimension shows that XaaS business models are supported by multi-actor ecosystems in which technological, financial, and service delivery partners play a central role. Partner engagement is typically differentiated across development and delivery phases, and governance structures vary according to the nature of the partner and the type of contribution provided. This heterogeneity in partner roles, continuity, and governance suggests that the Ecosystem dimension is likely to represent an important source of differentiation among XaaS business models in the subsequent cluster analysis (Figure 27).

DIMENSIONS	VARIABLES	CODING	TOT
Ecosystem	Presence of strategic partners	Financial	6
		Technical	5
		Technological	7
		Consultancy & research	1
		Service delivery	6
	Continuity of strategic partners' engagement	Financial_development	1
		Financial_delivery	0
		Financial_both	5
		Technical_development	4
		Technical_delivery	0
		Technical_both	1
		Technological_development	1
		Technological_delivery	5
		Technological_both	1
		Consultancy & research_development	1
		Consultancy & research_delivery	0
		Consultancy & research_both	0
		Service delivery_development	0
		Service delivery_delivery	5
		Service delivery_both	1
	Alliance governance	Financial_coordinated	1
		Financial_collaborative	5
		Technical_coordinated	4
		Technical_collaborative	1
		Technological_coordinated	7
		Technological_collaborative	0
		Consultancy & research_coordinated	0
		Consultancy & research_collaborative	1
		Service delivery_coordinated	1
		Service delivery_collaborative	5

Figure 27 Coding results for ecosystem variables

- **Organization structure and Culture**

The analysis of the *Organizational Structure and Culture* dimension provides evidence of how firms internally enable (or constrain) the implementation of XaaS offerings through leadership commitment, organizational arrangements, integration mechanisms, and channel configuration.

Starting from the **level of commitment of the provider's top management**, the results show an almost complete concentration on **widespread and strategic commitment** (16 out of 17 units of analysis), while **partial or localized commitment** appears only once and **weak or absent commitment** is not observed. This distribution indicates that, within the sample, XaaS initiatives are overwhelmingly supported at the highest managerial level and are generally framed as strategically relevant rather than marginal or purely experimental undertakings.

Coherently with this strong strategic commitment, the data on **internal organization** highlight that firms most frequently create a **new, dedicated business unit or team** to manage XaaS (11 cases), while reliance on **existing functions or business units** (e.g., sales/service) is observed in 6 cases. This suggests that, in many cases, the organizational response to XaaS involves structural specialization and dedicated accountability, likely reflecting the need to manage continuous service delivery, customer engagement over time, and new contractual logics.

The picture becomes more articulated when looking at **service strategy**. The most recurrent configuration corresponds to **fully integrated / strategically driven** strategies (8 cases), followed by **partially aligned / integrated** (5 cases), while **absent / not aligned** strategies still account for 4 cases. This distribution indicates that, despite near-universal top-management commitment, the translation into a coherent service strategy is not uniform across the sample: alongside firms where XaaS is clearly embedded as a strategic driver, a non-negligible subset still shows limited strategic alignment or incomplete integration.

A key organizational mechanism in XaaS models is the **sales–service integration level**. Here, **partially integrated** arrangements dominate (8 cases), followed by **integrated/unified** structures (5 cases), while **separated** sales and service functions are present in 4 cases. This suggests that most firms are positioned in an intermediate organizational form: coordination between commercial and delivery activities exists, but full lifecycle ownership is not consistently achieved across the sample. Given the continuous and performance-dependent nature of XaaS delivery, this dimension is likely to represent an important discriminant in the subsequent clustering phase.

The analysis of the **physical distribution channel** shows that **disintermediated models** are the most recurrent configuration (9 cases), while **intermediated** and **hybrid/intermediate** channels both account for 4 cases each. This indicates that, in many observed offerings, firms maintain direct control over customer relationships and contractual interactions, an element that is consistent with the

relational orientation of XaaS and the need for continuous engagement over time, while alternative channel configurations remain relevant in a substantial minority of cases.

In this context, disintermediation should not be interpreted as the absence of ecosystem partners involved in XaaS delivery. Rather, it refers to the reduction of traditional commercial intermediaries between manufacturers and customers, allowing providers to maintain more direct control over customer relationships and contractual interactions. At the same time, service delivery frequently continues to rely on collaborations with technological, financial, and operational partners within the broader XaaS ecosystem.

Finally, the **digital distribution channel** displays a markedly different pattern. **Absent digital channels** represent the most frequent configuration (11 cases), while **disintermediated digital channels** appear in 6 cases and **intermediated digital channels** are not observed. This suggests that, in most units of analysis, XaaS offerings are not managed through a dedicated digital interface or platform, whereas a smaller but significant subset already enables direct digital interaction with customers. This split points to heterogeneous levels of digital channel maturity across the sample, an aspect that may meaningfully contribute to cluster differentiation, especially when read together with the resources and data-related dimensions.

Overall, the Organizational Structure and Culture dimension portrays a sample characterized by very strong top-management commitment and, in most cases, the establishment of dedicated internal structures. However, variability emerges in the strategic embedding of service logic, the degree of sales–service integration, and especially the presence (or absence) of digital distribution channels. This combination of high convergence on leadership commitment and dispersion on operational and channel arrangements suggests that organizational choices are likely to play a significant role in distinguishing different XaaS configurations in the clustering stage (Figure 28).

DIMENSIONS	VARIABLES	CODING	TOT
Organization structure and culture	Level of commitment of the top management of the provider	Widespread and strategic commitment	16
		Partial or localized commitment	1
		Weak commitment or absent	0
	Internal organization	New, dedicated business unit or team	11
		Existing functions or business units (es. Sales service)	6
	Service strategy	Absent / Not aligned	4
		Partially aligned / Integrated	5
		Fully integrated / Strategically driven	8
	Sales–Service Integration level	Separated	4
		Partially integrated	8
		Integrated / Unified	5
	Physical distribution channel	intermediated	4
		hybrid/intermediate	4
		Disintermediated	9
	Digital Distribution channel	Absent	11
		Intermediated	0
		Disintermediated	6

Figure 28 Coding results for organization structure and culture variables

- **Economic and Finance**

The analysis of the *Economic and Financial* dimension illustrates how XaaS business models configure value capture mechanisms, risk exposure, and performance assessment across the sample, highlighting both dominant patterns and areas characterized by partial information.

Starting from the **revenue model and mechanism**, the results show a very strong predominance of **fixed-period or subscription-based payment models** (13 out of 17 units of analysis). **Pay-per-use mechanisms** are observed in a limited number of cases (3), while **payment per performance or availability** and **payment per result** appear only marginally (2 cases each). No instances of **one-off sales** are observed. This distribution indicates that, within the analyzed sample, XaaS offerings are primarily anchored in time-based recurring revenue logics, while more advanced outcome-based mechanisms remain relatively rare.

Turning to **main risks**, **financial risk** clearly emerges as the most recurrent category (13 cases), followed by **operational risk** (8 cases). **Technological risk** and **data security risk** are observed only sporadically, while **cannibalization risk** and **reputational risk** are not reported in the dataset; one case is coded as *N/A*. This pattern reflects the central economic exposure associated with XaaS models, where delayed revenue realization, long-term contractual commitments, and asset ownership retention place financial sustainability at the core of managerial concern, alongside the operational challenge of ensuring continuous service delivery.

In relation to **risk mitigation strategy**, the majority of firms report the adoption of a **formalized risk management model** (11 cases), while **no formal strategy** is observed in 6 cases. This suggests that, although XaaS adoption entails significant financial and operational uncertainty, not all firms have yet institutionalized structured risk management practices, pointing to heterogeneous levels of organizational maturity within the sample.

The analysis of **risk mitigation mechanisms** shows that firms typically rely on a combination of contractual, financial, and organizational instruments. **Contractual clauses** represent the most recurrent mechanism (8 cases), followed by the involvement of a **financial company** and **customer and/or portfolio diversification** (6 cases each). **Third-party instruments**, such as insurance, are used in a smaller number of cases (3), while **maintenance or monitoring programs** are reported only twice. **Digital risk monitoring tools** are not observed. Overall, these results indicate that risk mitigation is predominantly addressed through contractual and financial arrangements rather than through digitally enabled monitoring mechanisms.

Regarding **profitability measurement**, the results highlight a strong predominance of **operational performance KPIs** (16 cases), followed by **life-cycle-based KPIs** (10 cases), while **purely financial KPIs** are observed in 9 cases. This distribution suggests that XaaS profitability is primarily assessed

through metrics capturing service performance, availability, and operational effectiveness, often complemented by life-cycle perspectives, rather than relying solely on traditional financial indicators. Finally, the analysis of **pricing** must be interpreted with caution, as pricing information was available only for a limited subset of cases. Among the observed instances, **cost-plus pricing** is reported in 3 cases, **market-based pricing** in 1 case, while **value-based pricing** is not observed. Given the restricted availability of pricing data, these results cannot be interpreted as representative of the overall sample, but rather indicate that pricing practices remain underreported or insufficiently disclosed in several cases.

Overall, the Economic and Financial dimension depicts XaaS business models characterized by subscription-based revenue structures, a strong focus on financial and operational risk, and performance-oriented approaches to profitability measurement. At the same time, the uneven adoption of formal risk management strategies and the limited availability of pricing information highlight areas of heterogeneity and partial transparency, reinforcing the relevance of this dimension for differentiating XaaS configurations in the subsequent cluster analysis (Figure 29).

DIMENSIONS	VARIABLES	CODING	TOT
Economic and finance	Revenue model and mechanism	One-off sale	0
		Fixed period / subscription (payment per period)	13
		Pay-per-use	3
		Payment per performance / per availability	2
		Payment per result	2
	Main Risk	Financial risk	13
		Technological risk	1
		Operational risk	8
		Cannibalization risk	0
		Data security risk	2
		Reputational risk	0
		N/A	1
	Risk mitigation strategy	Formalized risk management model	11
		No formal strategy	6
	Risk mitigation mechanisms	Contractual clauses	8
		Financial company	6
		Customer and/or portfolio diversification	6
		Third-party instruments involvements (insurers..)	3
		Maintenance or monitoring programs	2
		Digitals risk monitoring tools	0
	Profitability Measurement KPI	financial economics KPI	9
		operational performance KPI	16
		life cycle KPI	10
	Pricing	Cost-plus	3
		Market-based	1
		Value-based	0

Figure 29 Coding results for economic and finance variables

- **Resources**

The analysis of the *Resources* dimension highlights the role of data, connectivity, and digital technologies in enabling and sustaining XaaS offerings, shedding light on the technological foundations that support continuous service delivery and performance-based logics.

Starting from **data connectivity**, the results show a clear predominance of **fully connected systems** (10 out of 17 units of analysis), followed by **partially connected systems** (4 cases) and **disconnected products** (3 cases). This distribution indicates that, in most XaaS offerings, continuous and automated data transmission is already in place, enabling monitoring and control of asset usage and performance. However, the presence of partially connected and disconnected solutions suggests that

full connectivity is not a universal prerequisite for XaaS implementation and that different levels of digital maturity coexist within the sample.

The analysis of **data exploitation** reveals that **basic operational data** represent the most widespread form of data usage (17 cases), indicating that all observed XaaS offerings rely at least on fundamental data such as machine status or usage information. Beyond this baseline, **performance and behavioral data** are exploited in 11 cases, while **integrated system and customer data** are used in only 4 cases. This pattern highlights a progressive layering of data exploitation practices: while basic data collection is ubiquitous, more advanced forms of data integration and cross-domain analysis remain limited to a subset of offerings, pointing to differentiated levels of analytical sophistication.

With respect to **customer data accessibility**, the results show a relatively balanced distribution across the three categories. **Full access to customer data** is observed in 7 cases, **limited or conditional access** in 6 cases, and **no specific data access** in 4 cases. This indicates that, although access to customer-generated data is common, it is often constrained by contractual, regulatory, or organizational factors. The coexistence of these configurations suggests that data governance and access arrangements represent a critical and variable aspect of XaaS resource configurations.

The analysis of the **role of technology** further clarifies how digital resources are deployed within XaaS offerings. **Real-time monitoring and/or analysis** emerges as the most recurrent technological role (14 cases), confirming the centrality of continuous data collection and analysis in supporting service provision and performance tracking. **Maintenance automation and/or operational continuity** is also relatively common (7 cases), indicating that technology is frequently used to ensure reliability and reduce downtime. In contrast, **functional monitoring for pricing definition** appears in only 3 cases, while **high levels of customization** are reported in 2 cases. No instances are observed for **safety guarantee** or **interoperability and/or modularity**. This distribution suggests that technological resources are primarily oriented toward monitoring and operational support, rather than toward advanced pricing mechanisms, interoperability, or highly customized service delivery.

Overall, the Resources dimension depicts XaaS offerings grounded in connected assets and widespread basic data exploitation, complemented by selective use of advanced analytics and customer data integration. While real-time monitoring represents a common technological backbone, significant variation emerges in data accessibility and in the strategic use of technology beyond operational continuity. This heterogeneity indicates that resource configurations are likely to play an important role in differentiating XaaS business models in the subsequent cluster analysis (Figure 30).

DIMENSIONS	VARIABLES	CODING	TOT
Resources	Data connectivity	Disconnected product	3
		Partially connected system	4
		Fully connected system	10
	Data Exploitation	Basic operational data	17
		Performance and behavioral data	11
		Integrated system & customer data	4
	Customer Data accessibility	Full access	7
		Limited/conditional access	6
		No specific data	4
	Technology role	Maintenance automation and/or operational continuity	7
		Real-time monitoring and/or analysis	14
		Safety guarantee	0
		Functional monitoring for pricing definition	3
		Interoperability and/or modularity	0
		High level of customization	2

Figure 30 Coding results for resources variables

- **Capabilities**

The analysis of the *Capabilities* dimension focuses on the organizational and managerial abilities that enable firms to design, deliver, and sustain XaaS business models. Before discussing the results, it is important to clarify a key methodological aspect: the capabilities reported in this dimension reflect **only those capabilities that companies explicitly identified as relevant for the delivery of their XaaS offering**. As a consequence, not all capability categories were systematically mapped for every unit of analysis, and the observed distributions should be interpreted as indicative of **perceived relevance** rather than as a complete assessment of firms' overall capability endowments.

Starting from **data-analysis capabilities**, the results indicate a limited level of analytical maturity among the capabilities explicitly mentioned by firms. **Basic data-analysis capabilities** are reported in 4 units of analysis, while **advanced capabilities** are observed in only 1 case; no instances of **intermediate capabilities** are detected. This suggests that, when firms refer to data-related capabilities in relation to XaaS delivery, they most often emphasize basic analytical skills supporting monitoring and operational decision-making, while more sophisticated analytical capabilities are rarely highlighted as critical enablers of the offering.

The analysis of **service design capabilities** shows a more pronounced emphasis on dynamic service development. **Continuous innovation** emerges as the most frequently mentioned capability (7 cases), followed by **basic service design capabilities** (3 cases), while **integrated product–service system (PSS) design** is not reported in the sample. This pattern suggests that firms primarily associate XaaS success with the ability to continuously adapt and improve service components over time, rather than with fully integrated product–service co-design practices.

With respect to **risk assessment capabilities**, the results reveal a fragmented picture. **Basic risk control** and **financial and operational integration** are each reported in 3 cases, while **structured risk management capabilities** appear in only 1 case. Given the selective nature of capability reporting, this distribution indicates that firms tend to acknowledge risk-related capabilities mainly

when they are directly linked to the economic sustainability or operational viability of the XaaS offering, rather than as part of a comprehensive and formalized risk management framework.

Finally, the analysis of **human and relational capabilities** highlights a strong emphasis on competences related to customer interaction and commercial management. **Hybrid selling and distribution skills** represent the most frequently mentioned capability (8 cases), followed by **managerial and organizational skills** (4 cases) and **basic skills** (2 cases). This suggests that firms perceive relational and hybrid competencies as particularly critical for XaaS delivery, reflecting the need to manage long-term customer relationships, negotiate service-based contracts, and coordinate across internal and external actors.

Overall, the Capabilities dimension reflects a selective and uneven capability landscape, shaped by firms' perceptions of what is most critical for XaaS delivery rather than by a comprehensive mapping of all existing capabilities. While service innovation and relational skills are frequently emphasized, advanced data-analysis and structured risk assessment capabilities are mentioned only sporadically. This selective emphasis underscores the role of perceived capability relevance in shaping XaaS configurations and suggests that capability-related differences may represent an important source of differentiation in the subsequent cluster analysis (Figure 31).

DIMENSIONS	VARIABLES	CODING	TOT
Capabilities	Data-analysis capabilities	Basic	4
		Intermediate	0
		Advanced	1
	service design capabilities	Basic design:	3
		Continuous innovation:	7
		Integrated PSS design	0
	Risk assessment capabilities	Base risk control	3
		Structured risk management	1
		Financial & operational integration	3
	Human and relational capabilities	Basic Skills	2
		Managerial & organizational skills	4
		Hybrid selling & distribution skills	8

Figure 31 Coding results for capabilities variables

- **Environmental sustainability**

The analysis of the *Environmental Sustainability* dimension examines how XaaS business models incorporate environmental considerations through lifecycle management, resource efficiency, dematerialization, and asset utilization practices.

Starting from **end-of-life and reverse logistics strategies**, the results show that **end-of-life or contract product collection** is the most recurrent practice (10 out of 17 units of analysis), followed by **remanufacturing services** (6 cases). No instances of **unstructured end-of-life management** are observed. This indicates that, across the sample, XaaS offerings are consistently associated with structured end-of-life practices, reflecting the central role of ownership retention in enabling providers to manage product recovery and post-use phases.

The analysis of **product-life extension strategies** highlights **the development of durable products** as the most frequent approach (9 cases), followed by **preventive and predictive maintenance programs** and **reuse or lifetime extension through refurbishment** (3 cases each). **Modular upgrades or component replacement** appear only marginally (1 case), while **no structured life-extension policy** is not observed. This distribution suggests that environmental benefits in XaaS are primarily pursued through design-for-durability and maintenance-oriented strategies, rather than through modularity or frequent upgrading mechanisms.

With respect to **resource efficiency**, the most recurrent configuration corresponds to the **implementation of eco-efficient design or processes** (10 cases), followed by **measurement and optimization of resource consumption** (6 cases). A smaller number of cases report **no specific initiatives for resource efficiency** (3 cases). This indicates that many firms embed resource efficiency directly into design and operational processes, while fewer explicitly rely on systematic measurement and optimization of energy or material consumption.

The analysis of **product–service substitution** shows a very clear pattern: **no substitution** is reported in all 17 units of analysis. This indicates that XaaS offerings in the sample do not aim to replace physical products entirely with services, but rather to complement and enhance product usage through service-based logics, reinforcing the interpretation of XaaS as an access- and performance-oriented model rather than a dematerialized alternative.

Turning to **dematerialization and transparency**, the results reveal a fragmented distribution. **Digital platforms supporting traceability and reporting** are observed in 8 cases, while **monitoring and reporting of environmental data to customers** appears only once; **no structured transparency or dematerialization practices** are reported in 8 cases. This suggests that, while some firms have begun to leverage digital tools to support transparency and traceability, structured communication of environmental performance to customers remains limited and uneven across the sample.

Finally, the analysis of **use and service intensity** highlights **optimization of asset use**, through maximized uptime or performance-based logics, as the most recurrent configuration (9 cases). **Inclusion of second-hand products in the XaaS offering** is observed in 6 cases, while **multi-contract asset utilization** (3 cases), **asset sharing among multiple users** (1 case), and **single-use or customer-specific assets** (1 case) appear less frequently. This distribution indicates that XaaS sustainability benefits are primarily pursued through improved utilization of assets over time, rather than through shared-use models or radical changes in ownership structures.

Overall, the Environmental Sustainability dimension shows that XaaS offerings are strongly associated with lifecycle-oriented practices, including structured end-of-life management, durable product design, and optimized asset utilization. At the same time, variability emerges in transparency

mechanisms, resource efficiency measurement, and advanced dematerialization practices. These results suggest that environmental sustainability in XaaS is mainly an outcome of ownership retention and usage optimization mechanisms, rather than the result of explicitly articulated sustainability strategies, and that this dimension may contribute selectively to distinguishing XaaS configurations in the subsequent cluster analysis (Figure 32).

DIMENSIONS	VARIABLES	CODING	TOT
Environmental sustainability	End-of-life and reverse logistics strategies	End-of-life/contract product collection	10
		Remanufacturing services offered	6
		No structured end-of-life management	0
	Product-life extension strategy	Preventive and predictive maintenance programs	3
		development of a durable product	9
		Modular upgrade or component replacement	1
		Reuse or lifetime extension throught refurbishment	3
		No structured life extension policy	3
	Resource efficiency	Measurements and optimization of resource, consumption (energy, materials..)	6
		Implementation of eco-efficient design or processes	10
		No specific initiatives for resource efficiency	3
	Product service substitution	Full substitution	0
		Partial substitution	0
		No substitution	17
	Dematerialization and transparency	Monitoring and reporting of environmental data to customers	1
		Digital platforms supporting traceability and reporting	8
		No structured transparency or dematerialization	8
	Use and service intensity	Asset sharing among multiple users	1
		Optimization of asset use (maximized uptime, performance-based logic)	9
		Multi-contract asset utilization	3
		Single-use or customer-specific asset	1
		Inclusion of second-hand products in the aaS offering	6

Figure 32 Coding results for environmental sustainability variables

5.3.2 XaaS business model configurations

Building on the descriptive analysis of the XaaS framework dimensions presented in the previous section, this part of the chapter moves toward the identification of recurring configurations of XaaS business models. The objective of this analysis is not to derive statistically generalizable clusters, but to examine how combinations of framework dimensions and variables tend to co-occur across different XaaS offerings, thereby revealing internally coherent and theoretically meaningful patterns of adoption. Consistent with the theory-driven nature of the study, the limited number of units of analysis, and the predominantly qualitative and categorical structure of the data, the analytical approach adopted is a qualitative cross-case analysis. Rather than relying on algorithmic clustering techniques, which typically require larger samples and continuous variables to ensure statistical robustness, the analysis follows a pattern-matching logic commonly employed in multiple-case study research (Yin, 2018). Cases are systematically compared across the framework dimensions to identify recurring similarities and contrasts, focusing on coherent patterns of attributes rather than on distance-based or additive measures. Accordingly, firms are not treated as independent observations to be statistically grouped, but as empirical instances through which recurring XaaS adoption configurations can be identified, compared, and theoretically interpreted. The resulting groupings therefore represent ideal-typical configurations that capture dominant patterns in how manufacturing

firms adopt and structure XaaS offerings. This analytical strategy is consistent with theory-driven multiple-case study designs, where cross-case comparison, pattern recognition, and replication logic are used to refine conceptual frameworks and identify meaningful regularities across cases, without implying statistical generalization beyond the studied sample (Yin, 2018).

As a first step in the cross-case analysis, XaaS business model configurations are delineated by adopting a theoretically grounded grouping criterion that reflects both the nature of the XaaS offering and the construction of the units of analysis: the type of XaaS offering. This criterion provides an initial analytical structure for comparing cases and for examining recurring patterns across offerings. Based on this distinction, two analytical groups of XaaS offerings are identified. The first group includes XaaS offerings structured as integrated product–service solutions, in which the physical asset remains central to value creation but is delivered through an as-a-service logic. The second group includes service-only XaaS offerings, in which the service is provided on an as-a-service basis, while the underlying product is acquired by the customer through traditional ownership-based transactions. This distinction is conceptually grounded in the XaaS framework developed in Chapter 4 and is empirically observable across the analyzed cases. By grouping cases according to this theoretically informed criterion, the analysis establishes a basis for systematic cross-case comparison, enabling the identification of similarities and contrasts in how different types of XaaS offerings are structured across the framework dimensions.

In a second step of the cross-case analysis, the identified case groupings are examined through a maturity lens, distinguishing between pilot and consolidated XaaS initiatives. Rather than constituting an additional classificatory criterion, maturity is treated as a transversal analytical dimension that supports the comparison of cases within and across the two groups of XaaS offerings. Specifically, the maturity lens is used to interpret variations in the degree of organizational embedding, economic structuring, resource deployment, and capability development associated with different XaaS initiatives. This perspective enables the analysis to capture the evolutionary character of XaaS business models, highlighting how similar XaaS offering types may be enacted and stabilized differently depending on their stage of development. By applying maturity as an interpretative dimension in the cross-case comparison, the analysis supports the identification of recurring patterns and meaningful contrasts across cases, thereby enriching the understanding of how XaaS business models evolve over time without implying a linear or deterministic development trajectory.

Subsequently, a cross-case comparison is conducted to identify recurring patterns of similarity and difference within and across the identified groups of XaaS offerings by systematically comparing cases along the dimensions of the XaaS framework. This comparative analysis focuses on how combinations of framework dimensions tend to co-occur across cases, rather than on the isolated

effect of individual variables. Particular attention is devoted to dimensions that exhibited greater variability in the descriptive analysis, such as organizational structure, economic and financial arrangements, resource configurations, and capability development, as these dimensions provide greater analytical leverage in distinguishing between groups of cases. Dimensions characterized by limited dispersion across the sample are instead treated as contextual conditions that frame, rather than differentiate, the observed XaaS offerings. On this basis, four analytically distinct groups of XaaS offerings are identified and presented, together with the firms associated with each group. Each group is then examined in detail to characterize its distinguishing features and internal consistency, followed by a systematic comparison across the four groups. This stepwise analytical approach enables the identification of theoretically meaningful patterns in XaaS adoption while maintaining close grounding in the empirical evidence and coherence with the underlying conceptual framework.

Type of XaaS offering	**Integrated product–service solutions**	**Service-only XaaS offerings**
Pilot initiatives	**Group 1** Kuka Robotics Rental ABB Robotics SEW-Eurodrive CGT STULZ Rental STULZ CaaS Cavanna	**Group 2** Turboden Toyota Handling Material Service Henkelhausen GmbH & Co
Consolidated initiatives	**Group 3** Toyota Handling Material Rental Kaer Sandvik Coromant pay-per-part	**Group 4** Kuka Robotics Service Prima Industrie W&H Sandvik Coromant pay-at-withdrawal

*Table **13*** summarizes the analytical grouping of the analyzed XaaS offerings based on the type of offering and the level of maturity, which serve as the organizing criteria for the cross-case analysis.

Type of XaaS offering	**Integrated product–service solutions**	**Service-only XaaS offerings**
Pilot initiatives	**Group 1** Kuka Robotics Rental ABB Robotics SEW-Eurodrive CGT STULZ Rental STULZ CaaS Cavanna	**Group 2** Turboden Toyota Handling Material Service Henkelhausen GmbH & Co

Consolidated initiatives	**Group 3** Toyota Handling Material Rental Kaer Sandvik Coromant pay-per-part	**Group 4** Kuka Robotics Service Prima Industrie W&H Sandvik Coromant pay-at-withdrawal

Table 13 Analytical grouping of the analyzed XaaS offerings by offering type and maturity level

The groups are described below.

- **Group 1: Integrated product–service XaaS offerings at a pilot stage**

The first group is characterized by integrated product–service XaaS offerings that are still at a pilot stage of development. Similar to the product–consolidated group, the physical asset remains central to the value proposition and is delivered through an as-a-service logic. However, in this group the integration between product and service is not yet fully stabilized, and the XaaS model is explored as an emerging alternative to traditional sales rather than as a fully institutionalized offering. The product continues to anchor value creation, but the surrounding service architecture and organizational support structures remain under development and refinement. The pilot nature of these configurations is reflected in their positioning within the provider's portfolio, where XaaS initiatives are often pursued as targeted offerings and bounded implementations designed to test feasibility, scalability, and operational requirements under real market conditions. As a result, these offerings tend to coexist with established ownership-based models, without yet systematically challenging their dominance. Standardization remains limited compared to consolidated configurations, and contractual as well as operational arrangements are more heterogeneous across providers and contexts. A recurring characteristic of the group is the emphasis on financial risk as a central uncertainty in pilot-stage adoption. Because these models are still being tested and adjusted, providers face ambiguity regarding cost structures, asset utilization, and the long-term economic sustainability of service-based monetization. In many cases, the asset remains under the provider's responsibility boundary, which supports the delivery of integrated services but also requires careful management of exposure throughout the pilot phase. Responsibilities related to asset performance, maintenance, and lifecycle activities are therefore implemented through evolving operational routines and are often progressively refined as experience accumulates. Rather than fully internalizing all lifecycle-related risks in a stable and routinized manner, providers experiment with mechanisms to balance operational responsibility and financial exposure, for instance through limited pilot scopes, contractual clauses, or selective customer engagement. From an economic and financial perspective, product–pilot XaaS models are characterized by exploratory revenue structures that are subject to iteration over time. Pricing mechanisms may follow time-based or usage-based logics, reflecting the attempt to translate product utilization into recurring revenues. However, revenue stability and long-term profitability

remain under evaluation, and the financial performance of the offering is not yet anchored in consolidated routines comparable to mature product–service models. Economic assessment is therefore closely tied to learning effects, the identification of viable cost drivers, and the capability to scale beyond early implementations, while financial risk remains salient across cases. Organizationally, these pilot initiatives require coordination across sales, service, operations, and finance functions, but such coordination is not yet fully embedded into established structures and routines. While strategic commitment to the initiative is widespread within the provider organizations, the internal configuration required to sustain XaaS delivery remains in an intermediate stage, where practices, responsibilities, and governance mechanisms are still being formalized. This generates a degree of fragility in the operational setup, as the service logic must coexist with product-centric legacies and incentive structures that have historically been aligned with transactional sales. Digital technologies play an enabling role in this group by supporting connectivity, monitoring, and data collection as part of service delivery. Providers rely on fully connected systems and exploit basic operational data as a minimum foundation to manage pilot implementations, and in a subset of cases they also extend data collection toward more advanced performance or behavioral information. Nevertheless, digital resources primarily support operational visibility and experimentation rather than full lifecycle optimization or advanced decision automation. Data exploitation remains oriented toward learning, operational control, and progressive refinement of service routines, consistent with the pilot nature of the offerings. Overall, the product–pilot group represents an intermediate stage of XaaS adoption, in which manufacturers experiment with integrating product-centered offerings into an as-a-service logic without yet achieving full organizational, economic, and operational consolidation. These configurations highlight the challenges associated with scaling asset-intensive business models toward service-based value creation, particularly in relation to financial exposure, internal alignment, and the stabilization of delivery routines. As such, they can be interpreted as transitional forms that may evolve toward more consolidated product–service XaaS models as capabilities mature, or remain limited in scope if strategic fit and economic sustainability are not achieved. Table 14 summarizes the defining characteristics of Group 1 as identified through cross-case analysis. The listed characteristics represent an ideal-typical pattern emerging from pilot initiatives and do not imply uniformity across individual offerings.

Analytical focus	**Group 1: Product–pilot XaaS (strictly data-driven)**
Type of XaaS offering	Product-centered XaaS offering in which the physical asset remains the core object of the proposition
Stage of development	Pilot stage configuration (early and not yet fully consolidated)

Central value logic	Asset-based access logic supported by service integration still under development
Role of ownership	Provider-led control and responsibility are required to support pilot delivery (ownership and governance may vary across cases)
Revenue structure	Recurring revenue logic is present but remains subject to testing and refinement during pilots
Risk allocation	Financial risk is the dominant perceived risk across cases, reflecting economic uncertainty in early-stage adoption
Organizational configuration	Widespread strategic commitment supports pilots, while internal arrangements remain heterogeneous and evolving
Role of digital technologies	Fully connected systems and basic operational data exploitation form the common enabling digital foundation
Distinctive capabilities	Ability to run pilot implementations through operational monitoring, coordination, and iterative adaptation of service routines

Table 14 Group 1: Integrated product–service XaaS

- **Group 2: Service-only XaaS offerings at a pilot stage**

The second group is characterized by service-only XaaS offerings that are still at a pilot stage of development. In these configurations, the as-a-service logic is applied exclusively to services, while the underlying physical assets remain outside the XaaS scope and are owned by the customer. Unlike product-centric XaaS models, value creation in this group is not anchored in granting access to the asset itself, but in providing access to specific service functionalities, operational support, or enhanced service continuity over time. The pilot nature of these offerings is reflected in their selective application, evolving design, and ongoing experimentation with contractual, organizational, and economic elements. A defining characteristic of this group lies in the exploratory extension of service logics beyond traditional after-sales or maintenance activities. Services are structured as recurring and contractualized offerings, but their scope, pricing mechanisms, and boundaries of responsibility are still being actively tested. In contrast to consolidated service-only models, these configurations do not yet rely on fully standardized service portfolios or highly routinized delivery processes. Instead, they are often applied to specific product categories or operational contexts identified as suitable for experimentation. As a result, the service offering remains configurable and context-dependent, with variation in how value is articulated and delivered across cases. From the customer perspective, the value proposition primarily revolves around access to specialized service capabilities, improved operational continuity, and greater predictability of service conditions over time, rather than full outsourcing of asset-related responsibilities. Services are designed to support customers in managing operational complexity and uncertainty, while customers typically retain a central role in asset ownership and decision-making. This configuration implies an interactive and co-creative service relationship, in which customers are involved in defining service scope, pricing logic, and performance indicators during the pilot phase. Economically, service-only pilot XaaS models are

characterized by provisional and evolving revenue structures. Subscription-based or fixed-period payment mechanisms are commonly adopted, reflecting an effort to introduce recurring revenue logics while maintaining flexibility during experimentation. Financial risk is perceived as a central challenge across cases, particularly given uncertainties related to pricing, cost structures, and long-term economic sustainability. Risk mitigation therefore represents an important design concern, even though formalized and standardized risk governance frameworks are not yet fully established at this stage. Organizationally, Group 4 reflects companies in transition toward more service-oriented business models. Top management commitment is strong and strategically articulated, framing XaaS initiatives as relevant pathways for future development rather than as peripheral experiments. At the same time, organizational structures and routines remain under development. Dedicated teams or emerging business units are typically established to explore service-based XaaS models, while full integration with existing sales, service, and operational functions is still incomplete. Commercialization relies predominantly on relational and consultative interactions, as digital distribution channels are generally absent and standardized go-to-market mechanisms are not yet in place. From a resource perspective, service-only pilot configurations are characterized by a strong reliance on human expertise, service know-how, and relational resources. Digital resources play a supporting role, with the exploitation of basic operational data enabling monitoring, coordination, and proactive service delivery. However, data use remains primarily oriented toward operational support rather than advanced analytics or systematic performance optimization. Resource constraints and capability gaps, particularly in digital service development and data-driven scaling, shape both the scope and the pace of service innovation within this group. Overall, the service-only pilot group represents an exploratory and transitional pattern of XaaS adoption, in which firms experiment with extending service-based value creation without altering asset ownership structures. These configurations highlight both the potential and the limitations of applying as-a-service logics to service-centric offerings under conditions of uncertainty and organizational transition. As such, Group 4 captures an early-stage pathway toward service-based XaaS that may evolve toward more consolidated service models or remain limited to focused applications within broader industrial business portfolios. **Error! Reference source not found.** summarizes the defining characteristics of Group 2 as identified through cross-case analysis. The listed characteristics represent an ideal-typical pattern emerging from pilot service-only XaaS offerings and do not imply full uniformity across individual initiatives.

Analytical focus	**Group 2: Service-only pilot XaaS**

Type of XaaS offering	Service-centered XaaS offering (services as the object of the proposition)
Stage of development	Pilot maturity pattern across cases
Central value logic	Service-based access logic aimed at supporting customer operations through proactive delivery
Role of ownership	Customer ownership of the asset is common; the service layer is delivered “as-a-service”
Revenue structure	Recurring revenue logic is present (fixed-period / subscription)
Risk allocation	Financial risk is the dominant perceived risk across cases
Organizational configuration	Widespread strategic commitment supported by new, dedicated teams/units
Role of digital technologies	Basic operational data exploitation supports proactive service delivery; digital distribution channels are generally absent
Distinctive capabilities	Capability to run service-only pilots through coordinated delivery routines and iterative refinement of service scope

Table 15 Group 2: Service-only pilot XaaS

- **Group 3: Integrated product–service XaaS offerings at a consolidated stage**

The third group is characterized by consolidated XaaS business models structured as integrated product–service solutions, in which the physical asset remains the primary locus of value creation while being delivered through an as-a-service logic. In these configurations, the product does not merely support the service offering but constitutes the core of the value proposition, around which service elements are systematically organized to ensure functionality and operational continuity across the lifecycle. This structural centrality of the asset differentiates the group from service-only XaaS models and reflects a product-centric interpretation of XaaS that builds on, rather than replaces, established manufacturing and engineering capabilities. Importantly, the group does not represent a substitution of the product through purely dematerialized service offerings; instead, value creation remains anchored in the asset, with services acting as enabling and stabilizing components of the overall proposition. The consolidated nature of these offerings is reflected in their stable organizational embedding and strategic positioning within the provider’s portfolio. Rather than representing experimental or peripheral initiatives, these XaaS models appear as institutionalized components supported by dedicated processes, routines, and governance mechanisms. Their maturity is reflected in the operationalization of service delivery activities and in the presence of structured performance measurement systems that allow providers to monitor operational efficiency and ensure the viability of the service-based configuration over time. In this sense, consolidation is not limited to market diffusion but also entails organizational alignment, process formalization, and the development of repeatable delivery logics that sustain the offering beyond initial adoption phases. A defining operational feature of this group is the proactive orientation of the service model. Providers actively manage service delivery and customer interactions through planned interventions,

monitoring practices, and structured operational routines, rather than responding only reactively to customer requests. This proactive approach enables higher control over the performance of the product–service system and supports continuity and reliability in service execution. Customers are therefore exposed to reduced operational burden in managing the asset, as service routines are designed to stabilize and standardize usage conditions and to reduce disruptions through continuous oversight. The resulting value proposition is grounded in reduced complexity and enhanced operational reliability, allowing customers to focus on usage rather than on the internal coordination of technical activities. From an economic and performance-management perspective, product–consolidated XaaS models in this group are primarily characterized by an operationally grounded logic, in which measurement systems and performance monitoring play a central role. Providers rely on operational performance KPIs to assess the functioning and efficiency of the offering and to ensure that service delivery remains economically sustainable over time. Rather than being driven mainly by financial mechanisms or purely transactional product margins, these models reflect an industrialized logic of value creation, where operational robustness, lifecycle management, and efficiency of execution become key determinants of economic viability. In this context, performance monitoring is tightly connected to the provider's ability to minimize disruptions, sustain asset availability, and maintain stable service operations at scale. Organizationally, the consolidation of these XaaS offerings requires integration across multiple internal functions that traditionally operate with different priorities and time horizons. Sales, service, operations, and finance must be aligned around a shared logic that emphasizes lifecycle value creation and long-term operational performance rather than one-off transactions. This alignment is supported by organizational commitment that extends beyond localized initiatives, indicating that XaaS adoption in this group is enabled by widespread strategic engagement and internal readiness. Culturally, these configurations reflect a service-oriented mindset that remains firmly anchored in engineering capabilities, process discipline, and execution excellence. Rather than emphasizing radical experimentation or disruptive business model innovation, consolidation in this group is associated with the institutional strengthening of routines and capabilities that support repeatability, reliability, and controlled scaling. Digital technologies play a supportive yet important role in enabling these configurations. Monitoring systems, data analytics, and digital interfaces provide continuous visibility on asset usage and operational conditions, allowing providers to track basic operational data as well as performance and behavioral data. These digital capabilities contribute to service stabilization by enabling more structured operational control and by supporting the proactive delivery approach characteristic of the group. However, in contrast to more digitally driven or service-centric XaaS configurations, digitalization in this group primarily serves to reinforce and scale asset-intensive service systems

rather than to redefine the core value proposition. Digital resources function as enablers of lifecycle oversight and operational discipline, strengthening the provider's ability to manage service delivery consistently and efficiently. Finally, the environmental dimension of these offerings reflects an orientation toward lifecycle responsibility and incremental improvement. The group shows common practices related to end-of-life management, including product collection mechanisms at contract termination, as well as the implementation of eco-efficient design principles or process improvements. At the same time, these sustainability practices do not imply a substitution of the product, but rather an approach in which environmental value is pursued through improvements in design, efficiency, and lifecycle handling within a product-centered logic. Overall, the distinctive capability underpinning the group lies in lifecycle orchestration: the ability to coordinate physical assets, service activities, organizational routines, and digital monitoring resources in a coherent and repeatable manner over time. Overall, the product–consolidated group represents a mature and industrialized form of XaaS adoption, in which providers deliver stable and scalable integrated product–service offerings grounded in operational robustness and systematic integration of product and service elements. These configurations illustrate how XaaS can function as a durable business model in its own right, rooted in repeatable service routines, proactive operational management, and digital connectivity that supports lifecycle execution. Table 16 summarizes the defining characteristics of Group 3 as identified through cross-case analysis. The listed characteristics represent an ideal-typical pattern emerging from the comparison of cases and do not imply full uniformity across individual offerings.

Analytical focus	**Group 3: Product–consolidated XaaS**
Type of XaaS offering	Integrated product–service solution in which the physical asset remains central to the offering
Stage of development	Consolidated and embedded within the provider's established portfolio
Central value logic	Provision of access to the product combined with provider-led lifecycle management and operational responsibility
Role of ownership	Asset ownership and control structures are primarily managed within the provider's organizational boundary, supporting lifecycle oversight
Revenue structure	Recurring revenue mechanisms are present (e.g., time- and/or usage-linked), supporting sustained service delivery over time
Risk allocation	Operational and lifecycle risks are managed largely by the provider through proactive service routines and monitoring
Organizational configuration	Cross-functional integration supports the coordination of product, service, operations, and financial logics
Role of digital technologies	Digital resources enable monitoring and operational data collection to support proactive service delivery and control

Distinctive capabilities	Lifecycle-oriented coordination of assets, service activities, and organizational routines in a repeatable manner

Table 16 Group 3: Product–consolidated XaaS

Group 4: Service-only XaaS offerings at a consolidated stage

The last group comprises consolidated service-centric XaaS configurations, in which the as-a-service logic is applied primarily to the delivery of services (and, in some cases, digital functionalities) layered on top of a traditionally sold and customer-owned installed base. Across these configurations, the physical asset does not fall within the as-a-service scope: customers retain ownership and remain ultimately responsible for the capital asset, while the provider monetizes ongoing lifecycle support through recurring or hybrid service arrangements. In this respect, Group 3 differs structurally from integrated product–service XaaS models: value creation is not anchored in granting access to the asset, but in sustaining, stabilizing, and enhancing the operation of customer-owned equipment through service architectures that have reached commercial and organizational consolidation. A core unifying mechanism of this group lies in the lifecycle-oriented value proposition. Customer value is framed in terms of increased operational predictability and continuity over time, achieved through service mechanisms that reduce uncertainty related to breakdowns, maintenance complexity, compliance requirements, and operational disruptions. Within this overarching lifecycle logic, two closely related value emphases may coexist across configurations: on the one hand, risk minimization and reliability through stabilized service execution, and on the other hand, the optimization of usage and operational processes enabled by service support and performance-oriented interventions. This logic is visible both in traditional service contracts (e.g., preventive/corrective maintenance and availability support) and in more digitally enabled service layers (e.g., documentation, traceability, reporting, and remotely activated features), which contribute to standardization and repeatability of delivery. Importantly, the service-centric nature of the group does not imply low strategic relevance. Rather, consolidation is expressed through portfolio-wide applicability and routinized delivery processes that allow services to scale across the installed base without requiring radical changes in asset ownership structures. From an economic perspective, these configurations rely primarily on recurring revenue mechanisms, most commonly subscription- or fixed-period contracts, sometimes complemented by transactional components (e.g., one-off interventions, activation of specific functionalities, or usage-triggered billing for specific service-enabled processes). This hybridization is coherent with the service-only logic: recurring contracts provide revenue stability and support long-term customer retention, while transactional elements preserve flexibility and allow monetization of episodic technical activities. Compared to product-centric XaaS, the provider's risk exposure is less related to capital lock-in and asset utilization, and more concentrated on execution-related risks, such as technological/service performance, response times, operational continuity, and, where digital

services are central, data security and reliability. Accordingly, risk mitigation tends to be enacted through service governance and operational controls (standard procedures, service level definition, inventory/logistics discipline, and contractual clauses in data-sensitive contexts) rather than through financial engineering or asset-backed risk-sharing mechanisms. While some configurations display explicit contractual safeguards and clearly formalized controls, others rely more strongly on established routines and operational discipline, reflecting a degree of heterogeneity in the formalization of risk governance despite the consolidated maturity of the offerings. Organizationally, Group 4 is characterized by high maturity in service execution, typically supported by established service functions and routines. However, a distinctive (and theoretically relevant) trait of these consolidated service-centric models is that they often represent institutionalized service businesses without necessarily constituting a fully articulated XaaS transformation agenda. Services are embedded and strategically recognized, yet may remain partially decoupled from a broader, explicit shift toward outcome-based contracting or full servitization. This is reflected in patterns of only partial sales–service integration in some configurations and in the reliance on existing commercial channels for service promotion, with the service logic frequently communicated through relational, installed-base-oriented interactions rather than standalone XaaS go-to-market systems. Where intermediated physical channels persist, digital layers may partially disintermediate customer interaction by providing direct access to platforms and service functionalities, creating a dual-channel structure (intermediated physical access versus direct digital interface). Resources and capabilities in this group reflect a service-centric execution logic supported by digital infrastructure. Resource bases range from partially connected infrastructures to fully connected systems, but data exploitation is consistently oriented toward operational support, through basic operational data and, in many cases, real-time monitoring and analysis, rather than advanced analytics-driven optimization or outcome measurement at scale. Consequently, the distinctive capabilities underlying Group 4 are less about lifecycle orchestration of provider-owned assets (as in integrated product–service XaaS), and more about (i) designing and delivering scalable service portfolios, (ii) coordinating service delivery processes and logistics to ensure responsiveness, and (iii) governing data- and compliance-sensitive service environments where reliability and accountability are critical. Overall, Group 4 represents a consolidated service-centric XaaS pattern in which the "as-a-service" logic primarily restructures how services are packaged, contracted, and delivered over time, strengthening provider involvement across the lifecycle while leaving asset ownership and capital investment decisions largely unchanged. Table 17 summarizes the defining characteristics of Group 4 as identified through cross-case analysis. The listed characteristics represent an ideal-typical pattern emerging from consolidated service-centric XaaS offerings and do not imply full uniformity across individual cases.

Analytical focus	Group 4: Service-centric XaaS
Type of XaaS offering	Service-centered XaaS offering (services as the core object of the proposition)
Stage of development	Consolidated maturity pattern across cases
Central value logic	Lifecycle support logic aimed at operational continuity and predictable performance (value emphasis may vary across cases)
Role of ownership	Customer ownership of the asset is dominant; the service layer is delivered "as-a-service" on top of the installed base
Revenue structure	Fixed-period / subscription recurring revenue logic is dominant
Risk allocation	Execution-related risks are central; risk governance formalization varies across cases
Organizational configuration	Widespread strategic commitment; in many cases supported by dedicated teams/units, with heterogeneous integration patterns
Role of digital technologies	Basic operational data exploitation is common; real-time monitoring/analysis is present in most cases; connectivity ranges from partial to full
Distinctive capabilities	Capability to scale service delivery and coordinate lifecycle support through repeatable routines and monitoring-enabled execution

Table 17 Group 4: Service-centric XaaS

5.3.3 Cross-group comparison and emerging patterns

The cross-case comparison highlights two orthogonal yet interrelated dimensions shaping the observed XaaS business model patterns: the object of the offering (product-centered versus service-centered XaaS configurations) and the level of maturity (pilot versus consolidated). Together, these dimensions generate four analytically distinct groups that differ not only in their structural configurations, but also in their underlying logics of value creation, risk allocation, and organizational embedding. Comparing product-centered and service-centered XaaS offerings reveals a fundamental difference in how responsibility and control are distributed across the provider–customer boundary. Product-centered configurations build the offering around the physical asset, with the as-a-service logic applied to product access and associated lifecycle-related activities. As a result, these models typically involve stronger provider responsibility for operational continuity and asset-related performance over time, which increases exposure to financial and operational risks associated with asset utilization and lifecycle management. By contrast, service-centered XaaS configurations operate primarily through service layers delivered on top of a customer-owned installed base, focusing on stabilizing and enhancing asset performance through recurring service provision rather than altering ownership structures. This distinction has important implications for revenue models, risk exposure, and required capabilities, with product-centered XaaS emphasizing lifecycle-oriented orchestration and utilization efficiency, and service-centered XaaS relying more on mature service execution,

responsiveness, and service governance capabilities. The maturity dimension further differentiates how these logics are enacted in practice. Consolidated configurations, both product-centered and service-centered, exhibit more institutionalized processes, routinized delivery mechanisms, and stable organizational arrangements that support scalability and economic sustainability. In these groups, XaaS offerings are embedded within the provider's established portfolio and supported by performance metrics that enable ongoing monitoring of operational efficiency and lifecycle viability. Pilot configurations, by contrast, are characterized by experimentation and iterative refinement of service scope, pricing mechanisms, and operational responsibilities. Organizational arrangements in pilot groups remain more fluid and frequently rely on dedicated teams or transitional units, reflecting ongoing learning and uncertainty regarding long-term economic feasibility. In line with this, financial risk emerges as a salient concern across pilot-stage groups, while the formalization of risk governance and delivery routines remains under development. Taken together, the comparison suggests that XaaS adoption does not follow a single linear trajectory. While pilot configurations may evolve toward more consolidated forms as routines stabilize and organizational capabilities mature, the analysis also indicates the persistence of distinct pathways shaped by the object of the offering. Product-centered and service-centered XaaS models appear to stabilize around different equilibria, reflecting enduring differences in asset centrality, customer involvement, and value appropriation mechanisms. The four groups therefore represent not sequential stages of a uniform transformation, but alternative and partially independent patterns of XaaS business model development. *Table **18*** summarizes the cross-case comparison across the four XaaS business model groups discussed above, highlighting their key distinguishing characteristics along the two analytical dimensions.

Analytical focus	**Group 1 Product–pilot**	**Group 2 Service–pilot**	**Group 3 Product–consolidated**	**Group 4 Service–consolidated**
Type of XaaS offering	Product-centered XaaS (pilot configurations)	Service-centered XaaS (pilot) layered on customer-owned installed base	Integrated product–service (product-centered)	Service-centered XaaS layered on customer-owned installed base
Stage of development	Pilot	Pilot	Consolidated	Consolidated
Central value logic	Experimental product-based access logic with emerging service integration	Exploratory recurring service access and proactive support to customer operations	Access to the product with lifecycle responsibility and proactive operational management	Lifecycle-oriented service support and operational continuity (risk minimization and/or process optimization)

Role of ownership	Provider-led delivery during pilots (ownership/arrangements may vary across cases)	Asset ownership retained by customer; service delivered "as-a-service"	Provider-led responsibility and control enabling lifecycle oversight (ownership typically provider-side)	Asset ownership retained by customer; provider monetizes service layer
Revenue structure	Recurring revenue logic present but evolving (iterative refinement)	Fixed-period / subscription recurring revenues (pilot and provisional)	Stable recurring revenues linked to time/usage/output	Predominantly fixed-period / subscription contracts, sometimes complemented by transactional components
Risk allocation	Financial risk is dominant; risk assumption is cautious and under evaluation	Financial risk is dominant; risk governance still under development	Provider manages operational and lifecycle risks through mature routines and monitoring	Execution-related and service-performance risks central; formalization varies
Organizational configuration	Widespread strategic commitment but heterogeneous and evolving setup	Dedicated teams/units supporting pilots; limited integration with existing structures	High integration and routinized delivery embedded in core portfolio	Mature service routines; partial sales–service integration may persist
Role of digital technologies	Fully connected systems; basic operational data as common foundation (some advanced data in subset)	Basic operational data exploitation supporting proactive service delivery; digital distribution channels generally absent	Fully connected systems; operational + behavioral/performance data enabling control	Basic operational data common; real-time monitoring in most cases; connectivity ranges from partial to full
Dominant capabilities	Capability to run and refine pilots: iterative learning, monitoring, and early scaling attempts	Capability to run service-only pilots through coordinated delivery routines and iterative refinement of service scope	Lifecycle orchestration and execution excellence in asset-intensive service systems	Scalable service portfolio design and service delivery governance enabled by monitoring

Table 18 the cross-case comparison

It is important to clarify that the distinction between product-based and service-based XaaS configurations does not exclusively depend on asset ownership structures. Rather, the classification reflects differences in service integration, lifecycle involvement, performance orientation, and provider responsibility. Consequently, service-based configurations do not necessarily imply provider ownership of the physical asset. In several cases, ownership remains with the customer while the provider delivers recurring monitoring, maintenance, or performance-related services. The classification should therefore be interpreted as configurational rather than purely ownership-based.

6 CHAPTER VI – CHALLENGES AND BEST PRACTICES

6.1 Scope and approach

The objective of this chapter is to provide a systematic analysis of the challenges and best practices associated with the adoption of X-as-a-Service (XaaS) models in the manufacturing context, by integrating insights from the extant literature with empirical evidence drawn from a multiple case study. As discussed in the previous chapters, despite the growing academic interest in XaaS, the literature remains fragmented and largely conceptual with respect to the identification and structuring of the challenges firms face through the adoption of such models. This fragmentation constitutes one of the key gaps addressed by this dissertation and represents a major motivation for the development of guidelines aimed at supporting manufacturing firms in the implementation of XaaS. In particular, prior studies tend to emphasize the strategic potential of XaaS while providing limited guidance on how challenges unfold in practice and how they vary across different types of XaaS offerings. Addressing this gap requires a systematic and empirically grounded analysis that connects theoretical insights with observed industrial experiences. Against this background, the chapter pursues a twofold purpose. First, it systematizes the challenges of XaaS adoption as discussed in the literature and contrasts them with those emerging from empirical cases of XaaS adoption in manufacturing firms. Second, by highlighting recurring patterns, convergences, and divergences between theory and practice, the chapter lays the analytical groundwork for the identification of best practices for effective XaaS implementation. In this way, the analysis of challenges serves not only as an end in itself, but also as a critical input for the subsequent chapter, which builds on these findings to derive actionable guidance for manufacturing firms adopting XaaS models.

This chapter adopts a qualitative research approach based on the integration of literature analysis and multiple case study analysis. The methodological process is structured in three interrelated phases, which together enable a comprehensive and theory-informed examination of the challenges associated with XaaS adoption. In the first phase, the analysis builds on the results of the literature review presented in the previous chapters. Among the identified body of academic publications on XaaS, particular attention is devoted to those studies that explicitly address challenges related to the adoption and implementation of XaaS models. These contributions are systematically analyzed through a thematic coding process aimed at identifying recurring issues and outcomes. The identified challenges are then aggregated into higher-level macro-categories based on conceptual similarity, resulting in a structured theoretical classification that serves as an analytical lens for the empirical investigation. The second phase focuses on the empirical analysis of challenges emerging from the multiple case study conducted in the manufacturing sector. The empirical setting builds on the same

sample of companies and XaaS offerings analyzed in the previous chapter, where the case study was employed to examine the adoption of the proposed framework and to identify configurations of XaaS implementation approaches. The dataset consists of 17 units of analysis, where each unit corresponds to a specific XaaS offering adopted by a manufacturing firm. Importantly, the unit of analysis is defined at the level of the XaaS offering rather than the firm, allowing for the examination of different configurations of XaaS adoption within the same organization. The analyzed offerings are distinguished between XaaS solutions based on an integrated product–service system (hereafter referred to as "product-based" XaaS) and XaaS solutions centered exclusively on service provision (hereafter referred to as "service-based" XaaS). Empirical data are analyzed using qualitative coding techniques consistent with the categories derived from the literature, while remaining open to the emergence of new themes not previously identified. This approach enables the identification of challenges and benefits experienced by firms in practice, as well as the detection of patterns and differences across the two types of XaaS offerings. In the third phase, a systematic comparison between the literature-based classification and the empirical findings is conducted. This comparative analysis allows for the assessment of the extent to which theoretical expectations are reflected in practice, as well as for the identification of discrepancies and novel insights. Particular attention is devoted to challenges that are either underrepresented or absent in the literature but emerge as salient in the empirical cases, as well as to those whose relevance varies depending on the nature of the XaaS offering. The outcomes of this comparison provide an integrated view of the challenges of XaaS adoption in manufacturing and lay the groundwork for the subsequent analysis of best practices.

6.1.1 Challenges from the literature

Building on the systematic literature review presented in Chapter 2, this section focuses on a targeted analysis of the challenges and benefits associated with the adoption of X-as-a-Service (XaaS) models in the manufacturing context. As discussed previously, the literature on XaaS is characterized by a high degree of conceptual richness but also by fragmentation, with contributions spanning multiple disciplines and addressing heterogeneous aspects of the model. Within this body of knowledge, a substantial number of studies explicitly investigate the organizational, technological, relational, and economic implications of transitioning from product-based to service-oriented business models. Rather than introducing a new review of the literature, this section draws on the same set of publications identified and analyzed in Chapter 2, narrowing the analytical focus to those contributions that discuss challenges and/or benefits related to XaaS adoption (48 papers). As highlighted in the classification of research objectives, while challenges and benefits represent one of the most frequently addressed themes in XaaS research, existing studies often examine them in

isolation, without providing a consolidated or structured perspective. Moreover, such challenges and benefits are frequently described at different levels of analysis and using overlapping terminology, which limits their comparability and practical applicability. To address this issue, the challenges identified in the literature are organized by distinguishing between internal barriers and challenges, originating within the adopting organization (e.g., cultural, organizational, technological, and capability-related aspects), and external barriers and challenges, arising from the broader ecosystem in which firms operate, including customers, suppliers, and market-related factors. In this context, the purpose of the present analysis is to systematize the challenges and benefits identified in the literature and to organize them into higher-level conceptual categories. This structured synthesis serves a dual role. First, it contributes to clarifying and consolidating existing knowledge on the implications of XaaS adoption for manufacturing firms and their stakeholders. Second, it provides a theoretical reference framework that guides the subsequent empirical analysis, enabling a systematic comparison between challenges and benefits emphasized in the literature and those emerging from the multiple case study. By doing so, this section lays the conceptual groundwork for the integrated analysis developed in the remainder of the chapter and for the identification of best practices discussed in the following chapter.

- **Internal Barriers and Challenges**

The literature identifies a wide range of **internal barriers and challenges** that manufacturing firms face when adopting XaaS models. These challenges primarily stem from the need to fundamentally transform organizational structures, capabilities, and managerial mindsets, moving beyond traditional product-centric logics toward service-oriented and outcome-based value creation. One of the most frequently discussed internal challenges concerns **cultural readiness and resistance to change**. Several studies emphasize that the transition to XaaS requires a profound cultural transformation, as organizations must shift from a logic centered on product sales and ownership to one focused on long-term service provision, usage, or performance outcomes (Grubic & Jennions, 2018a; Kowalkowski & Ulaga, 2024). Established mindsets, routines, and incentives often reinforce resistance to change, making it difficult for firms to embrace new ways of thinking about value creation, customer relationships, and risk sharing. Closely related to cultural aspects is the challenge associated with **strategic vision and leadership** . The literature highlights that many manufacturing firms struggle to articulate a clear strategic vision for XaaS adoption, particularly in terms of understanding where and how value is created within service-based business models (Smania et al., 2023; Souza-Zomer et al., 2018). A lack of top-management commitment and leadership further exacerbates this issue, as XaaS initiatives often require long-term investments and organizational alignment that extend beyond

short-term financial considerations (Baecker et al., 2021; Neely, 2008). Another major set of challenges relates to **organizational readiness and organizational change**. XaaS adoption frequently demands significant modifications to existing organizational structures, processes, and management systems (Azcárate-Aguerre et al., 2018; Batista et al., 2017; Chiarot et al., 2022). This includes redefining roles and responsibilities, adapting enterprise resource planning systems, revising budgeting and accounting practices, and integrating product, service, and supply chain activities. Several contributions point out that traditional organizational arrangements, optimized for product manufacturing and transactional exchanges, are often ill-suited to support continuous service delivery, product monitoring, and ongoing customer interaction (Allais & Gobert, 2016; Webb & Bil, 2011). The development of **capabilities and knowledge** emerges as one of the most critical internal challenges in the literature. Transitioning to XaaS requires firms to develop new service-related capabilities, technological expertise, and data-driven competencies (Costa et al., 2015; Wasserbaur et al., 2023). Studies report frequent skill gaps, particularly among technical personnel, as well as a lack of resources and structured training programs (Schaefers et al., 2021; Sousa-Zomer et al., 2018). The need to guarantee high service levels, manage increased requests for maintenance and repair, and operate advanced digital and monitoring technologies further amplifies the complexity of capability development (Guzzo et al, 2018; Costa et al., 2015). Additional challenges are linked to **product characteristics and brand-related aspects**. From a product perspective, firms must address issues related to customization versus standardization, technical requirements, and product design suitability for service-based use (Baecker et al., 2021; Grubic & Jennions, 2018a). At the same time, the literature notes that manufacturers with strong, product-intensive brands may face difficulties in extending their brand identity toward service-oriented or usage-based offerings, as customer perceptions are often deeply rooted in traditional product attributes (Wasserbaur et al., 2023; Korkeamäki et al., 2021). **Contractual aspects** also represent a significant internal challenge. The definition of XaaS contracts involves complex legal and administrative considerations, particularly with respect to ownership, usage rights, availability guarantees, and performance metrics (Chiarot et al., 2022; Guzzo et al., 2022). High contractual costs, increased administrative burden, and the need to manage more complex planning and control processes are frequently cited as barriers that hinder the scalability of XaaS models (Baecker et al., 2021; Azcarate-Aguerre et al., 2022). Finally, several studies highlight challenges related to **performance measurement, product monitoring, and data collection**. Effective XaaS implementation relies heavily on the ability to collect, share, and analyze data on product usage and performance (Smania et al., 2023; Schaefers et al., 2021). However, firms often face difficulties related to data accessibility, security, regulatory constraints, and the integration of monitoring systems (Aziz et al., 2020; Bech et al., 2019). These challenges are further compounded

by the **additional responsibilities** associated with guaranteeing availability and service continuity over extended periods (Holgado & Macchi, 2021; Grubic & Jennions, 2018b). Overall, as illustrated in *Figure* ***33***, the internal barriers and challenges discussed in the literature predominantly concern organizational transformation and capability development, underscoring the complexity of shifting from traditional manufacturing logics toward XaaS-oriented business models.

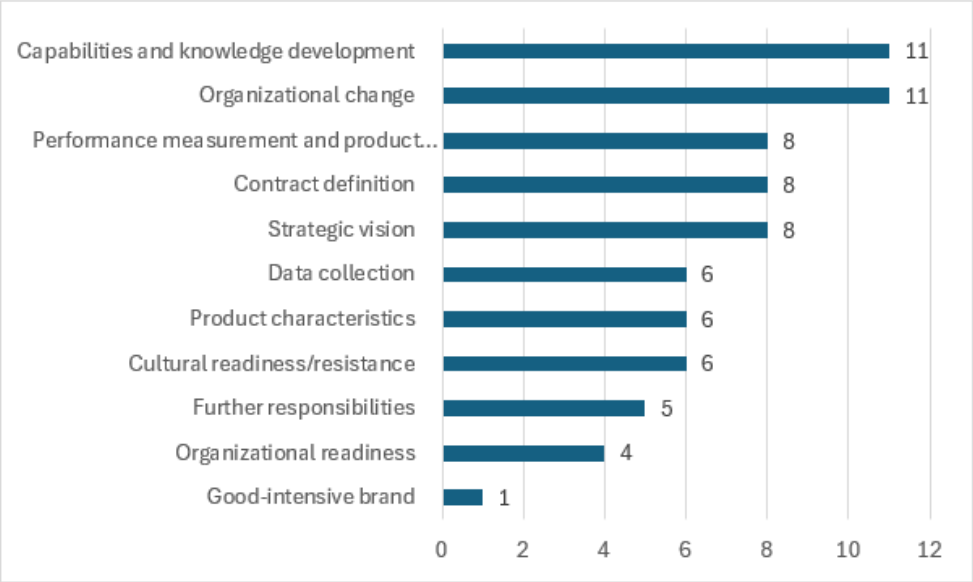


Figure 33 Internal challenges and barriers

To enhance analytical clarity and support subsequent empirical comparison, the internal barriers and challenges identified in the literature were further aggregated into a set of higher-level macro-categories. This aggregation was conducted by grouping conceptually related challenges that address similar underlying organizational issues, while preserving the richness of the original classifications. The resulting macro-categories reflect the main domains in which manufacturing firms must undertake substantial transformation in order to effectively adopt XaaS models. The first macro-category encompasses **cultural and strategic challenges**, which relate to the firm's ability to develop a service-oriented mindset and articulate a coherent strategic direction for XaaS adoption. This category includes issues associated with cultural readiness and resistance to change, as well as challenges related to strategic vision, leadership commitment, and the understanding of how value is created within service-based and outcome-oriented business models. These challenges are deeply intertwined, as the absence of a clear strategic vision often reinforces cultural resistance, limiting organizational engagement with XaaS initiatives. The second macro-category refers to **organizational and structural challenges**, capturing the internal adjustments required to align organizational structures, processes, and governance mechanisms with the requirements of XaaS delivery. This category includes organizational readiness and organizational change, such as the

redesign of roles and responsibilities, the adaptation of enterprise resource planning and management systems, and revisions to budgeting and accounting practices. These challenges highlight the tension between legacy organizational configurations optimized for product-centric operations and the need for more integrated, cross-functional structures capable of supporting continuous service provision and long-term customer relationships. A third macro-category is represented by **capability and knowledge-related challenges**, which concern the development of the skills, competencies, and expertise necessary to design, deliver, and manage XaaS offerings. This category includes challenges related to the development of service capabilities, technological and digital know-how, and data-driven competencies, as well as skill gaps and training requirements across different organizational roles. The literature consistently emphasizes that without adequate capability development, firms struggle to meet service-level expectations and to manage the increased complexity associated with XaaS models. The fourth macro-category comprises **product, data, and technology-related challenges**, which address the technical foundations enabling XaaS implementation. This category includes challenges related to product characteristics, such as customization versus standardization and technical suitability for service-based use, as well as issues concerning performance measurement, product monitoring, and data collection. Difficulties in ensuring data accessibility, security, regulatory compliance, and system integration further compound these challenges, underscoring the critical role of digital technologies in supporting XaaS delivery. Finally, the fifth macro-category encompasses **contractual and responsibility-related challenges**, which relate to the governance of XaaS relationships and the allocation of responsibilities and risks. This category includes challenges associated with contract definition, such as ownership structures, usage rights, availability guarantees, and performance metrics, as well as the additional responsibilities assumed by providers in guaranteeing availability and service continuity. These challenges reflect the increased complexity of managing long-term, service-based contractual arrangements compared to traditional product sales. Table 19 summarizes the macro-categories of internal barriers and challenges and the corresponding challenges identified in the literature.

Macro-category	Internal barriers and challenges incorporated
Cultural and strategic challenges	Cultural readiness and resistance to change; strategic vision; understanding of value creation in XaaS models; top management commitment and leadership
Organizational and structural challenges	Organizational readiness; organizational change; role and function redefinition; adaptation of enterprise resource planning systems; changes in management systems; revisions of budgeting and accounting practices; integration of product, service, and supply chain activities; after-sales organization; management of customer relationships

Capability and knowledge-related challenges	Development of service capabilities and methods; lack of skills and resources; training needs; variability in technicians' skill levels; technological and technical know-how; development of new capabilities required for XaaS delivery; ability to guarantee high service levels
Product, data, and technology-related challenges	Product characteristics (customization vs. standardization; technical requirements); performance measurement; product monitoring; data collection and data sharing; data accessibility; data security; regulatory constraints related to data management
Contractual and responsibility-related challenges	Contract definition (ownership, usage, and availability clauses); high contractual and administrative costs; increased complexity of management and planning processes; allocation of responsibilities; availability guarantees and service continuity obligations

Table 19 Macro-categories of internal barriers and challenges and associated challenges

- **External Barriers and Challenges**

In addition to internal organizational constraints, the literature highlights a set of **external barriers and challenges** that influence the adoption of XaaS models in the manufacturing context. These challenges originate outside the focal firm and are largely shaped by the interactions with actors operating within the broader business ecosystem. To enhance analytical clarity, the external challenges identified in the literature are grouped based on the **primary actor involved**, namely customers, suppliers, stakeholders, and the market environment. As summarized in Figure X, external barriers are most frequently associated with customers and suppliers, while market- and stakeholder-related challenges appear less prominently in the analyzed literature. This distribution reflects the relational and inter-organizational nature of XaaS models, which require close coordination across the value chain and a redefinition of traditional exchange relationships. Customer-related challenges represent the most extensively discussed category in the literature (Wasserbaur et al., 2023; Sousa-Zomer et al., 2018). Several studies emphasize that the successful adoption of XaaS models depends on achieving a sufficient **critical mass of customers** willing to transition from ownership-based consumption to usage- or outcome-based offerings . Resistance often stems from entrenched cultural norms, a strong "culture of having," and limited trust in service providers. Additional barriers include customers' limited understanding of XaaS value propositions, heterogeneous usage patterns, and uncertainty regarding long-term costs and benefits (Azcárate-Aguerre et al., 2018; Baecker et al., 2021). Willingness to pay, customer acceptance, and the need for communication and training are therefore frequently cited as critical external challenges affecting XaaS diffusion (Baecker et al., 2021; Guzzo et al., 2022). Supplier-related challenges constitute the second most prominent group of external barriers. The literature highlights that XaaS adoption often requires suppliers to assume new roles and responsibilities, which can lead to tensions within the value chain (Allais & Gobert, 2016;

Azarenko et al., 2009; Baecker et al., 2021). Issues related to contractual obligations, responsibility sharing, and profit distribution are particularly salient, as traditional supplier–manufacturer relationships are typically not designed to support long-term service-based collaboration (Sousa-Zomer et al., 2018; Schaefers et al., 2021; Allais & Gobert, 2016). Misaligned incentives, conflicts of interest, and the need to reposition suppliers within the value chain further complicate the implementation of XaaS models and may hinder coordination and trust among partners (Schaefers et al., 2021; Allais & Gobert, 2016; Azcárate-Aguerre et al., 2018). Beyond customers and suppliers, the literature also identifies challenges associated with **stakeholders** more broadly, including regulators, financial institutions, and other external actors. Although less frequently discussed, these challenges relate to the alignment of interests across multiple parties and to institutional constraints that may limit the feasibility or scalability of XaaS offerings (Webb & Bil, 2011; Azcárate-Aguerre et al., 2018). Regulatory uncertainty, in particular, may affect contractual arrangements, data sharing practices, and liability structures, thereby influencing firms' willingness to engage in XaaS models. Market-related challenges represent another relevant category of external barriers. Studies point to uncertainty regarding market dynamics, competitive intensity, and the emergence of new entrants offering alternative service-based solutions (Smania et al., 2023; Sousa-Zomer et al., 2018). The presence of unfamiliar competitors, combined with rapidly evolving customer expectations and technological developments, can increase perceived risk and reduce firms' confidence in the long-term viability of XaaS business models (Webb & Bil, 2011; Smania et al., 2023; Sousa-Zomer et al., 2018). Finally, some contributions highlight the presence of **rebound effects** associated with XaaS adoption. These effects refer to unintended consequences such as additional monitoring requirements or increased financial and operational costs that may arise as usage intensifies or as service provision expands (Haber & Fargnoli, 2021). Although discussed less frequently, rebound effects underscore the complexity of XaaS ecosystems and the potential trade-offs between efficiency gains and increased resource commitments. Overall, as illustrated in Figure 34, the external barriers and challenges identified in the literature are predominantly relational and ecosystem-driven, emphasizing the central role of inter-organizational coordination, customer acceptance, and value chain alignment in enabling the successful adoption of XaaS models.

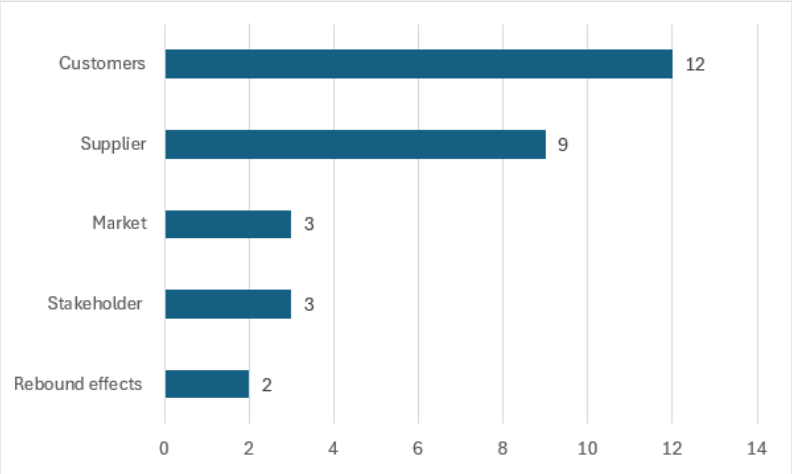


Figure 34 External challenges and barriers

To support a systematic comparison with internal barriers and to enhance the coherence of the analytical framework, the external challenges identified in the literature were aggregated into a set of higher-level macro-categories. These macro-categories were defined by extending the same conceptual logic adopted for internal challenges to the inter-organizational and ecosystem level, thereby capturing the external conditions that shape the adoption of XaaS models beyond the boundaries of the focal firm. The first macro-category refers to **relational and cultural challenges**, which capture the difficulties associated with the acceptance of XaaS models by external actors, particularly customers. This category includes challenges related to trust, customer acceptance, and cultural resistance to non-ownership-based consumption models, often described in the literature as a persistent "culture of having." It also encompasses issues related to communication, training, and the customer's ability to perceive and evaluate the value proposition of XaaS offerings. These challenges highlight the relational nature of XaaS adoption and the importance of building long-term, trust-based relationships with customers. The second macro-category comprises **ecosystem and organizational alignment challenges**, which concern the coordination and alignment of multiple actors involved in XaaS ecosystems. This category includes challenges related to supplier relationships, repositioning within the value chain, and the alignment of interests among manufacturers, suppliers, and other stakeholders. Conflicts of interest, misaligned incentives, and difficulties in sharing responsibilities across organizational boundaries are frequently cited as barriers that hinder effective collaboration and slow down XaaS implementation. A third macro-category is represented by **capability asymmetry and coordination challenges**, reflecting differences in skills, knowledge, and capabilities across actors within the ecosystem. The literature emphasizes that customers and suppliers often exhibit heterogeneous levels of technical competence and readiness to engage with XaaS offerings, leading to coordination difficulties and increased support and training

requirements. Variability in usage patterns and operational practices further exacerbates these challenges, increasing the complexity of managing XaaS relationships across diverse actors. The fourth macro-category addresses **market and competitive environment challenges**, which capture external uncertainties related to market dynamics and competitive conditions. This category includes challenges associated with market uncertainty, competitive intensity, and the entry of new players offering alternative service-based or digital solutions. Rapid changes in market conditions and customer expectations may increase perceived risk and limit firms' willingness to invest in XaaS models, particularly in the absence of established industry standards. Finally, the fifth macro-category encompasses **contractual, governance, and risk-sharing challenges**, which relate to the definition and management of inter-organizational agreements underpinning XaaS delivery. This category includes challenges associated with contractual obligations, the allocation of responsibilities and risks across actors, and the design of profit-sharing mechanisms along the value chain. It also incorporates rebound effects, such as additional monitoring requirements and unforeseen financial or operational costs, which may emerge as unintended consequences of XaaS adoption. These challenges underline the complexity of governing long-term, service-based relationships within multi-actor ecosystems. Overall, the identified macro-categories provide a structured and integrated view of the external barriers and challenges discussed in the literature and mirror the analytical structure adopted for internal challenges. This alignment facilitates the subsequent comparison between internal and external constraints and supports the empirical analysis of how XaaS adoption is shaped by interactions across organizational boundaries. Table 20 summarizes the macro-categories of external barriers and challenges and the corresponding challenges identified in the literature.

Macro-category	External barriers and challenges incorporated
Relational and cultural challenges	Customer acceptance of XaaS models; trust between providers and customers; customer culture and "culture of having"; perceived value and customer irrationality; communication and training needs; social and people-related barriers; heterogeneous usage patterns; willingness to pay
Ecosystem and organizational alignment challenges	Supplier relationships; contractual obligations across organizations; sharing of responsibilities and agreements; repositioning within the value chain; conflicts of interest among actors; misaligned profit-sharing mechanisms; stakeholder alignment
Capability asymmetry and coordination challenges	Differences in capabilities and knowledge across customers and suppliers; customers' ability to understand and use XaaS offerings; need for training and support across organizational boundaries; coordination of heterogeneous operational practices
Market and competitive environment challenges	Market uncertainty; competitive intensity; entry of new players; volatility in demand and usage patterns; presence of critical market barriers

Contractual, governance, and risk-sharing challenges	Inter-organizational contractual arrangements; allocation of risks and responsibilities across actors; governance of long-term service relationships; rebound effects, including additional monitoring requirements and increased financial or operational costs

Table 20 Macro-categories of external barriers and challenges and associated challenges

- **Synthesis of challenges from the literature**

Taken together, the analysis of the literature highlights that the adoption of XaaS models in the manufacturing context is constrained by a complex and interrelated set of **internal and external challenges**. Internal challenges primarily reflect the extent to which firms are able to transform their strategic orientation, organizational structures, capabilities, and technical infrastructures to support service-based and outcome-oriented value creation. These challenges underscore the difficulty of moving beyond product-centric logics and legacy organizational configurations that are deeply embedded in manufacturing firms. At the same time, external challenges emphasize that XaaS adoption cannot be understood solely as an intra-organizational transformation. Instead, it emerges as an ecosystem-level phenomenon shaped by interactions with customers, suppliers, and other external actors. Customer acceptance, relational dynamics, value chain alignment, and market uncertainty play a critical role in enabling or constraining the diffusion of XaaS models. Importantly, several challenges cut across internal and external boundaries, particularly those related to contractual governance, risk allocation, and responsibility sharing, highlighting the interdependence between organizational transformation and ecosystem coordination. Overall, the literature portrays XaaS adoption as a multidimensional process in which internal readiness and external alignment must co-evolve. This integrated perspective provides the basis for the comparative empirical analysis developed in the next section, where the challenges identified in the literature are contrasted with those emerging from the multiple case study in order to assess convergences, divergences, and context-specific patterns. Table 21 summarizes the internal and external challenges associated with XaaS adoption identified in the literature.

Level of analysis	Macro-category	Challenges identified in the literature
Internal	Cultural and strategic challenges	Cultural readiness and resistance to change; strategic vision for XaaS; understanding of value creation; leadership commitment
Internal	Organizational and structural challenges	Organizational readiness; organizational change; role and responsibility redefinition; adaptation of management systems; integration of product, service, and supply chain activities

Level of analysis	Macro-category	Challenges identified in the literature
Internal	Capability and knowledge-related challenges	Development of service capabilities; technological and digital know-how; skill gaps; training requirements; ability to guarantee high service levels
Internal	Product, data, and technology-related challenges	Product characteristics; performance measurement; product monitoring; data collection and sharing; data accessibility, security, and regulatory constraints
Internal	Contractual and responsibility-related challenges	Contract definition; ownership, usage, and availability clauses; administrative burden; increased responsibility for service continuity
External	Relational and cultural challenges	Customer acceptance; trust; customer culture and "culture of having"; perceived value; communication and training needs; heterogeneous usage patterns; willingness to pay
External	Ecosystem and organizational alignment challenges	Supplier relationships; stakeholder alignment; repositioning within the value chain; conflicts of interest; misaligned incentives and profit-sharing mechanisms
External	Capability asymmetry and coordination challenges	Heterogeneity of capabilities across actors; need for cross-organizational training and support; coordination of diverse operational practices
External	Market and competitive environment challenges	Market uncertainty; competitive intensity; entry of new players; volatility in demand and usage
External	Contractual, governance, and risk-sharing challenges	Inter-organizational contractual arrangements; allocation of risks and responsibilities; governance of long-term relationships; rebound effects

Table 21 Synthesis of internal and external challenges associated with XaaS adoption

To strengthen the methodological robustness of the challenge table derived from the literature (Table 21), the resulting set of internal and external challenges was further assessed through a structured comparison with two established studies in the servitization literature that adopted a comparable research design (Table 22). In particular, the framework was contrasted with the servitization challenge systematisation proposed by Alghisi and Saccani (2015), who developed a literature-based set of challenges and subsequently investigated them empirically through multiple case studies, aiming to examine internal and external alignment issues along the servitization journey. In addition, the framework was benchmarked against the barriers and challenges identified by Ardolino et al. (2024), who relied on a mixed-method approach combining a literature review and an empirical validation through a large-scale survey of machinery manufacturers.

This comparison serves two complementary purposes. First, it provides a cross-study consistency check, assessing whether the challenges extracted from the XaaS-focused literature reflect patterns that have already been discussed and empirically examined within the broader servitization stream. Second, it offers an external benchmark for the structuring logic adopted in Table 21. In particular, prior studies emphasise that servitization-related transformations simultaneously involve intra-organisational changes (e.g., strategic orientation, organisational structures, and capability development) and inter-organisational adjustments across the ecosystem (e.g., customer acceptance, partner coordination, and governance mechanisms). Accordingly, the comparison supports the relevance of distinguishing internal and external challenges, while also acknowledging that several issues, especially contractual governance and responsibility sharing, span across firm boundaries.

XaaS Challenges	Alghisi & Saccani, 2015	Ardolino et al., 2024
Cultural and strategic challenges	• Cultural readiness - Commitment and leadership • Strategic vision	• Shifting the company emphasis from a product-centric logic to service-centric logic to exploit new revenue opportunities • Developing and nurturing a service culture
Organizational and structural challenges	• Organisational readiness (hierarchy, inter-functional cooperation)	
Capability and knowledge-related challenges	• Scalability • Development of service capabilities and methods • Integration capabilities • Communication and training • Sourcing decisions	• Inclusion of human and digital capabilities to develop digital services • Balancing offer customization and standardization
Product, data, and technology-related challenges	• Good intensive brand (product relatedness of the firm's brand) • Knowledge management	• Definition of a strategy for the collection and use of data in support of product and service offering • Acquire/have available the appropriate technological infrastructure to provide services
Contractual and responsibility-related challenges	• Risks	• Building the right pricing for the service product offering • Use of instruments aimed at evaluating the risks and uncertainties of service offering
Relational and cultural challenges	• Coproduction	• Shifting the customer's focus from owning the product to using it • Making the sustainability value of the offer perceived • Consideration of customers opinion and needs in the development of the digital services

XaaS Challenges	Alghisi & Saccani, 2015	Ardolino et al., 2024
		• Incentivizing the customer to contribute in the value co-creation process
Ecosystem and organizational alignment challenges	• Timescale	• Ensuring the right balance between collaboration and competition within the ecosystem
Capability asymmetry and coordination challenges	• Customer/supplier interface capabilities	• Ensuring proper coordination between objectives within the ecosystem
Market and competitive environment challenges	• Critical mass • Supplier competition	• Having full support from government agencies
Contractual, governance, and risk-sharing challenges	• Risks	• Agreement on data collection, management and ownership with customers

Table 22 Comparison of the identified internal and external challenges with prior servitization studies

In particular, Table 22 confirms the central role of internal transformation barriers such as cultural and leadership readiness, organizational reconfiguration, and capability development, as well as the relevance of digital and data-related infrastructures to support advanced service delivery and performance-based models. At the same time, it aligns with prior servitization research in emphasizing the importance of external challenges related to customer acceptance, relationship management, and the need to ensure alignment with partners and broader ecosystem actors. Despite this overall convergence, the comparison also points to differences in emphasis and to issues that appear particularly salient in XaaS settings. While servitization studies provide a broad account of organizational and relational challenges, the XaaS-focused literature places stronger and more explicit attention on contractual governance and responsibility-related aspects that become critical when firms shift from transactional services to long-term, outcome- or usage-based agreements. These include challenges associated with defining contractual clauses concerning ownership, usage rights, and service availability, as well as managing the allocation of risks, responsibilities, and liabilities across organizational boundaries. Moreover, whereas digital infrastructure is widely recognised as an enabling factor in servitization, XaaS models tend to intensify data-related challenges, such as data accessibility, security, ownership, and compliance, because data becomes a key operational and contractual asset for monitoring performance, ensuring continuity of service, and enabling value capture mechanisms. Overall, anchoring the framework to prior mixed-method studies strengthens its validity as an analytically grounded structure to guide the subsequent empirical investigation.

Importantly, the set of challenges included in Table 21 does not represent an ad hoc or newly introduced classification. Rather, challenges were retained only when explicitly discussed in prior

XaaS and servitization research and when they emerged consistently across multiple studies. The cross-comparison with Alghisi and Saccani (2015) and Ardolino et al. (2024) further corroborates that the majority of challenges identified in Table 21 are already well established in the servitization literature, thereby providing an external validation of the challenge set and reducing the risk of construct arbitrariness. Where Table 21 introduces a more explicit emphasis on contractual governance, data rights, and responsibility allocation, this is not intended as a novel challenge category per se, but as an adaptation reflecting the higher relevance of these issues in long-term, outcome- and usage-based XaaS arrangements.

Building on this methodological foundation, the next section uses the Table 21 as a coding and interpretation scheme for the multiple-case study analysis, with the objective of assessing: (i) whether the challenges emphasised in the literature are mirrored in practice, and (ii) whether additional challenges emerge empirically that are currently underexplored in the XaaS and servitization research streams.

6.1.2 Challenges from the empirical evidence

Building on the challenges associated with XaaS adoption identified in the literature (Table 21), this section presents the empirical analysis based on a multiple case study conducted in the manufacturing sector. The purpose of this analysis is to examine how the challenges discussed in prior research manifest in real-world industrial settings and to assess the extent to which empirical evidence confirms, nuances, or extends existing knowledge. The empirical investigation draws on the same dataset introduced in the previous chapter, where the multiple case study was employed to analyze the adoption of the proposed XaaS framework and to identify configurations of implementation approaches. In this chapter, the focus shifts from adoption patterns to the **challenges experienced in practice**, allowing for a more fine-grained understanding of the organizational and ecosystem-level implications of XaaS implementation. The case study comprises 19 units of analysis, each corresponding to a specific XaaS offering adopted by a manufacturing firm. Importantly, the unit of analysis is defined at the level of the XaaS offering rather than the firm, enabling the examination of heterogeneous XaaS configurations within and across organizations. The analyzed offerings are divided in product-based solutions characterized by integrated product–service systems and service-based solutions centered on pure service provision. This diversity allows the empirical analysis to capture variation across different types of offerings. Guided by the macro-categories of internal and external challenges derived from the literature, the empirical analysis systematically identifies the challenges encountered by firms during XaaS adoption and implementation. The literature-based classification summarized in Table X is used as a reference framework for the empirical coding, while

remaining open to the emergence of additional challenges not previously emphasized in academic studies. This approach enables a structured comparison between theoretical expectations and empirical observations, highlighting convergences, divergences, and context-specific patterns. Table 23 provides an overview of the empirical sample and summarizes the 19 units of analysis included in the multiple case study. The cases span a wide range of manufacturing contexts, including energy systems, industrial automation, material handling, machine tools, cooling technologies, and industrial services. Several firms are represented by more than one unit of analysis, reflecting the coexistence of multiple XaaS offerings within the same organization. The majority of the units correspond to successful XaaS implementations, while a limited number of unsuccessful or non-scaled initiatives are included to capture boundary conditions and constraints associated with XaaS adoption.

Company	Unit of analysis	XaaS configuration	Outcome
Turboden	Monitoring- and performance-based service for ORC plants	Service-based	Success
Toyota Material Handling	Material handling equipment rental with integrated lifecycle services	Product-based	Success
Toyota Material Handling	Training-as-a-Service and Diagnostic-as-a-Service	Service-based	Success
Kaer	Cooling-as-a-Service (provider-owned systems, pay-per-use)	Product-based	Success
KUKA Robotics	Industrial robots rental with integrated services	Product-based	Success
KUKA Robotics	Maintenance and availability services for customer-owned robots	Service-based	Success
Prima Industrie	Maintenance and lifecycle service contracts for machine tools	Service-based	Success
Prima Industrie	Pay-per-use / product-based XaaS for machine tools	Product-based	Unsuccessful
ABB Robotics	Robot-as-a-Service	Product-based	Success
W&H	Digital monitoring and compliance services for medical equipment	Service-based	Success
W&H	Product-based XaaS (leasing / full-risk models)	Product-based	Not implemented / Unsuccessful
SEW-EURODRIVE	Predictive maintenance and installed-base management as-a-service	Product-based	Success

Company	Unit of analysis	XaaS configuration	Outcome
CGT (Caterpillar dealer)	Pay-per-performance equipment-as-a-service (“euro per ton”)	Product-based	Success
STULZ	Precision cooling equipment rental for temporary applications	Product-based	Success
STULZ	Cooling-as-a-Service with availability-based delivery	Product-based	Success
Sandvik Coromant	Pay-on-withdrawal cutting tools solution	Service-based	Success
Sandvik Coromant	Pay-per-part cutting tools solution	Product-based	Success
Cavanna	Packaging machinery rental for temporary production needs	Product-based	Success
Henkelhausen	Engine-as-a-Service	Service-based	Success

Table 23 Overview of empirical cases and units of analysis

To synthesize the results of the empirical analysis and relate them to the existing body of knowledge, the challenges associated with XaaS adoption are consolidated by integrating evidence from the literature and the multiple case study. Table 24 provides an overview of this synthesis, indicating which challenges discussed in prior research are confirmed by the empirical cases and highlighting additional challenges that emerge from practice. Challenges that are not explicitly or systematically addressed in the existing literature are marked with an asterisk.

Challenge	Macro-category	Type	Identified in literature	Confirmed by empirical cases	Emerging from cases
Shift from product-centric to service-centric logic	Cultural and strategic challenges	Internal	X	X	
Development of a service-oriented culture	Cultural and strategic challenges	Internal	X	X	
Strategic clarity on value creation and XaaS positioning	Cultural and strategic challenges	Internal	X	X	
Organizational readiness and cross-functional integration	Organizational and structural challenges	Internal	X	X	
Redefinition of roles, responsibilities, and governance	Organizational and structural challenges	Internal	X	X	

Challenge	Macro-category	Type	Identified in literature	Confirmed by empirical cases	Emerging from cases
Capability and skill development for service provision	Capability and knowledge-related challenges	Internal	X	X	
Availability of digital and technological infrastructure	Product, data, and technology-related challenges	Internal	X	X	
Data collection, management, and analytics capabilities	Product, data, and technology-related challenges	Internal	X	X	
Definition of pricing and revenue models for XaaS	Contractual and responsibility-related challenges	Internal	X	X	
Contractual complexity and risk allocation mechanisms	Contractual and responsibility-related challenges	Internal	X	X	
Balancing standardization and customization of offerings	Organizational and structural challenges	Internal	X	X	
Managing long-term responsibility and lifecycle risk	Contractual and responsibility-related challenges	Internal	X	X	
Customer acceptance of non-ownership-based models	Customer-related challenges	External	X	X	
Customer willingness to share data and collaborate	Customer-related challenges	External	X	X	
Trust building and relational governance with customers	Customer-related challenges	External	X	X	
Alignment with partners and suppliers in the ecosystem	Ecosystem and partner alignment challenges	External	X	X	
Risk sharing and profit allocation across the value chain	Ecosystem and partner alignment challenges	External	X	X	
Market readiness and demand uncertainty	Market-related challenges	External	X	X	
Regulatory and institutional constraints	Market-related challenges	External	X	X	
Expectation management on scope and responsibilities*	Customer-related challenges	External		X	X
Customer-side data immaturity*	Customer-related challenges	External		X	X
Standardization–flexibility trade-off at scale*	Organizational and structural challenges	Internal		X	X
Process invasiveness and loss of customer autonomy*	Customer-related challenges	External		X	X

Challenge	Macro-category	Type	Identified in literature	Confirmed by empirical cases	Emerging from cases
Component-level XaaS complexity*	Contractual and responsibility-related challenges	Internal		X	X
Dependence on OEM-owned data infrastructures*	Product, data, and technology-related challenges	Internal		X	X

Table 24 Challenges associated with XaaS adoption: literature and empirical evidence

Starting from the overview presented in Table 24, the following analysis discusses each challenge using evidence from the multiple case studies.

- **Shift from product-centric to service-centric logic**

Across the empirical sample, the transition from a product-centric to a service-centric logic emerges as a foundational challenge, whose implications differ depending on whether the XaaS configuration is product-based or service-based. In **product-based** offerings, where the provider retains ownership and assumes lifecycle responsibility, this shift entails a radical reframing of value creation—from selling an asset to guaranteeing outcomes such as availability, efficiency, or productivity. Kaer's Cooling-as-a-Service exemplifies this transformation, as the firm repositioned itself from equipment supplier to long-term service and asset owner, emphasizing performance guarantees and sustainability rather than technology per se (product-based, success). A similar logic underpins CGT's pay-per-performance "euro-per-ton" model, in which value is anchored to customer output rather than machine provision (product-based, success). In **service-based** configurations, the shift is less asset-disruptive but remains strategically significant, as it requires legitimizing digital and knowledge-intensive services as core value drivers. Turboden illustrates this dynamic: although already service-oriented, the move toward performance-based monitoring required recognizing IT and data analytics as strategic enablers rather than support functions (service-based, success). Evidence from failure cases reinforces the boundary conditions of this challenge. Prima Industrie's unsuccessful experimentation with product-based pay-per-use models shows that, where ownership remains economically rational for customers and providers lack sufficient scale or financial robustness to absorb risk, the transition from selling products to selling outcomes is difficult to sustain (product-based, failure). Overall, the findings indicate that a service-centric logic in XaaS is not merely a cultural aspiration, but in product-based models must be underpinned by financial, operational, and market conditions that render outcome-based exchange viable over time.

- **Development of a service-oriented culture.**

The development of a service-oriented culture emerges as a critical yet non-trivial challenge across the empirical cases, as XaaS adoption requires firms to redefine internal priorities, performance metrics, and professional identities. While often treated in the literature as a generic cultural shift, the empirical evidence shows that this challenge materializes in concrete organizational tensions, particularly at the interface between product-centric functions and emerging service- and data-oriented roles. In **service-based** XaaS configurations, the challenge primarily concerns the legitimization of services, especially digital and analytical activities, as core value-creating domains. Turboden illustrates this dynamic: despite a pre-existing service orientation, the introduction of monitoring- and performance-based services required recognizing data analytics, software development, and IT infrastructure as strategic capabilities rather than auxiliary support functions. This shift was gradual, as engineering-centric logics initially slowed internal alignment, but it ultimately enabled the successful scaling of the XaaS offering (service-based, success). In **product-based** XaaS models, the cultural challenge is more disruptive, as it directly affects sales practices and managerial mindsets. ABB Robotics' Robot-as-a-Service shows how sales organizations must move from transactional product selling toward a consultative approach focused on cash-flow flexibility, risk reduction, and long-term partnerships. This transition requires new incentive systems and training, given the misalignment between traditional sales KPIs and recurring-revenue logics. ABB's success is closely linked to its ability to foster this cultural shift progressively (product-based, success). The Toyota Material Handling case extends the cultural dimension beyond the focal firm. In its **service-based** Training-as-a-Service and Diagnostic-as-a-Service offerings, XaaS is used as a governance mechanism to align behaviors and capabilities across a heterogeneous dealer network. Here, success depends less on technology and more on the diffusion of shared service values and standards (service-based, success). Conversely, the **unsuccessful** product-based initiative of Prima Industrie highlights the risks associated with an underdeveloped service-oriented culture. Limited internal alignment, insufficient experience with long-term responsibility, and a persistent focus on product ownership constrained the firm's ability to embrace pay-per-use and outcome-oriented models. Overall, the findings suggest that while a service-oriented culture is a necessary condition for XaaS adoption across configurations, product-based models require a deeper reconfiguration of commercial identities, incentives, and risk perceptions to achieve sustainable implementation.

- **Strategic clarity on value creation and XaaS positioning.**

Strategic clarity regarding the value created through XaaS and the positioning of the offering within the firm's portfolio emerges as a central challenge across the empirical cases. While the literature often frames XaaS positioning as a natural extension of servitization strategies, the empirical evidence

shows that insufficient clarity on scope, objectives, and boundaries can generate internal and external misalignment, undermining implementation even when technological and organizational capabilities are in place. In **product-based** XaaS configurations, strategic clarity is particularly critical due to the higher levels of financial exposure and long-term responsibility involved. ABB Robotics' Robot-as-a-Service illustrates how successful adoption is supported by a deliberately narrow and well-defined positioning. By limiting RaaS to standardized robotic assets and explicitly excluding system integration and highly customized applications, ABB retains control over risk, enhances scalability, and communicates a clear value proposition centered on flexibility and reduced upfront investment rather than full automation outsourcing (product-based, success). A similar pattern is evident in Kaer's Cooling-as-a-Service model, where strategic clarity is achieved by anchoring the offering to guaranteed cooling performance and sustainability outcomes. Kaer's positioning as an asset owner and long-term operator enables customers to externalize technical and financial complexity, while guiding internal investments in monitoring technologies, service capabilities, and contractual design (product-based, success). In **service-based** XaaS models, strategic clarity mainly concerns the role of the offering within the broader service portfolio and its relationship with existing activities. Turboden's monitoring- and performance-based services are explicitly positioned as enablers of operational optimization and risk reduction, rather than substitutes for core engineering competences. This framing reduces internal resistance and facilitates customer acceptance by presenting the service as complementary and value-enhancing (service-based, success). The Toyota Material Handling case further shows how strategic clarity can be used as a governance mechanism: in its Training-as-a-Service and Diagnostic-as-a-Service offerings, XaaS is defined not primarily as a revenue innovation, but as a strategic tool to standardize capabilities, improve service quality, and protect the brand across a heterogeneous dealer network (service-based, success). Conversely, the **unsuccessful** product-based experimentation at Prima Industrie highlights the consequences of limited strategic clarity. Here, pay-per-use and outcome-oriented models were explored without a sufficiently articulated value proposition differentiating them from traditional sales or justifying ownership and risk transfer, leading to low internal legitimacy and limited market traction (product-based, failure). Overall, the findings indicate that strategic clarity is a critical antecedent of XaaS success across configurations, but its importance is amplified in product-based models, where ambiguity directly translates into financial and operational risk.

- **Organizational readiness and cross-functional integration**

Organizational readiness and cross-functional integration emerge as a pervasive challenge in XaaS adoption, as these models require sustained coordination among functions that are traditionally

separated, such as sales, service, engineering, IT, finance, and legal. While the literature often frames this issue in general terms, the empirical evidence shows that insufficient integration can slow down implementation and limit scalability, even when strategic intent is clear. In **product-based** XaaS configurations, the challenge is particularly pronounced due to the need to manage long-term responsibility and financial exposure. ABB Robotics' Robot-as-a-Service illustrates this complexity: the offering is developed and delivered through close collaboration among commercial, service, finance, and legal functions, with pilots used as a mechanism to gradually align internal stakeholders. The success of RaaS is closely tied to ABB's ability to orchestrate these functions around a shared logic of recurring revenues and risk management, rather than around one-off sales transactions (product-based, success). Similar integration challenges are visible in SEW-Eurodrive's predictive maintenance and installed-base services, where cross-functional coordination between engineering, service, and digital units was necessary to translate monitoring capabilities into scalable service offerings (product-based, success). In **service-based** XaaS models, cross-functional integration often centers on the interaction between technical and digital functions. Turboden's performance-based monitoring services required tighter coordination between service engineers and IT specialists, as well as the establishment of dedicated service structures to manage data-driven offerings. Initial limitations in IT resource availability slowed implementation, indicating that organizational readiness extends beyond formal structures to include the allocation of appropriate skills and capacities (service-based, success). Evidence from **unsuccessful** cases further reinforces the importance of organizational readiness. Prima Industrie's failed product-based experimentation reveals how limited internal integration and fragmented responsibilities constrained the firm's ability to design, price, and manage advanced XaaS contracts. In the absence of a coordinated organizational backbone, pay-per-use models remained isolated initiatives rather than scalable business models (product-based, failure). Overall, the empirical findings suggest that organizational readiness and cross-functional integration are critical enabling conditions for XaaS adoption across configurations. However, their relevance is amplified in product-based models, where misalignment among internal functions directly increases operational complexity and financial risk, thereby undermining the viability of outcome-oriented offerings.

- **Redefinition of roles, responsibilities, and governance**

The redefinition of roles, responsibilities, and governance structures emerges as a key challenge in XaaS adoption, as these models extend provider responsibility over longer time horizons and blur traditional boundaries between sales, service, and operational functions. While the literature often acknowledges this issue in abstract terms, the empirical evidence shows that unclear governance can

generate operational frictions and accountability gaps that hinder implementation. In **product-based** XaaS configurations, this challenge is particularly salient because providers assume ownership and performance responsibility for the asset. SEW-Eurodrive's predictive maintenance and installed-base management offering illustrates how successful implementation required the creation of dedicated roles, such as servitization or business development managers, tasked with coordinating technical, commercial, and digital activities. This governance solution enabled clearer accountability and supported the scaling of the offering across customers (product-based, success). A similar need for explicit governance mechanisms is visible in ABB Robotics' RaaS, where contractual responsibility, asset ownership, and service execution are carefully distributed among internal functions and external financial partners to avoid ambiguity (product-based, success). In **service-based** XaaS models, governance challenges tend to revolve around coordinating digital, technical, and customer-facing roles. Turboden's monitoring- and performance-based services required the formalization of responsibilities between service engineers and IT specialists to ensure data quality, responsiveness, and contractual compliance. The success of the offering depended on clarifying who was accountable for data interpretation, customer communication, and corrective actions, rather than relying on informal coordination (service-based, success). Failure evidence highlights the risks of insufficient role redefinition. Prima Industrie's unsuccessful product-based experimentation shows that, in the absence of clear governance and ownership of the XaaS initiative, responsibilities for pricing, risk management, and lifecycle performance remained fragmented. As a result, the offering struggled to achieve internal legitimacy and operational coherence, reinforcing the notion that role clarity and governance are not ancillary issues but core enablers of XaaS adoption (product-based, failure). Overall, the empirical findings indicate that redefining roles, responsibilities, and governance is essential across both product-based and service-based XaaS models. However, the challenge is amplified in product-based configurations, where unclear accountability directly translates into increased financial exposure and operational risk, undermining the sustainability of the XaaS offering.

- **Capability and skill development for service provision**

The development of appropriate capabilities and skills emerges as a central challenge across all XaaS configurations, as these models require competences that extend beyond traditional product engineering and field service. While the literature broadly emphasizes the need for "service capabilities," the empirical evidence shows that XaaS adoption specifically demands a combination of digital, analytical, contractual, and consultative skills that are often unevenly distributed within manufacturing firms. In **service-based** XaaS models, capability development is primarily oriented

toward digital and analytical competences. Turboden's performance-based monitoring services illustrate this challenge: the firm had to complement its engineering expertise with skills in data analytics, software development, and system integration to interpret operational data and translate it into actionable insights for customers. The initial scarcity of these competences slowed implementation, but their progressive internalization proved critical to the successful scaling of the service (service-based, success). A similar pattern is visible in W&H's digital monitoring and compliance services, where the ability to manage data accuracy, traceability, and regulatory documentation became a core capability underpinning service value creation (service-based, success). In **product-based** XaaS configurations, capability development extends beyond technical and digital skills to include financial modeling, risk assessment, and consultative selling. CGT's pay-per-performance "euro-per-ton" model highlights the importance of deep process knowledge and the ability to model customer production economics in order to design viable pricing mechanisms. These capabilities are markedly different from those required for traditional equipment sales and were developed progressively through pilot projects and close customer interaction (product-based, success). ABB Robotics' RaaS similarly required sales teams to acquire financial and contractual competences to engage with customer decision-makers on cash-flow flexibility and risk transfer rather than on technical specifications alone (product-based, success). Evidence from **unsuccessful** cases reinforces the importance of this challenge. Prima Industrie's failed product-based experimentation reveals that limited experience in pricing long-term service contracts and managing lifecycle risk constrained the firm's ability to operationalize pay-per-use models. In the absence of adequate service-specific capabilities, XaaS initiatives remained conceptually attractive but operationally fragile (product-based, failure). Overall, the empirical findings indicate that capability and skill development is a necessary condition for XaaS adoption across configurations. However, product-based models place particularly stringent demands on firms, as they require the integration of technical, digital, and financial competences to support long-term responsibility and outcome-oriented value creation.

- **Availability of digital and technological infrastructure**

The availability of adequate digital and technological infrastructure emerges as a foundational enabling condition for XaaS adoption, as both product-based and service-based configurations rely on connectivity, monitoring, and data management to support service delivery and contractual commitments. While the literature often treats digitalization as a generic prerequisite, the empirical evidence shows that infrastructure requirements vary significantly depending on the type of offering and the degree of responsibility assumed by the provider. In **service-based** XaaS models, digital

infrastructure typically serves to enable monitoring, reporting, and decision support, often without requiring full operational control. Turboden's monitoring- and performance-based services depend on reliable data acquisition and transmission from ORC plants and on the ability to process and visualize performance information for both internal teams and customers. In this context, infrastructure constraints, such as limited integration between heterogeneous systems and cybersecurity requirements, directly shape the scope and scalability of the service (service-based, success). Similarly, W&H's digital monitoring and compliance services rely on platforms that ensure traceability and the production of auditable documentation, making infrastructure reliability and data integrity central to service value creation (service-based, success). In **product-based** XaaS configurations, digital infrastructure becomes even more critical because it underpins the provider's ability to assume long-term responsibility for asset performance or availability. Kaer's Cooling-as-a-Service illustrates this dynamic: monitoring systems and the Kaer Connect platform are not ancillary features but essential operational tools for managing provider-owned assets, optimizing energy use, and ensuring contractual performance over time (product-based, success). SEW-Eurodrive's predictive maintenance and installed-base management offering similarly depends on sensors, gateways, and cloud infrastructure to detect early signs of degradation and support proactive maintenance planning; in this case, initial customer concerns about cloud connectivity highlight how infrastructure choices can become adoption barriers (product-based, success). Evidence from **unsuccessful** initiatives suggests that even when digital tools exist, infrastructure readiness may be insufficient to support more radical XaaS configurations. Prima Industrie's difficulties in moving toward product-based pay-per-use models indicate that limitations in data reliability and performance measurement reduce the provider's ability to price risk credibly and sustain long-term contractual responsibility (product-based, failure). Overall, the empirical findings confirm that digital and technological infrastructure is a necessary baseline for XaaS adoption. However, its role is amplified in product-based models, where infrastructure is directly tied to risk exposure and contractual viability, whereas in service-based models it primarily supports transparency, compliance, and incremental value creation.

- **Data collection, management, and analytics capabilities**

Beyond the mere availability of digital infrastructure, the ability to collect, manage, and analyze data effectively emerges as a distinct and critical challenge for XaaS adoption. The empirical evidence shows that data-related difficulties rarely stem from the absence of data alone, but rather from issues of data quality, integration, interpretation, and long-term usability, especially when services are delivered over extended lifecycles. In **service-based** XaaS configurations, data analytics capabilities

are central to transforming raw operational data into actionable insights and contractual value. Turboden's performance-based monitoring services illustrate this challenge: the high degree of customization of ORC plants results in heterogeneous data structures, making data normalization and interpretation complex. Moreover, cybersecurity constraints imposed by customers often limit direct data access, requiring alternative architectures that increase analytical effort. Despite these challenges, Turboden's ability to progressively build internal analytics capabilities enabled the successful delivery of performance-oriented services (service-based, success). A similar pattern is visible in W&H's digital monitoring and compliance services, where data accuracy, traceability, and auditability are essential for regulatory compliance, elevating data management from a technical issue to a core service capability (service-based, success). In **product-based** XaaS models, data analytics capabilities are even more tightly linked to risk management and economic viability. SEW-Eurodrive's predictive maintenance and installed-base management services rely on long-term data collection to detect gradual performance degradation and anticipate failures. This requires not only robust data pipelines but also advanced analytical models capable of operating over long time horizons, highlighting the strategic importance of data governance and lifecycle-oriented analytics (product-based, success). Kaer's Cooling-as-a-Service similarly depends on continuous data analysis to optimize energy efficiency and ensure contractual performance, reinforcing the centrality of analytics in managing provider-owned assets (product-based, success). Evidence from **unsuccessful** cases underscores the risks associated with inadequate data capabilities. Prima Industrie's difficulties in implementing product-based pay-per-use models suggest that limitations in performance measurement and data interpretation undermine the provider's ability to price outcomes and manage lifecycle risk effectively (product-based, failure). Overall, the empirical findings indicate that data collection, management, and analytics capabilities constitute a critical differentiator in XaaS adoption. While relevant across all configurations, these capabilities are particularly consequential in product-based models, where the inability to translate data into reliable performance and cost predictions directly threatens contractual sustainability.

- **Definition of pricing and revenue models for XaaS**

The definition of appropriate pricing and revenue models emerges as a critical challenge in XaaS adoption, as firms must translate long-term responsibility, uncertainty, and performance commitments into economically sustainable contracts. The empirical evidence shows that this challenge is particularly acute in **product-based** XaaS configurations, where pricing must incorporate asset ownership, utilization risk, lifecycle costs, and delayed cash flows. CGT's pay-per-performance "euro-per-ton" model exemplifies the complexity of this task. Pricing is anchored to

customer output rather than machine usage, requiring a detailed understanding of production processes and the definition of minimum guaranteed volumes to protect provider economics. The success of the model depends on carefully balancing risk-sharing mechanisms and incentive alignment, ensuring that both provider and customer benefit from efficiency improvements (product-based, success). Kaer's Cooling-as-a-Service similarly relies on sophisticated pricing structures that reflect guaranteed performance and energy efficiency outcomes, enabling customers to externalize both capital expenditure and operational risk while allowing the provider to recover long-term investments (product-based, success). In **service-based** XaaS models, pricing challenges are generally less capital-intensive but still significant, as revenues must justify continuous service delivery and digital infrastructure costs. Turboden's monitoring- and performance-based services illustrate how pricing is often incremental and negotiated, reflecting the complementary role of the service within broader customer relationships. Here, the challenge lies in monetizing data-driven value without undermining existing engineering or service revenues (service-based, success). Evidence from **unsuccessful** initiatives highlights the boundary conditions of pricing innovation. Prima Industrie's failed product-based pay-per-use experimentation indicates that, in the absence of reliable performance data and sufficient scale to diversify risk, pricing models become either unattractive to customers or unsustainable for the provider (product-based, failure). Overall, the empirical findings suggest that viable XaaS pricing requires not only technical and analytical capabilities, but also a clear understanding of risk allocation and customer value drivers, with product-based models facing substantially higher complexity and exposure.

- **Contractual complexity and risk allocation mechanisms**

Contractual complexity and the allocation of risk emerge as a major challenge in XaaS adoption, as these models require firms to formalize long-term responsibilities, performance commitments, and uncertainty within contractual arrangements. The empirical evidence shows that this challenge is particularly pronounced in **product-based** XaaS configurations, where ownership, availability, and performance risks are partially or fully transferred to the provider. ABB Robotics' Robot-as-a-Service illustrates how successful implementation depends on carefully designed contractual architectures. ABB mitigates risk exposure by limiting contractual scope and by involving financial partners who assume asset ownership and residual value risk, while ABB focuses on service delivery and technical performance. This separation of responsibilities reduces financial exposure and supports scalability, highlighting the role of contractual design as an enabling mechanism rather than a mere legal requirement (product-based, success). A similar logic is observed in Kaer's Cooling-as-a-Service, where contracts explicitly define performance thresholds, responsibilities, and exclusion clauses to

manage the high level of operational and financial risk associated with provider-owned systems (product-based, success). In **service-based** XaaS models, contractual complexity tends to revolve around defining service scope, data responsibilities, and liability boundaries rather than asset ownership. Turboden's performance-based monitoring services demonstrate how contracts must carefully specify data access, performance metrics, and response obligations, particularly when cybersecurity constraints limit real-time control. Clear contractual definitions proved essential to avoid misaligned expectations and to sustain long-term service relationships (service-based, success). Failure evidence further underscores the importance of risk allocation mechanisms. Prima Industrie's unsuccessful product-based experimentation reveals that ambiguous contracts and insufficient risk-sharing structures made it difficult to price uncertainty and protect provider economics, ultimately undermining the viability of pay-per-use offerings (product-based, failure). Overall, the empirical findings indicate that contractual complexity is an inherent feature of XaaS adoption. However, its implications are amplified in product-based models, where inadequate risk allocation directly increases financial exposure, whereas in service-based models contracts primarily function to clarify responsibilities and safeguard relational stability.

- **Balancing standardization and customization of offerings**

Balancing standardization and customization emerges as a recurring challenge in XaaS adoption, as providers must simultaneously ensure scalability and respond to heterogeneous customer requirements. The empirical evidence shows that this trade-off is particularly salient in **product-based** offerings, where reuse of assets, processes, and service routines is essential for economic sustainability, yet customer-specific applications often demand tailoring. In **product-based** models, ABB Robotics' Robot-as-a-Service illustrates how standardization can be actively used as a risk- and scalability lever. By restricting the offering to standardized robotic assets and excluding highly customized integration, ABB protects asset reusability and reduces contractual complexity, enabling the model to remain scalable across multiple customers (product-based, success). A similar tension is visible in KUKA's industrial robot rental with integrated services, where the provider benefits from standardized service processes but must still adapt to varied customer applications and operational contexts, requiring flexible service delivery without compromising industrialization (product-based, success). STULZ and Cavanna further reinforce this logic in rental-based models: the viability of temporary equipment rental depends on modular, standardized configurations that can be rapidly deployed and redeployed, while maintaining sufficient adaptability to fit different customer environments (product-based, success). In **service-based** XaaS, customization pressures often manifest in the data and analytics layer rather than in physical configurations. Turboden's

performance-based monitoring services illustrate how plant-level heterogeneity and customization increase the effort required to build dashboards, analytics models, and performance baselines, limiting scalability and raising service delivery costs even when the offering is conceptually standardized (service-based, success). Although not always resulting in outright failure, the evidence suggests that insufficient control over the standardization–customization balance can undermine the viability of more advanced product-based models. Prima Industrie's difficulties in scaling product-based experimentation are consistent with this mechanism: without standardized configurations and repeatable service processes, it becomes harder to price risk and sustain long-term contracts (product-based, failure). Overall, the findings indicate that successful XaaS adoption requires deliberate boundary setting, standardizing where scalability and risk control matter most, while allowing limited customization where customer fit is essential.

- **Managing long-term responsibility and lifecycle risk**

Managing long-term responsibility and lifecycle risk emerges as a defining challenge of XaaS adoption, particularly in **product-based** configurations where providers retain asset ownership and commit to availability or performance over extended time horizons. The empirical evidence shows that this challenge goes beyond technical reliability, encompassing financial exposure, residual value uncertainty, and the need to manage assets across multiple usage cycles. In **product-based** XaaS models, Kaer's Cooling-as-a-Service illustrates how providers internalize a broad spectrum of lifecycle risks, including operation, maintenance, energy efficiency, and obsolescence. Kaer's ability to manage these risks relies on careful asset design, continuous monitoring, and contractual mechanisms that align performance incentives over time, enabling the successful delivery of provider-owned systems (product-based, success). ABB Robotics' RaaS similarly highlights the importance of structuring responsibility through partnerships: by involving financial institutions that assume ownership and residual value risk, ABB reduces its direct exposure while maintaining control over service performance (product-based, success). CGT's pay-per-performance model further shows how lifecycle risk is managed through minimum volume commitments and long-term customer relationships that stabilize utilization rates (product-based, success). In **service-based** XaaS configurations, lifecycle risk is generally more limited, as ownership remains with the customer. However, long-term responsibility still manifests in the form of sustained service performance and reputational exposure. Turboden's performance-based monitoring services illustrate how extended contractual commitments require the firm to ensure data reliability and continuous analytical support over time, even when direct operational control is constrained (service-based, success). Failure evidence underscores the boundary conditions of this challenge. Prima Industrie's unsuccessful

product-based experimentation reveals that, when asset lifecycles are long, technological discontinuities are limited, and customer ownership remains economically attractive, the provider may struggle to justify and sustain long-term responsibility and associated risks (product-based, failure). Overall, the empirical findings suggest that managing lifecycle risk is a critical determinant of XaaS viability, with product-based models requiring sophisticated financial, operational, and contractual mechanisms to absorb and distribute long-term uncertainty.

- **Customer acceptance of non-ownership-based models**

Customer acceptance of non-ownership-based models emerges as a critical external challenge in XaaS adoption, particularly in **product-based** configurations where asset ownership is transferred from the customer to the provider. The empirical evidence shows that resistance to non-ownership is not merely cultural, but often grounded in economic rationality, risk perception, and established operational practices. In **product-based** XaaS models, acceptance largely depends on whether customers perceive the substitution of ownership with service access as advantageous. Kaer's Cooling-as-a-Service demonstrates how acceptance can be achieved when the model clearly reduces complexity and financial exposure for the customer. By externalizing capital expenditure, operational responsibility, and energy efficiency risk, Kaer enables customers to focus on core activities, making non-ownership a rational and attractive choice (product-based, success). Similar dynamics are visible in ABB Robotics' RaaS and CGT's pay-per-performance model, where customers accept non-ownership when it improves cash-flow flexibility and aligns costs with actual production output (product-based, success). In **service-based** XaaS configurations, customer acceptance is generally higher, as ownership remains unchanged and services are perceived as complementary rather than substitutive. Turboden's monitoring and performance-based services and W&H's digital compliance services illustrate how customers readily adopt service-based XaaS when it enhances transparency, reliability, or regulatory compliance without altering asset ownership structures (service-based, success). Failure evidence highlights the limits of customer acceptance in product-based models. Prima Industrie's unsuccessful experimentation with pay-per-use indicates that, in contexts characterized by long asset lifecycles, limited technological obsolescence, and stable utilization, customers may continue to prefer ownership, perceiving XaaS as economically unnecessary or strategically constraining (product-based, failure). Overall, the findings suggest that customer acceptance of non-ownership is contingent on clear economic benefits and risk reduction, and that product-based XaaS models must offer compelling value propositions to overcome entrenched ownership preferences.

- **Customer willingness to share data and collaborate**

Customer willingness to share data and engage in collaborative practices emerges as a key external challenge for XaaS adoption, as data access and ongoing interaction are often prerequisites for delivering service value. The empirical evidence shows that this challenge is shaped by trust, cybersecurity concerns, and perceived loss of control, and it manifests differently across **product-based** and **service-based** configurations. In **service-based** XaaS models, data sharing is central to enabling monitoring, diagnostics, and performance evaluation, yet customers often impose restrictions on access and usage. Turboden's performance-based monitoring services illustrate this tension: while customers recognize the value of data-driven insights, concerns related to cybersecurity and intellectual property frequently limit real-time data access. As a result, alternative architectures (e.g., delayed or filtered data transfer) were adopted, increasing analytical complexity but allowing collaboration to be sustained (service-based, success). A similar pattern is observed in W&H's digital monitoring and compliance services, where customers' willingness to share data is facilitated by regulatory requirements, which legitimize data exchange and reduce resistance (service-based, success). In **product-based** XaaS configurations, data sharing is more tightly linked to operational control and risk allocation. CGT's pay-per-performance model highlights how customers' limited data maturity and reluctance to systematically measure production initially constrained collaboration. In several cases, CGT had to deploy its own sensing and data infrastructure to enable the model, effectively lowering the entry barrier for customers while increasing provider responsibility (product-based, success). SEW-Eurodrive similarly reports customer hesitation toward cloud-based solutions, requiring extensive reassurance and trust-building to enable data-driven services (product-based, success). Failure evidence suggests that insufficient willingness to share data can undermine more advanced XaaS models. Prima Industrie's unsuccessful product-based experimentation indicates that limited data transparency and collaboration reduced the provider's ability to monitor performance and manage risk, weakening the economic rationale of pay-per-use offerings (product-based, failure). Overall, the findings suggest that customer data sharing and collaboration are not automatic outcomes of XaaS adoption but must be actively enabled through trust-building, regulatory alignment, and, in some cases, provider-led infrastructure investments.

- **Trust building and relational governance with customers**

Trust building and relational governance emerge as central conditions for XaaS adoption, particularly because XaaS arrangements involve long-term interdependence, information asymmetry, and, in many cases, an implicit redistribution of operational and financial risk. The empirical evidence shows that, beyond formal contracts, relational mechanisms are often required to sustain collaboration, manage exceptions, and handle unforeseen events over the lifecycle of the offering. In **product-based**

XaaS configurations, trust is especially critical because customers rely on the provider for the continuity of a mission-critical function and accept higher dependency. Kaer's Cooling-as-a-Service illustrates this dynamic: customers delegate ownership and operational responsibility for cooling infrastructure, making provider credibility, service reliability, and long-term responsiveness essential for acceptance and continuity (product-based, success). Similarly, CGT's pay-per-performance model requires customers to share sensitive operational data and accept provider involvement in process optimization; such "process intimacy" can only be sustained through strong relational governance and long-standing trust-based relationships (product-based, success). ABB Robotics' RaaS further reinforces this point: customers must trust not only the technology but also the provider's ability to manage service delivery over time and to handle contingencies linked to availability and upgrades (product-based, success). In **service-based** XaaS models, trust tends to revolve around data handling, transparency, and the perceived reliability of recommendations rather than asset ownership. Turboden's performance-based monitoring services show that trust is needed to legitimize remote diagnostics and performance recommendations, particularly when cybersecurity concerns make customers cautious about granting access. In this context, relational governance complements contractual arrangements by enabling gradual adoption, iterative adjustments, and sustained customer engagement (service-based, success). W&H's compliance services similarly benefit from trust, as customers must rely on the provider's ability to ensure traceable and auditable documentation in a regulated setting (service-based, success). Although explicit "trust failures" are rarely reported as isolated causes of failure, the **unsuccessful** product-based experimentation at Prima Industrie is consistent with weak relational foundations: without sufficient customer confidence in long-term value and risk sharing, pay-per-use offerings struggled to gain legitimacy and continuity (product-based, failure). Overall, the empirical findings indicate that trust and relational governance function as structural enablers of XaaS adoption, particularly in product-based models where dependency and exposure are higher, but also in service-based models where data access and continuous collaboration are necessary for value realization.

- **Alignment with partners and suppliers in the ecosystem**

Alignment with partners and suppliers emerges as a critical external challenge in XaaS adoption, as value creation and risk management increasingly depend on multi-actor ecosystems rather than on the focal firm alone. The empirical evidence shows that XaaS models often reconfigure traditional roles along the value chain, requiring new coordination mechanisms, incentive structures, and governance arrangements to ensure coherent service delivery. In **product-based** XaaS configurations, ecosystem alignment is particularly complex because ownership, financing, service

execution, and customer interaction may be distributed across multiple actors. ABB Robotics' Robot-as-a-Service illustrates this dynamic: the offering relies on financial partners who assume asset ownership and residual value risk, while ABB retains responsibility for service performance. Successful implementation depends on clear coordination between these actors, as misalignment could undermine both customer experience and economic sustainability (product-based, success). Similar challenges are visible in SEW-Eurodrive's predictive maintenance and installed-base services, where collaboration with technology partners providing sensors or digital components influences cost structures and architectural choices, making partner alignment a determinant of scalability (product-based, success). In **service-based** XaaS models, ecosystem challenges often revolve around coordinating semi-autonomous partners and ensuring consistent service quality. Toyota Material Handling's Training-as-a-Service and Diagnostic-as-a-Service offerings provide a clear example: the firm operates through a heterogeneous dealer network with varying levels of maturity and incentives. Here, XaaS is deliberately used as a governance mechanism to standardize access to diagnostics and training content, aligning partner behavior and protecting overall service quality (service-based, success). Turboden's monitoring services similarly depend on coordination with external technology providers and customers' IT departments, highlighting how service-based models also require ecosystem-level alignment, albeit with lower financial exposure (service-based, success). Evidence from **unsuccessful** initiatives reinforces the importance of this challenge. Prima Industrie's product-based experimentation suggests that limited ecosystem readiness and insufficient alignment with external actors constrained the firm's ability to sustain advanced pay-per-use offerings, as risk and responsibility could not be effectively shared or absorbed (product-based, failure). Overall, the empirical findings indicate that ecosystem alignment is a prerequisite for XaaS viability, with product-based models requiring particularly robust coordination mechanisms to manage distributed ownership, risk, and value creation.

- **Risk sharing and profit allocation across the value chain**

Risk sharing and profit allocation emerge as a central challenge in XaaS adoption because these models redistribute financial exposure, operational responsibility, and value capture among multiple actors. The empirical evidence shows that successful XaaS implementation often depends on designing mechanisms that make the new distribution of risks and rewards acceptable and economically sustainable for all involved stakeholders. In **product-based** XaaS configurations, the challenge is particularly salient because providers assume asset ownership and often commit to availability or performance, increasing their exposure to utilization uncertainty, residual value risk, and lifecycle costs. ABB Robotics' Robot-as-a-Service illustrates how risk allocation can be

deliberately engineered through value chain restructuring: by involving financial partners that assume asset ownership and residual value risk, ABB reduces its direct exposure while maintaining technical control and service responsibility. This arrangement enables scalability and stabilizes the provider's economic model, showing that risk sharing is not simply contractual, but also organizational and financial in nature (product-based, success). CGT's pay-per-performance model similarly relies on explicit risk-sharing mechanisms, including minimum guaranteed production volumes and pricing structures designed to protect provider economics while preserving customer incentives for efficiency (product-based, success). Kaer's Cooling-as-a-Service further reflects this logic: long-term asset ownership and operational responsibility require contracts that allocate risks related to performance, energy efficiency, and service continuity in a way that sustains provider investment and customer trust (product-based, success). In **service-based** XaaS models, risk allocation tends to be less capital-intensive, but profit sharing and responsibility distribution remain relevant where delivery depends on partners or networks. Toyota's Training-as-a-Service and Diagnostic-as-a-Service, for instance, implicitly reallocate value capture across the dealer ecosystem by using centralized service platforms to standardize capabilities and protect brand outcomes; here, the challenge is ensuring that partners perceive the arrangement as fair and beneficial, despite the centralization of service governance (service-based, success). Failure evidence highlights the consequences of insufficient risk-sharing architectures. Prima Industrie's unsuccessful product-based experimentation suggests that, without sufficient scale or financial mechanisms to diversify and price risk, the provider is forced either to absorb excessive exposure or to propose terms that customers find unattractive. In both cases, the model becomes unsustainable and fails to scale (product-based, failure). Overall, the empirical findings indicate that effective risk sharing and profit allocation are core determinants of XaaS viability, particularly in product-based models where the economic burden of long-term responsibility must be structurally redistributed across the value chain.

- **Market readiness and demand uncertainty**

Market readiness and demand uncertainty emerge as significant external challenges for XaaS adoption, as the viability of these models depends on customers' ability and willingness to engage with outcome-oriented, long-term contractual arrangements. The empirical evidence shows that readiness varies widely across industries and applications, and is strongly influenced by the measurability of outcomes, budgeting practices, and the maturity of customer decision-making processes. In **product-based** XaaS configurations, market readiness is closely linked to the predictability of usage and performance. CGT's pay-per-performance "euro-per-ton" model illustrates how demand uncertainty can be mitigated when customer processes are stable and output

can be clearly measured. In such contexts, XaaS adoption is facilitated, whereas more variable or less measurable environments limit scalability (product-based, success but boundary-limited). SEW-Eurodrive's experience similarly shows that customers' budgeting logics often favor traditional investment models; to address this, SEW structured its offerings as all-inclusive, multi-year service or rental solutions that translate upfront investments into predictable operating expenses, thereby reducing adoption barriers (product-based, success). In **service-based** XaaS models, market readiness is generally higher, as these offerings are perceived as incremental and less disruptive. Turboden's monitoring services and W&H's compliance-oriented services benefit from clearer value propositions tied to efficiency gains or regulatory requirements, which reduce uncertainty and facilitate adoption even in conservative markets (service-based, success). Failure evidence highlights the limits of market readiness in more radical configurations. Prima Industrie's unsuccessful product-based experimentation suggests that when customers perceive limited uncertainty in their operations and low benefits from shifting away from ownership, demand for XaaS remains weak, regardless of the technical feasibility of the offering (product-based, failure). Overall, the findings indicate that market readiness is a contextual determinant of XaaS adoption, with product-based models being particularly sensitive to demand uncertainty and requiring careful selection of application domains and customer segments.

- **Regulatory and institutional constraints**

Regulatory and institutional constraints emerge as a relevant challenge in XaaS adoption, as they shape both the feasibility of digital service delivery and the attractiveness of specific business models. The empirical evidence suggests that regulation can act simultaneously as a constraint, by increasing compliance requirements and limiting data practices, and as an enabler, by strengthening the value proposition of certain service-based offerings. In **service-based** XaaS configurations, regulatory intensity often reinforces the need for traceability, documentation, and auditable processes. W&H's digital monitoring and compliance services illustrate this dynamic: operating in a highly regulated medical context, the service must ensure data accuracy, integrity, and auditability, raising development and operational complexity. However, these same regulatory requirements increase customer willingness to adopt the offering, as compliance-related value is immediate and difficult to achieve internally (service-based, success). Similarly, in other monitoring-oriented services, institutional expectations around cybersecurity and data governance influence technical architectures and service boundaries, affecting how XaaS can be delivered (service-based, success). In **product-based** XaaS models, institutional constraints more often manifest indirectly through liability, asset ownership rules, and risk exposure. The empirical evidence suggests that highly regulated

environments can increase the perceived risk of transferring ownership or operational responsibility, thereby limiting the viability of more radical product-based models. This is consistent with the secondary evidence in W&H, where product-based, full-risk configurations were explored but not implemented successfully, indicating that regulatory environments and liability concerns can hinder the shift toward provider-owned models (product-based, unsuccessful/non-implemented). Overall, the findings indicate that regulatory and institutional constraints are not uniformly negative for XaaS adoption. Rather, they shape which configurations are more viable: service-based offerings that support compliance, traceability, and documentation tend to benefit from regulatory pressure, whereas product-based models may face stronger constraints due to heightened liability and governance complexity.

- **Expectation management on scope and responsibilities**

Expectation management regarding the scope of the XaaS offering and the allocation of responsibilities emerges from the empirical analysis as a critical challenge that is not systematically addressed in the literature. The cases show that even when the value proposition is technically sound, misaligned expectations between providers and customers can undermine adoption, particularly in **product-based** XaaS configurations where responsibility boundaries are less intuitive. In **product-based** models, customers often interpret XaaS offerings as more comprehensive than they actually are, assuming that the provider will take responsibility for the entire system or process. ABB Robotics' Robot-as-a-Service provides a clear example: despite ABB's deliberate positioning of RaaS around standardized robots, customers sometimes expected the offering to include full system integration or to function as a low-commitment trial. Managing these expectations required explicit communication of contractual boundaries and limitations, highlighting that RaaS covers the robot asset but not broader automation responsibilities (product-based, success with adoption barriers). Similar issues are visible in Kaer's Cooling-as-a-Service, where customers must clearly understand which aspects of cooling performance, energy efficiency, and operational responsibility are included in the contract and which remain under customer control. The success of the model depends on continuous clarification of these boundaries throughout the customer relationship (product-based, success). In **service-based** XaaS configurations, expectation management tends to concern the role of the service relative to existing activities. Turboden's performance-based monitoring services illustrate how customers may initially overestimate the degree of operational intervention implied by monitoring and analytics, requiring careful framing of the service as a decision-support and optimization tool rather than a full operational takeover (service-based, success). Failure evidence suggests that inadequate expectation management can exacerbate other challenges. In Prima

Industrie's unsuccessful product-based experimentation, ambiguity regarding the scope of pay-per-use and the extent of provider responsibility contributed to internal uncertainty and limited customer understanding, reducing the legitimacy and scalability of the offering (product-based, failure). Overall, the empirical findings indicate that expectation management is a distinct and critical challenge in XaaS adoption: clear articulation of scope and responsibilities functions as a prerequisite for trust, risk alignment, and long-term viability, especially in product-based models where responsibility transfer is most pronounced.

- **Customer-side data immaturity**

Customer-side data immaturity emerges from the empirical analysis as a significant challenge that is only marginally addressed in the existing literature, yet it plays a critical role in shaping the feasibility and scalability of XaaS models. The cases show that even when providers possess advanced digital and analytical capabilities, the effectiveness of XaaS offerings is often constrained by customers' limited ability to generate, structure, and use operational data. In **product-based** XaaS configurations, customer-side data immaturity directly affects the provider's capacity to monitor performance, price outcomes, and manage risk. CGT's pay-per-performance "euro-per-ton" model provides a clear illustration: many customers lacked systematic measurement of production volumes and process parameters, which are essential inputs for output-based pricing. To enable the model, CGT frequently had to deploy its own sensors and data collection systems, effectively compensating for customer-side deficiencies. While this approach supported adoption and contributed to successful implementations, it also increased provider responsibility and upfront investment (product-based, success with increased exposure). Similar dynamics are observed in SEW-Eurodrive's predictive maintenance services, where heterogeneous customer infrastructures and limited data standardization complicate data integration and delay the realization of value (product-based, success). In **service-based** XaaS models, customer-side data immaturity primarily limits the depth and sophistication of analytics rather than the basic feasibility of the offering. Turboden's monitoring services illustrate how variability in customers' digital maturity constrains the level of performance analysis that can be delivered, requiring simplified dashboards or additional manual interpretation in less mature contexts (service-based, success). In regulated environments such as W&H's compliance services, data immaturity is partially mitigated by institutional requirements that standardize documentation practices, thereby facilitating service delivery (service-based, success). Failure evidence reinforces the relevance of this challenge. Prima Industrie's unsuccessful product-based experimentation suggests that limited availability of reliable performance data reduced the firm's ability to quantify value, price risk, and justify outcome-oriented contracts, weakening the economic rationale of pay-

per-use models (product-based, failure). Overall, the empirical findings indicate that customer-side data immaturity is a structural constraint on XaaS adoption. While providers can partially compensate through technology and service design, doing so shifts additional responsibility and risk onto the provider, particularly in product-based configurations where data underpins contractual viability.

- **Standardization–flexibility trade-off at scale**

The standardization–flexibility trade-off at scale emerges from the empirical analysis as a critical challenge that becomes particularly salient once XaaS offerings move beyond pilot implementations and are scaled across customers, applications, or geographies. While the literature often addresses standardization and customization as a generic design tension, the empirical evidence shows that, in XaaS contexts, this trade-off directly affects operational efficiency, risk exposure, and scalability. In **product-based** XaaS configurations, standardization is a key enabler of economic sustainability, as it allows providers to reuse assets, streamline service processes, and manage lifecycle risk. ABB Robotics' Robot-as-a-Service illustrates how deliberate standardization supports scalability: by limiting the offering to a defined set of robot models and excluding highly customized integrations, ABB preserves asset reusability and reduces variability in service delivery, enabling controlled scaling of the model (product-based, success). Similar dynamics are visible in KUKA's robot rental with integrated services, where standardized rental fleets and service routines support operational efficiency, while application-specific adaptations must be carefully bounded to avoid eroding margins (product-based, success). STULZ and Cavanna further confirm this pattern in temporary equipment rental contexts, where modular and standardized configurations are essential for rapid deployment and redeployment across customers (product-based, success). In **service-based** XaaS models, the trade-off tends to manifest in the digital and analytical layers rather than in physical assets. Turboden's performance-based monitoring services show how high levels of plant customization increase the effort required to standardize data models, dashboards, and analytics routines. While flexibility is necessary to accommodate heterogeneous customer configurations, excessive customization limits scalability and increases service delivery costs, even when the underlying service logic is well defined (service-based, success). Evidence from **unsuccessful** or constrained initiatives suggests that failure to manage this trade-off can undermine XaaS viability. Prima Industrie's difficulties in scaling product-based experimentation are consistent with limited standardization of offerings and processes, which constrained the firm's ability to price risk and replicate solutions across customers (product-based, failure). Overall, the empirical findings indicate that effective XaaS adoption requires explicit boundary setting: standardization must be enforced where it underpins

scalability and risk control, while flexibility should be selectively allowed to ensure customer fit without compromising economic sustainability.

- **Process invasiveness and loss of customer autonomy**

Process invasiveness and the perceived loss of customer autonomy emerge from the empirical analysis as a distinct challenge, particularly relevant for XaaS models that are outcome-oriented and require deep integration with customer operations. While this issue is only marginally addressed in the literature, the cases show that the degree to which XaaS offerings intervene in customers' processes can significantly influence acceptance, trust, and long-term sustainability. In **product-based** XaaS configurations, this challenge is especially salient because providers often need access to operational data and decision rights to guarantee performance or availability. CGT's pay-per-performance "euro-per-ton" model illustrates this dynamic clearly: in order to ensure productivity outcomes, the provider requires detailed visibility into customer production processes and, in some cases, the ability to influence operational choices such as machine utilization or configuration. Although this level of involvement enables efficiency gains and supports the economic logic of the model, it can also be perceived by customers as intrusive, making adoption more likely in contexts characterized by long-standing relationships and high levels of trust (product-based, success with boundary conditions). Similar concerns are visible in ABB Robotics' Robot-as-a-Service, where customers may perceive outcome-oriented contracts as constraining their freedom to modify processes or redeploy assets without provider involvement, reinforcing the need for clear contractual boundaries (product-based, success). In **service-based** XaaS models, process invasiveness is generally lower, but not absent. Turboden's performance-based monitoring services show that even advisory or monitoring-oriented offerings can raise concerns when they require continuous data access or generate recommendations that implicitly challenge established operational practices. In such cases, providers must carefully frame their role as supportive rather than prescriptive, maintaining customer autonomy while delivering value (service-based, success). Failure evidence suggests that unmanaged perceptions of invasiveness can exacerbate resistance to XaaS. Prima Industrie's unsuccessful product-based experimentation is consistent with this pattern: customers' reluctance to cede control over machine usage and decision-making contributed to the limited acceptance of pay-per-use models (product-based, failure). Overall, the empirical findings indicate that process invasiveness and loss of autonomy represent a critical adoption barrier, particularly in product-based XaaS. Successful implementations balance the need for operational involvement with mechanisms that preserve customer decision rights and reinforce trust.

- **Component-level XaaS complexity**

Component-level XaaS complexity emerges from the empirical analysis as a challenge that is not systematically addressed in the literature, yet it becomes salient when XaaS models target subsystems or components rather than a full integrated solution. The cases suggest that "partial" XaaS configurations introduce additional boundary-setting difficulties, as responsibilities, interfaces, and risks are distributed across the provider, the customer, and often third-party integrators. In **product-based** configurations, ABB Robotics' Robot-as-a-Service provides a clear illustration of this complexity. ABB deliberately focuses the offering on the robot asset while excluding full cell integration and broader automation responsibilities. While this boundary choice supports scalability and risk control, it also increases the need to coordinate interfaces between the robot, the customer's production system, and external integrators. In practice, customers may struggle to understand the division of responsibilities, and expectation misalignment can emerge when the "as-a-service" logic is interpreted as covering the entire automation solution (product-based, success with boundary-management requirements). A related form of component-level complexity is evident in Henkelhausen's Engine-as-a-Service (service-based, success), where the engine is provided as a service while the customer retains ownership of the broader vehicle or equipment. This creates distinctive challenges in defining liability, performance responsibility, and contractual boundaries—particularly in cases where failures may be caused by interactions between the engine and the surrounding system. Even when the model is successful, these interface dependencies increase contractual and operational complexity compared to full-solution XaaS configurations. Failure evidence further underscores the relevance of this issue. Prima Industrie's unsuccessful experimentation with product-based pay-per-use models suggests that when responsibility boundaries are unclear and the provider cannot control all determinants of performance, the economic and contractual viability of partial XaaS configurations weakens (product-based, failure). Overall, the empirical findings indicate that component-level XaaS increases the importance of interface governance: successful adoption requires explicit boundary setting, clear accountability for performance determinants, and coordination mechanisms across multiple actors involved in the broader system.

- **Dependence on OEM-owned data infrastructures**

Dependence on OEM-owned data infrastructures emerges from the empirical analysis as a relevant challenge that is only partially addressed in the literature, particularly in XaaS models where data access and analytics are central to value creation. The cases show that while provider-owned platforms and digital infrastructures enable service scalability and performance control, they can also create asymmetries in power, lock-in risks, and concerns over data governance. In **service-based**

XaaS configurations, OEM-owned data infrastructures often function as enabling platforms for monitoring, analytics, and compliance. Turboden's performance-based monitoring services rely on proprietary digital architectures to collect and process operational data from ORC plants. While this infrastructure enables consistent service delivery and advanced analytics, customer concerns regarding cybersecurity, data ownership, and access rights required architectural adaptations and negotiated governance arrangements (service-based, success). A similar dynamic is visible in W&H's digital monitoring and compliance services, where centralized platforms ensure traceability and regulatory compliance, but also position the provider as the primary data intermediary in the customer relationship (service-based, success). In **product-based** XaaS models, dependence on OEM-owned data infrastructures is even more consequential, as data directly underpin contractual commitments related to availability or performance. Kaer's Cooling-as-a-Service illustrates how provider-owned platforms are essential for managing provider-owned assets and ensuring contractual performance over time. However, this centralization increases customer dependence on the provider's digital ecosystem, reinforcing concerns about long-term lock-in and reduced autonomy (product-based, success with structural dependency). SEW-Eurodrive's predictive maintenance services similarly rely on OEM-controlled data environments, with customer resistance to cloud-based solutions highlighting the sensitivity of data governance and control issues (product-based, success). Failure evidence suggests that unresolved concerns over data control can constrain more radical XaaS adoption. Prima Industrie's unsuccessful product-based experimentation is consistent with this pattern, as limited customer trust in data-sharing arrangements and platform dependence reduced acceptance and hindered scalability (product-based, failure). Overall, the empirical findings indicate that dependence on OEM-owned data infrastructures represents a structural trade-off in XaaS adoption: while centralized platforms are critical enablers of service performance and scalability, they also raise governance and autonomy concerns that must be actively managed through transparency, contractual safeguards, and architectural choices.

6.1.3 Integrated view of XaaS challenges

The Table 25 reports all 19 units of analysis included in the multiple case study. Several firms contribute more than one unit of analysis, reflecting the coexistence of different XaaS offerings within the same organization. Unsuccessful product-based initiatives are reported separately and marked with X.

Challenge	TUR-S	TOY-P	TOY-S	KAE-P	KUK-P	KUK-S	PRI-S	PRI-PX	ABB-P	WH-S	WH-PX	SEW-P	CGT-P	STU-P1	STU-P2	SAN-S	SAN-P	CAV-P	HEN-S
Shift from product- to service-centric logic	X	X	X	X	X	–	–	X	X	–	X	X	X	X	X	–	X	X	X
Development of a service-oriented culture	X	X	X	X	X	X	–	X	X	X	X	X	X	X	X	X	X	X	X
Strategic clarity on value creation & positioning	X	X	X	X	X	X	–	X	X	X	X	X	X	X	X	X	X	X	X
Organizational readiness & cross-functional integration	X	X	X	X	X	X	–	X	X	X	X	X	X	X	X	X	X	X	X
Redefinition of roles, responsibilities & governance	X	X	X	X	X	X	–	X	X	X	X	X	X	X	X	X	X	X	X
Capability & skill development	X	X	X	X	X	X	–	X	X	X	X	X	X	X	X	X	X	X	X
Digital & technological infrastructure availability	X	X	X	X	X	X	–	X	X	X	X	X	X	X	X	X	X	X	X
Data collection, management & analytics	X	X	X	X	X	X	–	X	X	X	X	X	X	X	X	X	X	X	X
Pricing & revenue model definition	X	X	X	X	X	–	–	X	X	–	X	X	X	X	X	X	X	X	X
Contractual complexity & risk allocation	X	X	X	X	X	–	–	X	X	–	X	X	X	X	X	X	X	X	X

Challenge	TUR-S	TOY-P	TOY-S	KAE-P	KUK-P	KUK-S	PRI-S	PRI-PX	ABB-P	WH-S	WH-PX	SEW-P	CGT-P	STU-P1	STU-P2	SAN-S	SAN-P	CAV-P	HEN-S
Standardization–customization balance	X	X	X	X	X	X	–	X	X	X	X	X	X	X	X	X	X	X	X
Lifecycle responsibility & long-term risk	X	X	–	X	X	–	–	X	X	–	X	X	X	X	X	–	X	X	–
Customer acceptance of non-ownership	–	X	–	X	X	–	–	X	X	–	X	X	X	X	X	–	X	X	–
Customer data sharing & collaboration	X	X	X	X	X	X	–	X	X	X	X	X	X	X	X	X	X	X	X
Trust & relational governance	X	X	X	X	X	X	–	X	X	X	X	X	X	X	X	X	X	X	X
Ecosystem & partner alignment	X	X	X	X	X	X	–	X	X	X	X	X	X	X	X	X	X	X	X
Risk sharing & profit allocation	X	X	–	X	X	–	–	X	X	–	X	X	X	X	X	–	X	X	–
Market readiness & demand uncertainty	X	X	X	X	X	X	–	X	X	X	X	X	X	X	X	X	X	X	X
Regulatory & institutional constraints	–	–	–	–	–	–	–	–	–	X	X	–	–	–	–	–	–	–	X
Expectation management on scope*	X	X	X	X	X	X	–	X	X	X	X	X	X	X	X	X	X	X	X
Customer-side data immaturity*	X	X	X	X	X	X	–	X	X	X	X	X	X	X	X	X	X	X	X
Standardization–flexibility at scale*	X	X	X	X	X	X	–	X	X	X	X	X	X	X	X	X	X	X	X

Challenge	TUR-S	TOY-P	TOY-S	KAE-P	KUK-P	KUK-S	PRI-S	PRI-PX	ABB-P	WH-S	WH-PX	SEW-P	CGT-P	STU-P1	STU-P2	SAN-S	SAN-P	CAV-P	HEN-S
Process invasiveness & autonomy loss*	–	X	–	X	X	–	–	X	X	–	X	X	X	X	X	–	X	X	–
Component-level XaaS complexity*	–	–	–	–	X	–	–	X	X	–	X	–	–	–	–	–	X	–	X
Dependence on OEM-owned data infrastructures*	X	X	X	X	X	X	–	X	X	X	X	X	X	X	X	X	X	X	X

Table 25 Presence of challenges across the empirical units of analysis

Note: Abbreviations indicate the units of analysis. TUR-S = Turboden – Monitoring and performance-based service (service-based); TOY-P = Toyota Material Handling – Material handling equipment rental with integrated lifecycle services (product-based); TOY-S = Toyota Material Handling – Training-as-a-Service and Diagnostic-as-a-Service (service-based); KAE-P = Kaer – Cooling-as-a-Service (product-based); KUK-P = KUKA Robotics – Industrial robots rental with integrated services (product-based); KUK-S = KUKA Robotics – Maintenance and availability services for customer-owned robots (service-based); PRI-S = Prima Industrie – Maintenance and lifecycle service contracts for machine tools (service-based); PRI-P✗ = Prima Industrie – Product-based XaaS offering (unsuccessful); ABB-P = ABB Robotics – Robot-as-a-Service (product-based); WH-S = W&H – Digital monitoring and compliance services for medical equipment (service-based); WH-P✗ = W&H – Product-based XaaS offering (unsuccessful); SEW-P = SEW-Eurodrive – Predictive maintenance and installed-base management as-a-service (product-based); CGT-P = CGT – Pay-per-performance equipment-as-a-service (euro-per-ton model, product-based); STU-P1 = STULZ – Precision cooling equipment rental for temporary and transitional applications (product-based); STU-P2 = STULZ – Cooling-as-a-Service with provider-owned systems and availability-based delivery (product-based); SAN-S = Sandvik Coromant – Pay-on-withdrawal cutting tools solution (service-based); SAN-P = Sandvik Coromant – Pay-per-part cutting tools solution (product-based); CAV-P = Cavanna – Packaging machinery rental for temporary production needs (product-based); HEN-S = Henkelhausen – Engine-as-a-Service (service-based). Unsuccessful initiatives are marked with ✗.

The comparative analysis summarized in Table 25 reveals a set of recurring patterns that cut across the empirical units of analysis and help to explain differences in XaaS implementation outcomes. First, the table highlights a clear distinction between **product-based** and **service-based** XaaS configurations in terms of the breadth and intensity of challenges encountered. Product-based offerings systematically exhibit a higher concentration of internal challenges, particularly those related to strategic clarity, pricing, contractual complexity, lifecycle risk, and standardization, reflecting the greater financial exposure and long-term responsibility assumed by providers. Service-based offerings, by contrast, tend to face a more limited and focused set of challenges, primarily related to data management, customer collaboration, and capability development, consistent with their lower degree of asset-related risk. Second, the comparison between **successful and unsuccessful initiatives** suggests that failure is rarely associated with the presence of a single dominant challenge. Rather, unsuccessful product-based attempts are characterized by the **simultaneous accumulation of multiple unresolved challenges**, especially at the strategic, organizational, and contractual levels. In these cases, the absence of clear positioning, inadequate risk allocation mechanisms, and limited organizational readiness appear to reinforce one another, ultimately undermining the scalability and economic sustainability of the offering. Conversely, successful cases do not imply the absence of challenges, but rather the presence of organizational and managerial responses that prevent such challenges from escalating into structural barriers. Third, the table shows that several challenges marked as emerging, such as expectation management on scope and responsibilities, customer-side data immaturity, process invasiveness, and dependence on OEM-owned data infrastructures, are **highly recurrent across the empirical cases**, despite being only marginally addressed in the literature. These challenges cut across both product-based and service-based configurations, but become particularly critical in more advanced and outcome-oriented XaaS models, where deeper customer integration and data dependence are required. Their systematic presence suggests that they represent structural features of XaaS adoption in practice rather than idiosyncratic case-specific issues. Taken together, these patterns indicate that XaaS success cannot be explained solely by the type of offering or by technological maturity, but depends on how firms **anticipate, prioritize, and manage interrelated challenges** throughout the adoption process. This observation provides the foundation for the subsequent analysis of best practices, which shifts the focus from *what challenges firms face* to *how successful adopters address them in practice*, thereby identifying recurrent organizational, strategic, and governance mechanisms that enable effective and sustainable XaaS implementation.

To strengthen the analytical connection between challenges and managerial responses,

Table *26* provides a consolidated mapping between the main challenge categories identified in the literature and empirical analysis and the corresponding best practices discussed in the following section. Rather than representing isolated managerial recommendations, these practices emerge as organizational and strategic mechanisms aimed at mitigating specific implementation barriers related to cultural transformation, ecosystem coordination, contractual governance, capability development, and lifecycle risk management. This mapping highlights the interdependence between challenges and responses and reinforces the interpretation of XaaS adoption as a systemic and multidimensional transformation process.

Challenge macro-category	Main implementation challenges	Corresponding best practices
Cultural and strategic challenges	Resistance to service-oriented logic; lack of strategic clarity; limited leadership alignment	Define a clear and controllable XaaS value proposition; progressively develop a service-oriented culture; align leadership and incentives around long-term service objectives
Organizational and structural challenges	Fragmented governance; limited cross-functional integration; tensions between scalability and customization	Establish dedicated governance structures; promote cross-functional coordination; balance standardization and flexibility through modular service architectures
Capability and knowledge-related challenges	Lack of digital, analytical, contractual, and lifecycle management capabilities	Develop hybrid product–service capabilities; invest in analytics and lifecycle management competences; adopt pilot-based and learning-by-doing approaches
Product, data, and technology-related challenges	Data accessibility and quality issues; monitoring complexity; limited customer data maturity; dependence on digital infrastructures	Build scalable digital infrastructures; implement robust data governance mechanisms; standardize monitoring and analytics processes; support customer-side digital maturity
Contractual and responsibility-related challenges	Pricing uncertainty; lifecycle responsibility exposure; contractual complexity; risk allocation issues	Adopt transparent contractual structures; implement outcome-oriented pricing mechanisms; define clear responsibility allocation and risk-sharing mechanisms
Relational and ecosystem challenges	Customer resistance to non-ownership models; trust issues; ecosystem misalignment; coordination difficulties across actors	Develop trust-based relationships; proactively manage customer expectations; orchestrate ecosystem relationships; align incentives and governance mechanisms across partners
Market and competitive environment challenges	Market uncertainty; unstable demand; competitive pressure; limited market readiness	Start from scalable and economically viable XaaS configurations; target customer segments with clear value potential; progressively expand service scope and ecosystem complexity

Table 26 Mapping between XaaS challenges and corresponding best practices

6.2 Best practices for effective XaaS implementation

Building on the integrated analysis of challenges, risk exposure, and benefits associated with as-a-Service adoption, this chapter focuses on the identification of **best practices** that enable manufacturing firms to implement XaaS models effectively and sustainably. While the previous chapter examined *what* challenges firms face and *why* XaaS adoption is pursued despite such challenges, the present chapter shifts the analytical focus to *how* successful firms address these challenges in practice. In this study, best practices are not conceived as universal prescriptions or standardized solutions. Rather, they are defined as **recurrent managerial, organizational, and strategic configurations** observed across successful XaaS implementations and systematically absent or weak in unsuccessful initiatives. As such, best practices emerge from empirical evidence as context-sensitive mechanisms that help firms manage the inherent complexity of XaaS, balance risk and value creation, and translate the expected benefits of as-a-service models into sustainable outcomes over time. The identification of best practices is grounded in the multiple case study analysis presented in the previous chapters. Specifically, best practices were derived through a comparative examination of successful and unsuccessful XaaS initiatives, as well as through the analysis of differences between product-based and service-based configurations. This process involved triangulating the challenges encountered by firms, the organizational and strategic responses adopted, and the resulting implementation outcomes. Practices were considered "best" when they (i) recurred across multiple successful cases, (ii) contributed to mitigating multiple interrelated challenges, and (iii) were not systematically present in cases where XaaS initiatives failed to scale or were discontinued. To ensure conceptual coherence and analytical consistency, best practices are structured according to the **eight dimensions of the XaaS framework** developed in this research: value proposition, customers, ecosystem, resources, economic and financial model, organizational structure and culture, capabilities, and environmental sustainability. These dimensions, previously employed to analyze and compare XaaS adoption patterns across cases, are here reinterpreted in a **prescriptive perspective**, highlighting how specific configurations along each dimension support effective XaaS implementation. For each dimension, the chapter discusses the main best practices emerging from the empirical evidence, illustrates them through examples from the analyzed cases, and synthesizes them in a dedicated table. While best practices are presented by dimension for analytical clarity, the empirical findings suggest that their effectiveness depends on their **mutual consistency across dimensions**. In this sense, successful XaaS implementation does not rely on isolated practices, but on coherent configurations that align strategic intent, organizational capabilities, ecosystem relationships, and economic mechanisms. By articulating best practices along the dimensions of the framework, this chapter contributes to transforming the XaaS framework from

an analytical tool into a **managerial guide** for manufacturing firms considering or pursuing XaaS adoption. In doing so, it provides actionable insights that bridge theory and practice and lays the foundation for future research on the design and governance of as-a-service business models in industrial contexts.

- **Best practices related to the value proposition**

The empirical analysis shows that effective XaaS implementation is strongly contingent upon how firms define, scope, and communicate their **value proposition**. Across the analyzed cases, successful XaaS initiatives are characterized by a deliberate and disciplined articulation of what is offered through the as-a-service model, which benefits are guaranteed, and which responsibilities remain outside the scope of the offering. In this respect, best practices related to the value proposition play a foundational role, as they shape customer expectations, internal alignment, and the overall feasibility of the XaaS model. A first best practice concerns the **clear scoping and boundary definition of the XaaS offering**. Successful cases consistently avoid overly broad or ambiguous value propositions and instead define XaaS in relation to a limited and controllable set of outcomes. This practice is particularly evident in product-based configurations, where the provider assumes ownership and lifecycle responsibility. ABB Robotics' Robot-as-a-Service exemplifies this approach: the company deliberately restricts the scope of its RaaS offering to standardized robotic assets, explicitly excluding highly customized system integration and complex applications. By doing so, ABB aligns the promised value with its ability to manage technical and financial risks, enabling scalability while preserving economic sustainability. Conversely, the unsuccessful product-based experimentation observed at Prima Industrie illustrates the consequences of insufficient scoping, where outcome-oriented models were explored without a clearly articulated boundary between traditional product sales and XaaS, generating confusion for both internal stakeholders and customers. A second best practice relates to the **shift from asset-centric to outcome-oriented value propositions**, while maintaining a strong link between promised outcomes and controllable performance drivers. Across successful cases, XaaS value propositions are framed around availability, performance, or productivity rather than around the physical asset itself. Kaer's Cooling-as-a-Service represents a paradigmatic example: the company explicitly positions its offering around guaranteed cooling performance and sustainability outcomes, rather than around cooling equipment. This reframing enables customers to externalize technical complexity and focus on operational outcomes, while legitimizing Kaer's role as asset owner and long-term service provider. Importantly, this outcome orientation is not abstract, but grounded in measurable and contractually enforceable indicators, which supports trust and economic viability. Similar logics are observed in CGT's "euro-per-ton"

model, where the value proposition is anchored to customer output rather than to machine availability, reinforcing alignment between value creation and customer business objectives. A third best practice concerns the **progressive and modular articulation of the value proposition**, particularly in contexts characterized by customer uncertainty or resistance to non-ownership models. Several successful cases adopt a gradual approach, introducing XaaS as an extension or evolution of existing offerings rather than as a disruptive replacement. Service-based configurations frequently leverage this strategy. Turboden's monitoring- and performance-based services are positioned as enablers of operational optimization and risk reduction, complementing rather than substituting core engineering activities. This modular framing reduces customer resistance, facilitates internal acceptance, and allows the firm to incrementally expand the scope of its XaaS offering as trust and capabilities mature. By contrast, attempts to introduce fully outcome-based or pay-per-use models without such gradual framing tend to face stronger resistance, particularly in product-based settings. Finally, successful cases demonstrate the importance of **aligning the value proposition with the economic logic of both provider and customer**. XaaS offerings that clearly articulate how value is created and shared over time are more likely to achieve internal legitimacy and market acceptance. Toyota Material Handling's service-based Training-as-a-Service and Diagnostic-as-a-Service offerings illustrate this alignment: these solutions are positioned not primarily as revenue-generating innovations, but as mechanisms to improve service quality, standardize competencies, and protect the brand across the dealer network. This strategic positioning clarifies the value logic for all stakeholders and supports long-term adoption. Overall, the empirical evidence suggests that best practices related to the value proposition are not about maximizing the scope or ambition of XaaS offerings, but about **designing focused, outcome-oriented, and credible value promises**. By clearly defining boundaries, grounding outcomes in controllable performance drivers, and progressively articulating the offering, firms are better able to manage customer expectations, mitigate risk exposure, and create the conditions for sustainable XaaS implementation. Based on the empirical evidence discussed above, Table 27 provides a synthesis of the best practices related to the Value Proposition dimension

.Best practice	Main challenges addressed
Clear scoping and boundary definition of the XaaS offering	Lack of strategic clarity; lifecycle risk exposure; pricing and contractual complexity
Outcome-oriented value proposition grounded in controllable performance drivers	Shift from product-centric to service-centric logic; customer acceptance; risk allocation
Progressive and modular articulation of the XaaS value proposition	Customer resistance to non-ownership; expectation management; scalability constraints
Alignment between value proposition and economic logic of provider and customer	Internal misalignment; value capture uncertainty; organizational legitimacy of XaaS

Table 27 Best practices related to value proposition dimension

- **Best practices related to customers**

The empirical evidence highlights that customer-related practices play a critical role in enabling XaaS adoption, as the success of as-a-service models ultimately depends on customers' willingness to accept new logics of ownership, risk sharing, and interaction over time. Across the analyzed cases, successful XaaS implementations are characterized by deliberate practices aimed at managing customer expectations, reducing adoption barriers, and fostering trust-based, long-term relationships. A first best practice concerns **customer education and expectation management regarding the XaaS logic**. Successful firms invest significant effort in explaining the rationale, scope, and implications of XaaS offerings, particularly in terms of non-ownership, pricing mechanisms, and provider responsibilities. This practice is especially relevant in product-based configurations, where customers are required to relinquish ownership of critical assets. ABB Robotics' Robot-as-a-Service illustrates how extensive customer engagement and consultative selling are used to clarify that the value of RaaS lies not in asset possession, but in flexibility, risk reduction, and predictable costs. Similarly, CGT's pay-per-performance model requires customers to understand and accept a shift from purchasing equipment to paying for output, which is facilitated through transparent communication of performance metrics and contractual conditions. By contrast, unsuccessful initiatives, such as Prima Industrie's product-based experimentation, show that insufficient clarification of the XaaS logic can generate skepticism and hinder adoption. A second best practice relates to the **progressive involvement of customers through pilots, trials, or limited-scope offerings**. Rather than requiring full commitment upfront, successful firms often introduce XaaS through incremental steps that allow customers to experience the model and build confidence over time. This approach is evident in both product-based and service-based configurations. In service-based offerings, Turboden's monitoring and performance services are initially positioned as decision-support tools, enabling customers to perceive tangible value before deeper contractual commitments are established. In product-based contexts, rental and pay-per-use models adopted by firms such as STULZ and Cavanna serve as transitional arrangements that lower entry barriers and facilitate learning on both sides. This gradual engagement reduces perceived risk and supports long-term relationship building. A third best practice concerns the **management of customer autonomy and process invasiveness**. XaaS models often require deeper integration into customer operations, including access to data, process standardization, and coordination of maintenance activities. Successful cases demonstrate sensitivity to these issues, carefully balancing provider involvement with customer control. Toyota Material Handling's service-based Training-as-a-Service and

Diagnostic-as-a-Service offerings exemplify this approach: while Toyota defines standardized service processes to ensure quality and brand consistency, it also allows sufficient flexibility to accommodate heterogeneous dealer and customer contexts. This balance helps mitigate resistance related to perceived loss of autonomy and facilitates acceptance of service-based XaaS solutions. Finally, successful cases emphasize the importance of **building trust-based, long-term customer relationships** as a foundation for XaaS adoption. Trust is reinforced through transparency in performance measurement, clear contractual arrangements, and consistent service delivery. In outcome-oriented models, such as Kaer's Cooling-as-a-Service, trust is further strengthened by the provider's willingness to assume operational and financial responsibility over extended time horizons. The empirical evidence suggests that trust is not merely a relational outcome, but a prerequisite for effective XaaS implementation, particularly in configurations where customers depend heavily on provider performance. Overall, the analysis indicates that best practices related to customers focus on **reducing cognitive, organizational, and relational barriers** to XaaS adoption. Through education, progressive engagement, careful management of process integration, and trust-building mechanisms, successful firms are able to align customer expectations with the logic of XaaS and create the relational conditions necessary for sustainable as-a-service models. The main best practices related to the Customers dimension are summarized in Table 28.

Best practice	Main challenges addressed
Customer education and expectation management regarding XaaS logic	Customer resistance to non-ownership; misunderstanding of value proposition; adoption barriers
Progressive customer involvement through pilots and limited-scope offerings	Risk aversion; uncertainty about performance; scalability constraints
Careful management of customer autonomy and process invasiveness	Resistance to operational integration; data sharing reluctance; loss of control concerns
Trust-building through transparency and long-term relational orientation	Lack of trust; contractual complexity; dependency concerns

Table 28 Best practices related to the customer dimension

- **Best practices related to the ecosystem**

The empirical analysis shows that the configuration and governance of the **ecosystem** represent a critical determinant of XaaS implementation effectiveness. Because XaaS models extend responsibility beyond the focal firm and redistribute risk, resources, and decision rights across multiple actors, successful adoption depends on how firms orchestrate relationships with partners, customers, and complementary service providers. Across the analyzed cases, best practices related to the ecosystem focus on clarifying roles, aligning incentives, and enabling coordinated value creation over extended time horizons. A first best practice concerns the **explicit definition of roles and responsibilities across the ecosystem**. Successful XaaS initiatives are characterized by a clear

allocation of ownership, operational responsibility, and risk among the involved actors. This practice is particularly salient in product-based configurations, where providers retain asset ownership while relying on external partners for financing, installation, or local service delivery. ABB Robotics' Robot-as-a-Service illustrates how clearly delineating responsibilities, between ABB, system integrators, and financial partners, helps maintain control over performance while avoiding ambiguity that could undermine accountability. By contrast, empirical evidence from unsuccessful initiatives suggests that unclear role definition can amplify contractual complexity and increase coordination costs. A second best practice relates to the **use of ecosystem partnerships to share and mitigate risk**. Given the financial and operational exposure associated with XaaS, successful firms rarely operate in isolation. Instead, they leverage partnerships with financial institutions, service providers, and technology suppliers to distribute risk and enhance scalability. CGT's pay-per-performance model exemplifies this approach, as the company relies on strong relationships with its parent group and financial partners to sustain long-term asset ownership and performance guarantees. Similarly, Kaer's Cooling-as-a-Service model is supported by a carefully structured network of partners that enables the firm to manage capital intensity and operational complexity. These cases suggest that ecosystem configuration is not ancillary, but integral to the viability of XaaS models. A third best practice concerns **ecosystem orchestration and governance mechanisms**. Successful firms actively coordinate interactions among ecosystem actors rather than relying on loosely coupled or purely contractual relationships. Toyota Material Handling's service-based XaaS offerings provide a clear illustration: Toyota uses Training-as-a-Service and Diagnostic-as-a-Service not only to deliver value to customers, but also to align behaviors, competencies, and service standards across its dealer network. In this case, XaaS functions as a governance tool that enables the focal firm to steer a heterogeneous ecosystem toward shared objectives. This orchestration capability is particularly important in service-based configurations, where value creation depends on consistent execution across multiple touchpoints. Finally, the empirical evidence highlights the importance of **selective ecosystem complexity**. Successful XaaS implementations avoid overextending the ecosystem by involving only those partners that are essential for delivering the promised value. Overly complex ecosystems increase coordination costs, dilute accountability, and complicate contractual arrangements. In contrast, firms that carefully select partners based on strategic fit and capability complementarity are better able to maintain control and ensure service quality over time. Overall, best practices related to the ecosystem emphasize that XaaS adoption is inherently a **multi-actor endeavor**. Effective ecosystem design and governance enable firms to manage risk, scale offerings, and ensure consistent value delivery, thereby addressing several of the external challenges identified in the empirical analysis. These practices underscore the role of the focal firm not merely as a service

provider, but as an ecosystem orchestrator capable of aligning diverse actors around a shared XaaS value proposition. Table 29 summarizes the main best practices related to the Ecosystem dimension emerging from the empirical analysis.

Best practice	Main challenges addressed
Explicit definition of roles and responsibilities across the ecosystem	Contractual complexity; accountability ambiguity; coordination challenges
Risk-sharing through strategic partnerships	Financial exposure; lifecycle risk; scalability constraints
Active ecosystem orchestration and governance	Ecosystem misalignment; inconsistent service delivery; partner heterogeneity
Selective configuration of ecosystem partners	Excessive coordination costs; loss of control; operational complexity

Table 29 Best practices related to the Ecosystem dimension

- **Best practices related to organizational structure and culture**

The empirical analysis highlights that XaaS adoption requires not only strategic and contractual changes, but also a profound transformation of firms' **organizational structures and cultural orientations**. Because XaaS models challenge traditional product-centric logics, successful implementation depends on how firms realign internal governance, roles, incentives, and mindsets to support long-term, service-oriented value creation. Across the analyzed cases, best practices related to organizational structure and culture emerge as critical enablers of XaaS scalability and sustainability. A first best practice concerns the **establishment of dedicated governance structures for XaaS initiatives**. Successful firms avoid managing XaaS offerings through purely traditional product organizations and instead introduce dedicated teams, hybrid units, or cross-functional governance mechanisms. This practice is particularly evident in product-based configurations, where XaaS entails higher levels of financial exposure and operational responsibility. ABB Robotics' Robot-as-a-Service illustrates how the creation of dedicated roles and coordination mechanisms enables the firm to integrate sales, service, and financial perspectives, preventing misalignment between short-term commercial objectives and long-term contractual commitments. By contrast, unsuccessful product-based initiatives, such as those explored by Prima Industrie, reveal that treating XaaS as an extension of conventional product sales can lead to organizational friction and limited internal legitimacy. A second best practice relates to the **alignment of incentive systems with the logic of recurring revenues and long-term performance**. XaaS models challenge traditional performance metrics centered on unit sales and short-term margins. Successful firms adapt incentive structures to reward lifecycle performance, customer retention, and service quality. ABB Robotics' transition toward consultative selling in RaaS, as well as CGT's pay-per-performance model, demonstrates how revised KPIs and compensation schemes support cultural alignment and reduce

resistance within commercial teams. In the absence of such alignment, internal actors may prioritize short-term product sales over the long-term objectives of XaaS, undermining implementation. A third best practice concerns the **progressive development of a service-oriented culture**, rather than the imposition of abrupt cultural change. Empirical evidence suggests that cultural transformation is more effective when framed as an evolution of existing competencies and values. In service-based configurations, this often involves legitimizing digital, analytical, and service-related roles as core contributors to value creation. Turboden's monitoring- and performance-based services exemplify this dynamic: although the firm already possessed a service orientation, the successful scaling of XaaS required elevating data analytics and IT capabilities from support functions to strategic assets. This cultural shift was achieved gradually, through learning and internal legitimization, rather than through radical restructuring. A further best practice involves **top-management sponsorship and organizational commitment to XaaS**. Across successful cases, XaaS initiatives are explicitly supported by senior management, which plays a key role in resolving internal tensions, allocating resources, and signaling the strategic importance of the model. In contrast, empirical evidence from unsuccessful initiatives suggests that the absence of visible top-management commitment exacerbates organizational inertia and reinforces product-centric behaviors. Overall, best practices related to organizational structure and culture emphasize that XaaS implementation is not merely a technical or commercial challenge, but an organizational transformation process. Dedicated governance structures, aligned incentives, gradual cultural change, and strong leadership commitment collectively enable firms to internalize the logic of XaaS and to sustain long-term service-oriented value creation. Table 30 summarizes the main best practices related to the Organizational structure and culture dimension emerging from the empirical analysis.

Best practice	Main challenges addressed
Dedicated governance structures for XaaS initiatives	Organizational misalignment; role ambiguity; lack of internal legitimacy
Incentive systems aligned with recurring revenues and lifecycle performance	Short-term sales orientation; internal resistance; profitability uncertainty
Progressive development of a service-oriented culture	Cultural inertia; dominance of product-centric logic; resistance to change
Strong top-management sponsorship of XaaS initiatives	Lack of commitment; resource constraints; organizational inertia

Table 30 Best practices related to the Organizational structure and culture dimension

- **Best practices related to the economic and financial model**

The empirical analysis highlights that the configuration of the **economic and financial model** represents one of the most critical dimensions for the viability of XaaS offerings, particularly in

product-based configurations. Because XaaS models replace upfront revenues with long-term, usage- or outcome-based cash flows, successful implementation depends on how firms design pricing mechanisms, manage financial exposure, and align economic incentives with controllable performance drivers. A first best practice concerns the **adoption of outcome- or usage-based pricing mechanisms anchored to measurable and controllable variables**. Successful cases consistently avoid pricing schemes based on ambiguous or weakly controllable outcomes, instead linking revenues to indicators that can be reliably monitored and influenced by the provider. CGT's "euro-per-ton" model exemplifies this approach: pricing is directly tied to customer output, a metric that is transparent, measurable, and closely linked to equipment performance. Similarly, Kaer's Cooling-as-a-Service model bases revenues on guaranteed cooling performance, supported by continuous monitoring systems. These practices reduce disputes, enhance trust, and mitigate financial risk. In contrast, unsuccessful product-based initiatives reveal that poorly defined pricing metrics can exacerbate uncertainty and undermine profitability. A second best practice relates to the **financial structuring of long-term exposure and upfront investments**. Successful XaaS providers proactively address the capital intensity of product-based models by leveraging financial partnerships, internal risk buffers, or phased investment strategies. ABB Robotics' Robot-as-a-Service illustrates how collaboration with financial partners enables the firm to retain asset ownership while maintaining balance-sheet sustainability. Similarly, CGT benefits from strong financial backing within its corporate group, which supports long-term asset deployment and delayed revenue realization. These cases indicate that financial robustness and access to capital are not peripheral conditions, but core enablers of XaaS adoption. A third best practice concerns the **alignment between pricing logic, cost structure, and lifecycle responsibilities**. Successful firms explicitly account for maintenance, upgrades, downtime, and end-of-life costs when designing XaaS pricing models. This lifecycle-oriented perspective enables providers to internalize risks and to price services in a way that reflects total cost implications over time. Empirical evidence suggests that failures often occur when firms underestimate lifecycle costs or rely on overly optimistic utilization assumptions, as observed in some discontinued product-based experiments. Finally, the empirical analysis highlights the importance of **progressive economic experimentation and scalability testing**. Rather than committing immediately to large-scale XaaS deployment, successful firms often pilot pricing and revenue models on a limited scale, refining assumptions and contractual terms before scaling. Rental and pay-per-use models adopted by firms such as STULZ and Cavanna exemplify this cautious approach, allowing providers to learn about cost dynamics and customer behavior while containing financial risk. Overall, best practices related to the economic and financial model emphasize that XaaS viability depends on **financial discipline and transparency**, not merely on innovative pricing. By grounding

pricing mechanisms in controllable metrics, proactively managing capital intensity, and adopting a lifecycle-oriented cost perspective, firms are better equipped to balance risk and value creation in XaaS implementations. Table 31 summarizes the main best practices related to the Economic and financial model dimension emerging from the empirical analysis.

Best practice	Main challenges addressed
Outcome- or usage-based pricing anchored to controllable performance metrics	Pricing complexity; revenue uncertainty; contractual disputes
Financial structuring of long-term exposure through partnerships or buffers	Capital intensity; balance-sheet risk; scalability constraints
Lifecycle-oriented pricing and cost modeling	Underestimation of lifecycle costs; profitability risk
Progressive experimentation and scaling of pricing models	Financial uncertainty; risk of premature large-scale deployment

Table 31 Best practices related to the Economic and financial model dimension

- **Best practices related to resources**

The empirical analysis indicates that the configuration and control of **resources**, including physical assets, data, digital infrastructures, and financial resources, play a pivotal role in determining the feasibility and sustainability of XaaS models. Because XaaS shifts responsibility for performance and availability to the provider, successful implementation depends on how firms secure access to critical resources and retain sufficient control over them throughout the lifecycle of the offering. A first best practice concerns the **retention of control over critical physical assets in product-based XaaS configurations**. Successful cases consistently show that providers maintain ownership and decision rights over assets that are central to value creation and risk management. Kaer's Cooling-as-a-Service exemplifies this approach: by retaining ownership of cooling systems, Kaer can optimize design, maintenance, and operation in line with performance guarantees. Similarly, ABB Robotics' Robot-as-a-Service relies on provider-owned robotic assets to ensure availability and standardization. In contrast, empirical evidence from unsuccessful product-based initiatives suggests that partial or ambiguous asset control can undermine the provider's ability to manage lifecycle risks and deliver contracted outcomes. A second best practice relates to the **development and governance of data and digital infrastructures as strategic resources**. Across both product-based and service-based configurations, data emerge as a critical enabler of monitoring, optimization, and performance-based contracting. Successful firms invest in proprietary or tightly governed digital platforms that enable real-time data collection and analysis while safeguarding access and control. Turboden's monitoring and performance-based services illustrate how OEM-controlled data infrastructures support predictive insights and continuous improvement. The empirical evidence further suggests that dependence on customer-owned or fragmented data infrastructures increases vulnerability and limits

scalability, highlighting the importance of proactive data governance. A third best practice concerns the **selective allocation and protection of financial resources** to support long-term XaaS commitments. Product-based XaaS models, in particular, require sustained financial capacity to absorb upfront investments and delayed revenue streams. Successful firms explicitly allocate financial resources to XaaS initiatives and, where necessary, complement internal resources with external financing arrangements. CGT's pay-per-performance model and ABB's RaaS offering demonstrate how access to financial resources underpins the ability to retain asset ownership and manage lifecycle responsibilities over extended time horizons. Finally, the empirical analysis highlights the importance of **modularity and scalability in resource configuration**. Successful XaaS providers design assets, digital systems, and service processes in a modular manner, enabling reuse across customers and facilitating scalability. Rental-based models adopted by STULZ and Cavanna illustrate how standardized and modular assets reduce complexity and resource intensity, supporting both economic and operational sustainability. By contrast, highly customized resource configurations tend to increase cost variability and constrain scalability. Overall, best practices related to resources emphasize that XaaS success depends not only on access to resources, but on **strategic control, governance, and modular configuration** of those resources. By retaining control over critical assets and data, ensuring financial support for long-term commitments, and designing scalable resource architectures, firms are better positioned to manage risk and deliver consistent value through XaaS models. Table 31 summarizes the main best practices related to the Resources dimension emerging from the empirical analysis.

Best practice	Main challenges addressed
Retention of control over critical physical assets	Lifecycle risk exposure; performance uncertainty; accountability issues
Provider-led governance of data and digital infrastructures	Data dependency; limited scalability; monitoring and control challenges
Dedicated allocation of financial resources to XaaS initiatives	Capital intensity; delayed cash flows; financial sustainability
Modular and scalable configuration of assets and systems	Resource intensity; customization–standardization trade-offs; scalability constraints

Table 32 Best practices related to the Resources dimension

- **Best practices related to capabilities**

The empirical analysis highlights that the development and orchestration of **organizational capabilities** represent a central enabler of XaaS implementation across all configurations. While resources define what firms can deploy, capabilities determine how effectively such resources are combined, adapted, and leveraged over time. Successful XaaS adoption is therefore closely linked to firms' ability to build, integrate, and continuously evolve a set of technical, service-related, digital,

and managerial capabilities. A first best practice concerns the **development of hybrid capabilities that integrate product, service, and financial expertise**. Across the analyzed cases, successful XaaS providers move beyond functionally siloed competencies and foster cross-domain capabilities that enable lifecycle-oriented decision-making. This practice is particularly critical in product-based configurations, where pricing, maintenance, and risk management are tightly interdependent. ABB Robotics' Robot-as-a-Service illustrates how combining engineering expertise with service management and financial assessment capabilities supports informed decisions on asset deployment and contract design. In contrast, empirical evidence from unsuccessful initiatives suggests that capability fragmentation, where technical, commercial, and financial decisions are made in isolation, can undermine XaaS viability. A second best practice relates to the **development of data analytics and digital capabilities as core enablers of XaaS**. Successful cases consistently treat data collection, monitoring, and analytics not as support activities, but as strategic capabilities that underpin performance guarantees and continuous improvement. Turboden's monitoring- and performance-based services exemplify how advanced analytics capabilities enable predictive insights and operational optimization, reinforcing the credibility of outcome-oriented offerings. Similar dynamics are observed in Kaer's Cooling-as-a-Service, where data-driven control of system performance is essential for meeting contractual commitments. The absence or underdevelopment of such capabilities significantly constrains the scope and scalability of XaaS models. A third best practice concerns the **ability to learn and adapt through experimentation and feedback loops**. Successful XaaS providers adopt an iterative approach to capability development, leveraging pilots, early contracts, and customer feedback to refine service processes, pricing mechanisms, and technical solutions. Rental and pay-per-use models adopted by firms such as STULZ and Cavanna illustrate how experiential learning enables firms to progressively build operational and commercial capabilities while containing risk. This adaptive capability is particularly important in contexts characterized by uncertainty and novelty, where predefined routines are insufficient. A further best practice involves the **development of customer-facing and relational capabilities**. XaaS models require continuous interaction with customers over extended periods, demanding skills related to relationship management, problem-solving, and coordination. Toyota Material Handling's service-based Training-as-a-Service and Diagnostic-as-a-Service offerings highlight how relational and pedagogical capabilities support customer engagement and capability transfer across organizational boundaries. These capabilities are critical not only for value delivery, but also for sustaining trust and alignment over time. Overall, best practices related to capabilities emphasize that XaaS adoption is a **dynamic learning process** rather than a one-time transformation. By building hybrid, data-driven, adaptive, and relational capabilities, firms enhance their ability to manage complexity, respond to

uncertainty, and sustain performance-oriented service delivery. The empirical evidence suggests that capability development is both an antecedent and an outcome of successful XaaS implementation, reinforcing its central role in enabling long-term value creation. Table 33 summarizes the main best practices related to the Capabilities dimension emerging from the empirical analysis.

Best practice	Main challenges addressed
Development of hybrid product–service–financial capabilities	Capability fragmentation; lifecycle decision complexity; internal misalignment
Data analytics and digital capabilities as core XaaS enablers	Limited monitoring capability; performance uncertainty; scalability constraints
Iterative learning through experimentation and feedback	Uncertainty; lack of experience; premature scaling risks
Customer-facing and relational capability development	Trust building; customer engagement challenges; coordination complexity

Table 33 Best practices related to the Capabilities dimension

- **Best practices related to environmental sustainability**

The empirical analysis indicates that **environmental sustainability** emerges as an enabling and reinforcing dimension of XaaS implementation rather than as an isolated objective. While environmental benefits are often highlighted in the literature as an inherent promise of XaaS, the empirical evidence suggests that such benefits materialize only when sustainability considerations are intentionally embedded into the design, governance, and operation of XaaS offerings. Successful cases therefore adopt best practices that align environmental objectives with economic and operational incentives. A first best practice concerns the **design of XaaS offerings around lifecycle optimization**. Successful firms explicitly leverage provider ownership and long-term responsibility to improve durability, maintainability, and efficiency over the entire lifecycle of the solution. Kaer's Cooling-as-a-Service exemplifies this approach: by retaining ownership of cooling systems, the firm is incentivized to optimize energy efficiency, maintenance schedules, and system upgrades over time. This lifecycle-oriented design reduces resource consumption and supports environmental performance while simultaneously lowering operational costs, demonstrating the complementarity between sustainability and economic viability in product-based XaaS models. A second best practice relates to the **use of monitoring and data-driven control to improve resource and energy efficiency**. Across both product-based and service-based configurations, successful XaaS providers rely on continuous data collection and analytics to optimize system performance and minimize waste. Turboden's monitoring and performance-based services illustrate how real-time data enables the identification of inefficiencies and supports proactive interventions that improve both operational and environmental outcomes. This practice reinforces the role of digital capabilities as a bridge between XaaS value creation and sustainability objectives. A third best practice involves the **alignment of**

environmental and economic incentives through contractual mechanisms. Successful cases embed sustainability-related objectives into performance indicators, service levels, or outcome guarantees, ensuring that environmental improvements are not treated as externalities. In pay-per-performance and availability-based models, providers benefit economically from reducing energy consumption, downtime, and material wear, thereby internalizing environmental performance within the business model. Empirical evidence suggests that when such alignment is absent, environmental benefits remain aspirational and weakly realized. Finally, the empirical analysis highlights the importance of **positioning sustainability as a complementary value dimension rather than the sole driver of XaaS adoption**. While environmental benefits can reinforce customer acceptance and corporate legitimacy, successful firms avoid framing XaaS exclusively as a sustainability initiative. Instead, sustainability is integrated into broader value propositions centered on performance, reliability, and cost predictability. This positioning enhances credibility and avoids overreliance on environmental arguments that may not resonate equally across customer segments. Overall, best practices related to environmental sustainability emphasize that XaaS can support more sustainable industrial systems when environmental objectives are operationalized through lifecycle responsibility, data-driven optimization, and aligned economic incentives. Rather than emerging automatically, environmental benefits depend on deliberate design and governance choices, reinforcing the need for an integrated approach to XaaS implementation across all framework dimensions. Table 34 summarizes the main best practices related to the Environmental sustainability dimension emerging from the empirical analysis.

Best practice	Main challenges addressed
Lifecycle-oriented design enabled by provider ownership	Resource inefficiency; premature asset replacement; lifecycle cost uncertainty
Data-driven monitoring for resource and energy efficiency	Limited visibility on environmental performance; operational inefficiencies
Alignment of environmental and economic incentives through contracts	Weak realization of sustainability benefits; misaligned objectives
Integration of sustainability as a complementary value dimension	Limited customer acceptance; credibility risks

Table 34 Best practices related to the Environmental sustainability dimension

6.2.1 Synthesis of best practices and managerial implications

This chapter identified a set of best practices that enable manufacturing firms to implement XaaS models effectively while mitigating the challenges and risks discussed in the previous chapters. Based on a comparative analysis of successful and unsuccessful XaaS initiatives, the findings suggest that XaaS success does not depend on isolated decisions, but rather on the alignment of mutually reinforcing practices across multiple dimensions of the proposed framework.

By organising best practices along the eight framework dimensions (value proposition, customers, ecosystem, organisational structure and culture, economic and financial model, resources, capabilities, and environmental sustainability), the analysis highlights that XaaS implementation requires coordinated action across strategic, organisational, economic, and technological domains. Firms achieving more sustainable XaaS outcomes are those that align the scope of the value proposition with controllable outcomes, actively manage customer expectations, orchestrate ecosystem relationships, and support long-term service delivery through appropriate organisational structures, financial mechanisms, and capability development.

The findings also show that best practices are highly interdependent. For example, outcome-oriented value propositions require complementary pricing models, data governance mechanisms, and capabilities in analytics and lifecycle management. Similarly, ecosystem orchestration practices are closely connected to governance structures and financial arrangements. This reinforces the idea that XaaS adoption should be approached as a systemic organisational transformation rather than as a collection of isolated initiatives.

From a managerial perspective, the identified practices provide actionable guidance for firms pursuing XaaS adoption. Rather than prescribing a single optimal configuration, they offer empirically grounded principles that can be adapted to different industrial contexts and XaaS configurations. In this sense, the framework not only contributes to theory development, but also serves as a practical decision-support tool for managers navigating the transition toward as-a-service business models.

Table 35 provides a consolidated overview of the best practices identified across the eight framework dimensions. Overall, the synthesis suggests that successful XaaS implementation depends on the firm's ability to balance strategic alignment, organisational readiness, ecosystem coordination, and long-term value creation objectives within an integrated and adaptive business model.

Framework dimension	**Best practices**
Value proposition	Clear scoping and boundary definition of XaaS offerings; outcome-oriented value propositions grounded in controllable performance drivers; progressive and modular articulation of XaaS offerings; alignment between value proposition and economic logic
Customers	Customer education on XaaS logic and non-ownership models; progressive customer involvement through pilots and limited-scope offerings; careful management of customer autonomy and process invasiveness; trust-building through transparency and long-term relational orientation

Framework dimension	Best practices
Ecosystem	Explicit definition of roles and responsibilities across the ecosystem; risk-sharing through strategic partnerships; active ecosystem orchestration and governance; selective configuration of ecosystem partners
Organizational structure and culture	Dedicated governance structures for XaaS initiatives; incentive systems aligned with recurring revenues and lifecycle performance; progressive development of a service-oriented culture; strong top-management sponsorship
Economic and financial model	Outcome- or usage-based pricing anchored to controllable metrics; financial structuring of long-term exposure through partnerships or buffers; lifecycle-oriented pricing and cost modeling; progressive experimentation and scaling of pricing models
Resources	Retention of control over critical physical assets; provider-led governance of data and digital infrastructures; dedicated allocation of financial resources to XaaS initiatives; modular and scalable configuration of assets and systems
Capabilities	Development of hybrid product–service–financial capabilities; data analytics and digital capabilities as core XaaS enablers; iterative learning through experimentation and feedback; development of customer-facing and relational capabilities
Environmental sustainability	Lifecycle-oriented design enabled by provider ownership; data-driven monitoring for resource and energy efficiency; alignment of environmental and economic incentives through contracts; integration of sustainability as a complementary value dimension

Table 35 Overview of best practices across the XaaS framework dimensions

7 CHAPTER VII – XAAS AND ENVIRONMENTAL SUSTAINABILITY

7.1 Scope and approach

The relationship between X-as-a-Service (XaaS) business models and environmental sustainability remains only partially understood and empirically under-evidenced in the extant literature. Service-based and Product–Service System (PSS) configurations have long been associated with the potential to reduce environmental impacts by extending product lifetimes, intensifying asset utilization, or improving resource efficiency throughout the use phase (Mont, 2002; Baines et al., 2007; Tukker, 2004; Yang and Evans, 2019). Within this perspective, servitization has been frequently framed as a pathway to decouple economic value creation from material consumption and pollution by shifting the focus from ownership-based transactions toward performance- or outcome-oriented value propositions.

However, subsequent research has questioned the existence of a direct and inevitable connection between service-based business models and environmental sustainability outcomes. In particular, it has been highlighted that PSS adoption does not automatically lead to resource-efficient or environmentally superior solutions, and may instead generate unintended consequences such as rebound effects, burden shifting across lifecycle stages, or increased usage intensity depending on customer behavior and system configuration (Tukker, 2015; Kjaer et al., 2018; Guzzo et al., 2022). Moreover, service-based offerings do not necessarily achieve the decoupling of economic growth from resource consumption that is often theoretically attributed to them (Kjaer et al., 2019). Rather, environmental performance appears to be contingent upon the specific characteristics of the service offering and the alignment between business model configurations and sustainability-related lifecycle factors such as resource consumption, product lifetime, or emissions (Bocken et al., 2014; Kjaer et al., 2019; Roman et al., 2023).

Despite a growing number of conceptual and empirical studies addressing the environmental implications of PSS (Reim et al., 2015; Sousa-Zomer et al., 2018; Yang and Evans, 2019), existing contributions predominantly focus on the sustainability potential of service-based offerings rather than on actually achieved environmental outcomes (Ries et al., 2023). In practice, companies often develop PSS primarily to pursue business or operational objectives, while environmental benefits tend to emerge as indirect or additional effects rather than as explicitly designed performance targets (Matschewsky, 2019). This suggests that the realization of sustainability gains depends not merely on the adoption of service-based logic per se, but on how value creation, delivery, and value capture mechanisms are configured to activate lifecycle-oriented environmental improvement mechanisms.

Against this backdrop, this chapter investigates how XaaS adoption may influence environmental sustainability performance in manufacturing contexts, and how service-based business models can be designed and leveraged to achieve environmental improvements in practice. To this end, the analysis adopts the concept of Environmental Value Drivers (EVDs) as an analytical lens for examining the mechanisms through which service-based offerings may affect environmental performance across the product lifecycle. EVDs refer to lifecycle-related factors associated with sustainable development, such as resource efficiency, product lifetime extension, intensified usage, reuse and recycling, dematerialization, or pollution reduction, that enable organizations to integrate environmental considerations into their offerings and decision-making processes (Tukker, 2004; Hristov et al., 2021).

In this study, Environmental Value Drivers (EVDs) are conceptualized as lifecycle-level mechanisms that contribute to environmental improvement but cannot be directly observed at the firm level. Rather than representing environmental outcomes per se, EVDs describe the pathways through which service-based business model configurations may potentially influence environmental performance across different lifecycle stages. As such, the presence of EVDs within XaaS offerings can only be inferred indirectly through the implementation of lifecycle-oriented operational and contractual practices embedded in the business model configuration.

Methodologically, the chapter follows a multi-step approach combining insights from the literature on PSS environmental sustainability with evidence derived from the XaaS-focused literature review conducted in this study. First, environmental value drivers associated with service-based business models are identified and conceptualized based on prior research on PSS sustainability mechanisms. Second, the body of literature addressing XaaS in manufacturing is analyzed to assess which environmental value drivers are addressed in existing studies, whether and under which conditions XaaS adoption is associated with improved environmental sustainability compared to ownership-based models, and which factors enable or hinder the realization of such benefits. Third, the analysis is extended by examining a set of servitization-related services, identified from prior literature and observed within XaaS offerings, which are used as observable proxies to assess how different Environmental Value Drivers (EVDs) are reflected in the configuration of the XaaS business model. Finally, this conceptual linkage between XaaS services and environmental value drivers is used to inform the empirical investigation presented in the following sections. In particular, the analysis of the interviewed firms focuses on identifying which services are currently implemented within their XaaS offerings, and how such services may reflect the representation of specific environmental value drivers and, consequently, inform the potential environmental sustainability implications of the analyzed business models. This approach enables moving beyond normative expectations of

sustainability benefits towards a more practice-based understanding of how XaaS models can be configured to support environmental performance improvements in practice.

7.2 How PSS and XaaS enable environmental value drivers

In order to investigate how XaaS adoption may influence environmental sustainability performance, this chapter adopts the concept of Environmental Value Drivers (EVDs) as the primary analytical lens. EVDs refer to lifecycle-related mechanisms through which XaaS business models may affect environmental performance by reducing resource consumption, extending product lifetimes, or minimizing emissions and waste across different stages of the product lifecycle (Tukker, 2004; Hristov et al., 2021).

Prior research on Product–Service Systems (PSS) has identified a variety of mechanisms through which XaaS offerings can potentially generate environmental benefits, including impact reduction mechanisms (Tukker, 2004), sustainability tactics (Reim et al., 2015), resource reduction enablers (Kjaer et al., 2018), or sustainable value opportunities (Moro et al., 2022). Despite the conceptual similarities across these constructs, they are often vaguely defined or inconsistently operationalized across studies (Yang and Evans, 2019; Kjaer et al., 2018). Building on this stream of research, recent work has proposed to harmonize such concepts under the notion of Environmental Value Drivers, defined as factors that support the integration of environmental considerations into organizational offerings and decision-making processes, ultimately contributing to reduced lifecycle environmental impacts (Tukker, 2004; Hristov et al., 2021).

In line with the PSS sustainability literature, the following EVDs are identified as the primary mechanisms through which XaaS models may influence environmental performance (Saccani et al., 2024):

- **Resource efficiency during the usage phase:** represents one of the most widely discussed environmental mechanisms associated with PSS adoption. By shifting from ownership-based to XaaS value propositions, providers are incentivized to improve the operational efficiency of products in use, for instance through maintenance contracts, energy optimization services, or remote monitoring solutions that reduce resource consumption during operation (Lee et al., 2012; Bressanelli et al., 2018; Kjaer et al., 2018). For example, predictive maintenance services enabled by IoT-based monitoring can reduce energy losses or material waste by preventing performance degradation and inefficient operating conditions.
- **Lifetime extension:** it enables products to remain in use for longer periods, thereby potentially reducing the demand for new materials and slowing resource loops across the

lifecycle (Baines et al., 2007; Bocken et al., 2014; Kjaer et al., 2018). Lifecycle services such as preventive maintenance, refurbishment, or modular upgrades may contribute to prolonging product durability and delaying end-of-life disposal. In an XaaS context, provider ownership retention may further incentivize design for durability and reparability, as the provider directly benefits from extended product lifespans.

- **Intensified product usage:** it aims to enhance the utilization rate of existing assets by increasing the functional output generated from the same installed product capacity through improved availability, sharing arrangements, pooling mechanisms, or pay-per-use schemes (Amaya et al., 2014; Geissdoerfer et al., 2018). The environmental benefit derives from obtaining more value from assets that already exist, thereby reducing idle capacity and improving utilization efficiency. For instance, equipment-sharing platforms or availability-based contracts may allow the same industrial asset to be used more intensively over time, increasing its productive use without necessarily increasing the number of assets deployed. While intensified product usage focuses on increasing the utilization efficiency of existing assets, product system substitution concerns reducing the number of physical assets required to deliver the same functionality through shared or service-based configurations. The two mechanisms therefore operate through different pathways: the former increases the use of existing products, whereas the latter reduces the overall product stock needed to satisfy customer demand.**Improved recycling and reuse:** it can be facilitated through provider ownership and product take-back agreements, which enable more efficient reverse logistics processes and support remanufacturing or refurbishment strategies (Reim et al., 2015; Bressanelli et al., 2018). In XaaS offerings, customers may also exhibit greater acceptance of reused or remanufactured products, since the functional outcome rather than product ownership becomes the primary value proposition.
- **Product system substitution:** it may occur when XaaS offerings replace multiple individually owned products or ownership-based asset systems with shared, integrated, or service-based solutions capable of delivering the same functionality using fewer physical assets (Bocken et al., 2014; Kjaer et al., 2018). The environmental benefit derives from reducing the overall stock of products required to satisfy a given demand. For example, mobility-as-a-service solutions may substitute private vehicle ownership by providing access to shared transportation services, potentially reducing material throughput and emissions at the system level.**Dematerialization and transparency:** it can be achieved through the provision of functional outcomes instead of physical products and through the use of digital technologies enabling monitoring and traceability of product-related data (Beuren et al., 2013;

Alcayaga et al., 2019). The availability of information regarding product condition, maintenance history, or performance may support more accurate resource management by preventing unnecessary transportation, stock creation, or premature replacement.

- **Reduction of pollution and hazardous material usage** may be enabled through product redesign, clean material cycles, or the adoption of more efficient technologies facilitated by XaaS business models (Manninen et al., 2018; Yang and Evans, 2019). In particular, Use- and Result-oriented PSS may support the adoption of environmentally superior technological solutions by redistributing investment costs across multiple users or lifecycle phases.

Importantly, EVDs should not be interpreted as independent or automatically activated mechanisms. Different service configurations may trigger multiple interacting pathways affecting environmental performance, which may either reinforce expected sustainability benefits or generate adverse effects that offset them (Lee et al., 2012; Guzzo et al., 2022). Consequently, the environmental impact of XaaS adoption depends on the extent to which specific lifecycle-oriented services embedded within the business model contribute to representing one or more EVDs in a given operational context.

While the Product–Service System (PSS) literature has extensively discussed the environmental sustainability potential associated with XaaS business models, the extent to which such mechanisms are explicitly addressed within XaaS research remains heterogeneous across different environmental value drivers. Importantly, the Environmental Value Drivers identified in the PSS literature may operate at different analytical levels. While some EVDs, such as lifetime extension, resource efficiency, or improved reuse, can be influenced through firm-level lifecycle management services embedded in XaaS offerings, others, such as product system substitution, primarily emerge at the broader consumption or system level as a result of shifts from ownership- to access-based value propositions. Importantly, this does not imply that product system substitution cannot be empirically observed. Prior research provides empirical examples of such effects, particularly in contexts such as mobility systems, where access-based solutions replace privately owned assets and reduce the overall product base (Saccani et al., 2024). However, no clear evidence of product system substitution emerged within the cases analyzed in this study. Accordingly, the analysis focuses on those EVDs that can be directly linked to the services observed within the XaaS offerings examined. To address this issue, a subset of 45 papers from the XaaS-focused literature review conducted in this study, selected on the basis of the presence of explicit or implicit environmental sustainability implications, was analyzed through the lens of Environmental Value Drivers (EVDs). Building on the classification introduced in the previous section, the selected contributions were examined to identify which EVDs are conceptually associated with XaaS offerings and through which operational mechanisms such impacts are expected to materialize.

With respect to **resource efficiency**, XaaS business models are frequently described as enabling the reduction of material and energy consumption across the product lifecycle by shifting responsibility for operational performance from customers to providers (Kambanou and Sakao, 2020; Mourtzis et al., 2021; Opresnik and Taisch, 2015; Yang and Evans, 2019). For instance, smart PSS configurations may minimize the consumption of natural resources during the use phase by integrating monitoring and optimization functionalities, while lifecycle service provision may contribute to reducing performance losses associated with inefficient operation or maintenance practices (Holgado and Macchi, 2023; Karaca et al., 2018; Kim et al., 2022).

Closely related to this mechanism, several studies explicitly highlight the role of XaaS offerings in improving **energy efficiency** during product operation (Azcárate-Aguerre et al., 2018; Chun and Lee, 2017; Kambanou and Sakao, 2020; Peruzzini and Germani, 2014; Sassanelli et al., 2022); In particular, digitalized PSS solutions may enable real-time monitoring of energy consumption patterns, thus supporting operational optimization strategies aimed at minimizing environmental impacts associated with product usage (Despeisse et al., 2012; Mourtzis et al., 2021).

Similarly, **lifetime extension** emerges as a recurrent mechanism through which XaaS models are expected to influence environmental performance. Rental, leasing, or performance-based contracts may shift responsibility for end-of-life management and lifecycle optimization from customers to providers, thereby incentivizing maintenance, refurbishment, or modular upgrade strategies aimed at prolonging asset durability (Allais & Gobert, 2016; Haber and Fargnoli, 2021; Matschewsky, 2019; Smania et al., 2023). Sensor-enabled monitoring services may further contribute to extending operational life by preventing premature failure through predictive maintenance practices (Alix et al., 2021; Holgado and Macchi, 2023).

XaaS offerings have also been associated with **intensified product usage**, as sequential or shared access to the same physical asset may enable higher utilization rates compared to ownership-based consumption models (Costa et al., 2015; Karaca et al., 2018; Mourtzis et al., 2021; Sousa-Zomer et al., 2017; Yang et al., 2018). For example, access-based or shared-use service models may allow multiple users to access the same equipment over time, thereby increasing functional output per installed unit and potentially reducing the need for additional product manufacturing.

In addition, XaaS business models may facilitate **recycling and reuse** strategies by enabling reverse logistics processes through ownership retention or contractual product take-back agreements (Haber and Fargnoli, 2021; Pallaro et al., 2017; Sousa-Zomer et al., 2018; Sassanelli et al., 2022). Modular design approaches embedded within PSS configurations may further support component replacement or reuse across different customers or lifecycle stages (Azcárate-Aguerre et al., 2018; Peruzzini et al., 2013a; Peruzzini et al., 2013b).

At a system level, **product system substitution** represents another mechanism frequently discussed in relation to servitized business models. By shifting from ownership-based consumption toward access- or performance-based service provision, XaaS offerings may replace traditional product acquisition with function-oriented solutions, potentially reducing material throughput associated with manufacturing additional product units (Allais & Gobert, 2016; Costa et al., 2015; Despeisse et al., 2012; Matschewsky, 2019).

Furthermore, several studies emphasize the role of digital technologies embedded in XaaS offerings in enabling **dematerialization and transparency** through real-time data collection, product tracking, or performance monitoring (Chiarot et al., 2022; Mourtzis et al., 2021; Opresnik and Taisch, 2015). Such information availability may support improved resource management services by preventing unnecessary transportation, inventory accumulation, or premature replacement of products.

Environmental improvements may also occur through the **reduction of pollution or hazardous material usage**, as XaaS configurations may support product redesign, cleaner material cycles, or the adoption of environmentally superior technological solutions (Allais & Gobert, 2016; Haber and Fargnoli, 2021; Peruzzini et al., 2013c).

Finally, several contributions explicitly associate PSS and XaaS adoption with the broader objective of achieving **resource decoupling**, understood as the reduction of environmental impacts relative to economic output through access-based or function-oriented consumption models (Allais & Gobert, 2016; Costa et al., 2015; Despeisse et al., 2012; Matschewsky, 2019). In this perspective, XaaS business models are frequently presented as enabling the decoupling of value creation from material throughput by replacing ownership-based consumption with performance-oriented solutions.

Taken together, the analysis indicates that the sustainability potential of XaaS models is frequently articulated in relation to specific environmental value drivers, although the representation of such mechanisms appears contingent upon the adoption of lifecycle-oriented services and the alignment between business model configurations and environmental performance objectives.

To further assess whether XaaS adoption is associated with improved environmental sustainability compared to ownership-based models, the selected studies were analyzed along two complementary dimensions.

First, each contribution was examined to determine whether it explicitly presents XaaS as environmentally superior to traditional product-oriented models. Based on this criterion, the reviewed studies were categorized according to the type of sustainability impact reported.

The analysis indicates that only a limited number of studies provide an unequivocal positive assessment of the environmental benefits associated with XaaS adoption. Specifically, a limited number of contributions suggest that XaaS configurations systematically lead to improved

environmental sustainability outcomes compared to ownership-based models (Allais & Gobert, 2016; Costa et al., 2015; Haber and Fargnoli, 2021; Pallaro et al., 2017; Sousa-Zomer et al., 2018).

Conversely, the majority of contributions indicate that environmental benefits are not inherent to XaaS adoption but rather occur only under specific conditions. These conditions relate to the presence of particular services, contractual arrangements, and user behaviour patterns, which influence how XaaS models are implemented and used in practice (Alix et al., 2021; Chiarot et al., 2022; Holgado and Macchi, 2023; Karaca et al., 2018; Kim et al., 2022; Matschewsky, 2019; Mourtzis et al., 2021; Sassanelli et al., 2022).

A further group of studies does not provide a clear or empirically grounded assessment of environmental outcomes, either because sustainability implications are not explicitly addressed or because the discussion remains conceptual (Despeisse et al., 2012; Opresnik and Taisch, 2015; Peruzzini et al., 2013a; Peruzzini et al., 2013b; Peruzzini et al., 2013c).

To better specify the conditions under which environmental benefits are expected to materialize, the subset of studies reporting conditional outcomes was further analyzed to identify recurring enabling and hindering factors. These conditions include recurring factors related to the presence of specific services, contractual arrangements, and user behaviour patterns, which influence how XaaS models are implemented and used in practice.

*Table **36*** summarizes these conditions and the main references supporting each of them.

Condition	**Main supporting references**
Predictive and preventive maintenance	Holgado and Macchi (2023); Smania et al. (2023); Alix et al. (2021); Karaca et al. (2018); Kim et al. (2022)
Monitoring and optimization of resource consumption	Mourtzis et al. (2021); Alix et al. (2021); Chiarot et al. (2022); Kambanou and Sakao (2020)
Product take-back and reverse logistics	Pallaro et al. (2017); Sousa-Zomer et al. (2018); Sassanelli et al. (2022)
Remanufacturing and refurbishment practices	Azcárate-Aguerre et al. (2018); Peruzzini et al. (2013a); Smania et al. (2023)
Shared-use / access-based configurations	Sousa-Zomer et al. (2017); Mourtzis et al. (2021); Yang et al. (2018); Costa et al. (2015)
Provider ownership retention	Haber and Fargnoli (2021); Matschewsky (2019); Sousa-Zomer et al. (2018)
Performance- or usage-based contracts	Sousa-Zomer et al. (2017); Yang et al. (2018); Sassanelli et al. (2022)
Lifecycle responsibility allocation to provider	Haber and Fargnoli (2021); Matschewsky (2019); Allais & Gobert (2016)
Efficient user behaviour and appropriate usage patterns	Karaca et al. (2018); Kim et al. (2022); Mourtzis et al. (2021)
Risk of rebound effects (increased usage)	Sousa-Zomer et al. (2017); Mourtzis et al. (2021); Despeisse et al. (2012)
Careless or suboptimal use by customers	Matschewsky (2019); Smania et al. (2023)

Operational complexity (e.g. reverse logistics, infrastructure)	Despeisse et al. (2012); Costa et al. (2015); Mourtzis et al. (2021)

Table 36 Conditions under which the environmental benefits of XaaS are expected to materialize

As shown in

Table *36*The environmental benefits associated with XaaS are most consistently linked to the presence of specific services, such as predictive maintenance, monitoring and optimization, and product take-back arrangements. These services enable providers to influence product performance, extend operational life, and support resource efficiency and reuse strategies (Holgado and Macchi, 2023; Smania et al., 2023; Alix et al., 2021; Mourtzis et al., 2021).

At the same time, contractual conditions play a critical role. In particular, ownership retention by the provider and performance- or usage-based contractual mechanisms are frequently associated with stronger incentives for lifecycle optimization and resource efficiency (Haber and Fargnoli, 2021; Matschewsky, 2019; Sousa-Zomer et al., 2017; Yang et al., 2018). Conversely, several studies highlight that environmental benefits may be hindered by behavioural factors, such as increased usage intensity or rebound effects resulting from easier access to product functionality, as well as by operational challenges related to reverse logistics or service implementation (Sousa-Zomer et al., 2017; Mourtzis et al., 2021; Despeisse et al., 2012). Overall, these findings suggest that environmental sustainability outcomes in XaaS contexts are contingent upon the alignment between service design, contractual arrangements, and user behaviour, rather than being an inherent consequence of the business model itself. Building on these findings, the analysis further examines how the services identified in the reviewed literature are associated with specific Environmental Value Drivers (EVDs). Rather than treating sustainability outcomes as a binary effect of XaaS adoption, this step focuses on mapping the relationship between observable services and the environmental mechanisms they are expected to activate. This mapping enables a more granular understanding of how environmental improvements may be enabled through different XaaS configurations.

Table 37 presents this second mapping by linking the main services identified in the literature to the EVDs they are expected to support, together with the key references underpinning each association.

Service	Resource efficiency	Lifetime extension	Intensified usage	Recycling & reuse	Dematerialization & transparency	Main supporting references
Predictive and preventive maintenance	●	●			○	Holgado and Macchi (2023); Smania et al. (2023); Alix et al. (2021); Karaca et al. (2018); Kim et al. (2022)

Service	Resource efficiency	Lifetime extension	Intensified usage	Recycling & reuse	Dematerialization & transparency	Main supporting references
Monitoring and optimization of resource consumption	●	○			●	Mourtzis et al. (2021); Alix et al. (2021); Chiarot et al. (2022); Kambanou and Sakao (2020)
Remanufacturing and refurbishment		●		●		Azcárate-Aguerre et al. (2018); Peruzzini et al. (2013a); Smania et al. (2023)
Modular upgrades and component replacement	○	●		○		Peruzzini et al. (2013b); Peruzzini et al. (2013c); Allais & Gobert (2016)
Asset redeployment across contracts	○	○	●	●		Mourtzis et al. (2021); Sousa-Zomer et al. (2017); Pallaro et al. (2017)
Environmental data monitoring and reporting	○				●	Chiarot et al. (2022); Opresnik and Taisch (2015); Mourtzis et al. (2021)

Table 37 Mapping between XaaS services and Environmental Value Drivers (EVDs)

As shown in Table 37 different services are associated with distinct environmental value drivers. In the table, a filled circle (●) indicates a primary relationship between a service and an EVD, while an empty circle (○) denotes a secondary or indirect association.

In particular, maintenance and monitoring are primarily linked to lifetime extension and resource efficiency, as they enable improved operational performance and prolonged asset utilization (Alix et al., 2021; Holgado and Macchi, 2023; Haber and Fargnoli, 2021). More specifically, predictive and preventive maintenance, as well as monitoring and optimization services, support performance improvements and reduced resource consumption.

Services related to product recovery, such as remanufacturing and refurbishment practices, are instead associated with recycling and reuse mechanisms, as they enable the recovery and reintroduction of products and components across multiple usage cycles (Pallaro et al., 2017; Sousa-Zomer et al., 2018; Sassanelli et al., 2022; Azcárate-Aguerre et al., 2018).

In contrast, intensified product usage is mainly supported by asset redeployment across multiple contracts, which increase the utilization rate of existing assets and reduce the need for additional product manufacturing (Costa et al., 2015; Mourtzis et al., 2021; Sousa-Zomer et al., 2017; Yang et al., 2018).

Finally, digital monitoring and data-driven services contribute not only to resource efficiency but also to dematerialization and transparency, by enabling real-time tracking of performance and resource consumption. In addition, services related to environmental data monitoring and reporting enhance

traceability and information availability, supporting more informed decision-making processes (Chiarot et al., 2022; Opresnik and Taisch, 2015; Mourtzis et al., 2021).

Overall, the mapping highlights that the environmental sustainability of XaaS models depends not on the adoption of the model per se, but on the specific services through which it is implemented and on the environmental mechanisms these services are able to activate. Importantly, several services are associated with multiple EVDs, suggesting that environmental improvements may result from the combined and interacting effects of different service configurations rather than from isolated mechanisms.

7.3 Mechanisms hindering the implementation of environmental sustainability drivers in XaaS

While the previous section highlighted the lifecycle-oriented services through which XaaS models may support or hinder the representation of environmental value drivers, the analysis of the same subset of 45 XaaS studies also reveals the presence of countervailing mechanisms that may offset or even reverse the expected sustainability benefits of XaaS business models. In particular, several contributions emphasize that the environmental performance of XaaS offerings may be negatively affected by behavioural, operational, or systemic factors emerging from the reconfiguration of ownership, usage patterns, and lifecycle responsibilities.

A first set of challenges relates to the potential emergence of **rebound effects** associated with increased accessibility to product functionality in the absence of ownership (Allais & Gobert, 2016; Costa et al., 2015; Haber and Fargnoli, 2021). Usage-based or subscription-oriented service models may lower the perceived marginal cost of product utilization for customers, thereby incentivizing higher usage intensity and increasing operational resource consumption during the use phase. In such cases, intensified product usage may offset the environmental benefits associated with reduced installed product bases or improved operational efficiency (Sousa-Zomer et al., 2017; Mourtzis et al., 2021).

Similarly, several studies highlight the risk of **careless usage behaviours** in XaaS consumption models, where customers may exhibit lower incentives to preserve product condition in the absence of ownership responsibility (Matschewsky, 2019; Smania et al., 2023). Such behavioural shifts may result in accelerated wear-and-tear, increased maintenance needs, or premature failure, thereby undermining expected lifetime extension effects and potentially increasing resource consumption across the lifecycle.

Operational challenges may also arise from the increased **complexity of reverse logistics processes** associated with product take-back, refurbishment, or remanufacturing strategies (Pallaro et al., 2017;

Sousa-Zomer et al., 2018). The environmental benefits of reuse or recycling services may be partially offset by additional transportation requirements, infrastructure investments, or energy consumption associated with product recovery and redistribution activities (Despeisse et al., 2012; Costa et al., 2015).

In addition, the literature points to the possibility of delayed environmental breakeven points in XaaS configurations. In this study, an environmental breakeven point is defined as the moment in time at which the cumulative environmental benefits generated during the use phase compensate for the higher environmental impacts initially associated with product design, production, or supporting infrastructure.

This is particularly relevant in cases where extended product lifetimes or shared usage models require higher upfront investments in durable product design or supporting infrastructure (Haber and Fargnoli, 2021; Sassanelli et al., 2022). In such contexts, environmental gains associated with reduced material throughput may only materialize after prolonged usage periods, and may be contingent upon actual usage patterns or customer retention over time.

Furthermore, several studies highlight that the economic feasibility of repair or refurbishment activities may influence environmental outcomes. In situations where repair costs exceed replacement costs, providers may be incentivized to substitute rather than maintain existing products, thereby limiting the representation of lifetime extension or reuse-related EVDs (Allais & Gobert, 2016; Matschewsky, 2019).

Finally, systemic challenges related to behavioural or organizational change may also hinder the realization of sustainability benefits in XaaS contexts. The adoption of XaaS consumption models may require the development of new operational capabilities, infrastructure systems, or customer engagement services, whose environmental implications depend on the scale and efficiency of implementation (Sousa-Zomer et al., 2018; Mourtzis et al., 2021).

Taken together, these findings suggest that XaaS adoption may give rise to countervailing mechanisms capable of offsetting the environmental improvements associated with lifecycle-oriented services. Consequently, the environmental sustainability of XaaS business models cannot be assumed a priori, but rather depends on the interaction between business model configuration, user behaviour, and operational system design.

To complement the analysis of enabling services, the reviewed literature also highlights the presence of countervailing mechanisms that may hinder or offset the environmental benefits associated with XaaS adoption. These mechanisms reflect behavioural, operational, economic, and systemic challenges emerging from the reconfiguration of ownership, usage patterns, and lifecycle responsibilities.

*Table **38*** summarizes the main hindering mechanisms identified in the reviewed studies, together with the key references supporting each of them.

Hindering mechanism	Description	Main supporting references
Rebound effects due to increased accessibility	Increased access to product functionality and lower perceived marginal costs may lead to higher usage intensity, offsetting efficiency gains and increasing resource consumption	Allais & Gobert (2016); Costa et al. (2015); Haber and Fargnoli (2021); Sousa-Zomer et al. (2017); Mourtzis et al. (2021);
Careless or suboptimal user behaviour	Lack of ownership may reduce user incentives to preserve product condition, leading to accelerated wear, increased maintenance, and shorter product lifetimes	Matschewsky (2019); Smania et al. (2023);
Reverse logistics and operational complexity	Take-back, refurbishment, and remanufacturing processes may require additional transport, infrastructure, and energy, potentially offsetting environmental benefits	Pallaro et al. (2017); Sousa-Zomer et al. (2018); Despeisse et al. (2012); Costa et al. (2015)
Delayed environmental breakeven	Environmental benefits may only emerge after extended usage periods due to higher upfront investments in durable products or infrastructure	Haber and Fargnoli (2021); Sassanelli et al. (2022)
Economic trade-offs in repair vs replacement	High repair costs may incentivize product replacement rather than maintenance, limiting lifetime extension and reuse benefits	Allais & Gobert (2016); Matschewsky (2019)
Organizational and systemic complexity	Implementation of XaaS may require new capabilities, infrastructure, and coordination mechanisms, whose environmental impact depends on scale and efficiency	Sousa-Zomer et al. (2018); Mourtzis et al. (2021)

Table 38 Mechanisms hindering the realization of environmental sustainability in XaaS models

As shown in Table 37, several mechanisms may counteract the expected environmental benefits of XaaS models. While increased accessibility to product functionality represents the most direct form of rebound effect, other mechanisms such as careless user behaviour and reverse logistics complexity can also be interpreted as indirect rebound phenomena, as they may offset or reduce the environmental gains generated by improved resource efficiency and lifecycle extension strategies. At the same time, additional operational and systemic challenges, such as delayed breakeven points, economic trade-offs, and organizational complexity, may further limit or postpone the realization of environmental benefits.

Overall, these findings reinforce the argument that the environmental sustainability of XaaS models cannot be assumed a priori, but depends on the interaction between service design, contractual arrangements, user behaviour, and system-level implementation conditions.

7.4 Representation of Environmental Value Drivers through XaaS services

To operationalize the analysis of Environmental Value Drivers (EVDs) within XaaS configurations, this study adopts a services-based analytical perspective grounded in the assumption that EVDs cannot be directly observed at the organizational level, but are instead reflected through specific operational, contractual, and technological services embedded within the design and implementation of XaaS offerings.

This approach is consistent with prior Product–Service System (PSS) and XaaS literature, which conceptualizes environmental improvements as the result of underlying lifecycle-related mechanisms, such as lifetime extension, resource efficiency, or reuse, enabled through concrete service practices rather than directly measurable outcomes (Tukker, 2004; Reim et al., 2015; Kjaer et al., 2018; Moro et al., 2022). In this perspective, services represent observable configurations through which such mechanisms can be identified and interpreted in empirical settings.

Accordingly, lifecycle-oriented services were used as empirical proxies to assess the extent to which different EVDs are represented within the analyzed business model configurations. The selection of services considered in this study is grounded in both the literature review presented in Chapter 4 and the conceptualization of EVDs introduced in Section 7.2, and reflects the most recurrent and theoretically grounded practices associated with environmental value creation in XaaS and PSS contexts (Allais & Gobert, 2016; Costa et al., 2015; Haber and Fargnoli, 2021; Matschewsky, 2019; Mourtzis et al., 2021; Pallaro et al., 2017; Sousa-Zomer et al., 2018; Saccani et al., 2024).

The association between the identified services and specific EVDs is based on the environmental mechanisms they are expected to activate, as discussed in the literature. In particular, maintenance, refurbishment, and modular upgrade services are linked to lifetime extension, as they contribute to prolonging product operational life (Baines et al., 2007; Bocken et al., 2014; Kjaer et al., 2018; Saccani et al., 2024). Monitoring and optimization services are associated with resource efficiency, as they enable the reduction of energy and material consumption during use (Lee et al., 2012; Bressanelli et al., 2018; Kjaer et al., 2018; Saccani et al., 2024). Product recovery services, such as take-back and remanufacturing, are connected to recycling and reuse mechanisms (Reim et al., 2015; Bressanelli et al., 2018; Saccani et al., 2024), while asset sharing and redeployment services are associated with intensified product usage (Amaya et al., 2014; Geissdoerfer et al., 2018; Saccani et al., 2024). Finally, digital monitoring and reporting services are linked to dematerialization and

transparency through improved information availability and traceability (Beuren et al., 2013; Alcayaga et al., 2019; Saccani et al., 2024).

While not representing services per se, contractual and revenue model configurations (e.g. performance-based or usage-based models) may play a critical role in enabling or reinforcing the environmental mechanisms associated with the identified services (Saccani et al., 2024).

Service	EVD	Main supporting references
Maintenance and lifecycle support services (preventive, predictive, refurbishment)	Lifetime extension; Resource efficiency	Alix et al. (2021); Holgado and Macchi (2023); Karaca et al. (2018); Kim et al. (2022); Azcárate-Aguerre et al. (2018); Saccani et al. (2024)
Design and upgrade services (modularity, durability)	Lifetime extension	Peruzzini et al. (2013a); Peruzzini et al. (2013b); Saccani et al. (2024)
Resource monitoring and optimization services	Resource efficiency; Dematerialization & transparency	Mourtzis et al. (2021); Kambanou and Sakao (2020); Chiarot et al. (2022); Saccani et al. (2024)
Product recovery services (take-back, remanufacturing, reuse)	Recycling & reuse	Pallaro et al. (2017); Sousa-Zomer et al. (2018); Azcárate-Aguerre et al. (2018); Saccani et al. (2024)
Asset sharing and utilization services (redeployment, multi-contract use, shared access)	Intensified usage	Costa et al. (2015); Mourtzis et al. (2021); Sousa-Zomer et al. (2017); Saccani et al. (2024)
Environmental data and reporting services	Dematerialization & transparency	Chiarot et al. (2022); Opresnik and Taisch (2015); Saccani et al. (2024)

Table 39 Mapping between XaaS services and Environmental Value Drivers (EVDs)

Table 39 summarizes the mapping between lifecycle-oriented XaaS services and Environmental Value Drivers adopted in this study. The table reflects a theoretically informed interpretation of how observable service configurations may represent underlying environmental mechanisms, in line with prior studies linking PSS service characteristics to environmental value drivers (Tukker, 2004; Kjaer et al., 2018; Saccani et al., 2024).

As shown in Table 39, services supporting lifetime extension emerge as the most articulated category, including maintenance, refurbishment, and design-related interventions. This is consistent with prior literature highlighting lifecycle extension as one of the most prominent environmental mechanisms associated with servitized offerings (Baines et al., 2007; Kjaer et al., 2018). In contrast, services associated with resource efficiency and dematerialization are more narrowly concentrated around

monitoring and data-driven functionalities, which are typically enabled by digital technologies embedded in XaaS configurations (Bressanelli et al., 2018; Alcayaga et al., 2019).

Similarly, recycling and reuse mechanisms are primarily linked to product recovery services, as also emphasized in the PSS literature on take-back systems and remanufacturing strategies (Reim et al., 2015; Bressanelli et al., 2018; Saccani et al., 2024), while intensified usage is associated with asset sharing and multi-user utilization practices, consistent with access-based and use-oriented service models (Amaya et al., 2014; Geissdoerfer et al., 2018; Saccani et al., 2024).

Overall, the table provides the analytical foundation for the empirical investigation, enabling the systematic assessment of which Environmental Value Drivers are represented within the analyzed XaaS configurations through the implementation of specific services. This interpretation is consistent with recent conceptual work emphasizing that the environmental performance of XaaS and PSS models depends on the alignment between service configurations and the environmental mechanisms they are expected to activate (Saccani et al., 2024).

7.5 Empirical analytical approach

While the environmental sustainability potential of XaaS models has been widely discussed in the literature, assessing the actual environmental performance of XaaS offerings in practice remains a challenging task. In particular, sustainability impacts associated with XaaS adoption are typically mediated by underlying mechanisms rather than directly observable at the organizational level. As discussed in the previous sections, Environmental Value Drivers (EVDs) represent intermediate mechanisms through which XaaS business models may influence environmental performance across different stages. However, such mechanisms cannot be directly measured within the scope of firm-level qualitative investigations.

To address this limitation, the empirical analysis conducted in this study focuses on identifying the XaaS services currently implemented within the XaaS offerings of the interviewed firms, corresponding to the same companies included in the empirical investigation described in Chapter 5 and reported in the Appendix. The observed services were derived from the literature review presented in Chapter 4 and incorporated into the research protocol as observable indicators used to operationalize the variables of the Environmental Sustainability dimension within the analytical framework developed in the same chapter (Saccani et al., 2024). Accordingly, the presence of specific service-related practices, such as preventive maintenance programs, asset sharing, remanufacturing services, or resource consumption monitoring, was used to assess the extent to which one or more Environmental Value Drivers may be represented within the analyzed business model configurations.

More specifically, the analysis focused on identifying the XaaS services implemented across the case companies. These services were subsequently examined in light of the Environmental Value Drivers introduced in Section 7.2 in order to assess the extent to which such drivers are represented within the analyzed XaaS configurations. This approach enables inferring the environmental sustainability mechanisms potentially embedded within each business model by linking observable operational services to environmental improvement pathways, such as lifetime extension, resource efficiency, intensified product usage, or improved recycling and reuse.

Consequently, the empirical investigation does not aim to directly quantify environmental impacts associated with XaaS adoption, but rather to assess the extent to which Environmental Value Drivers are represented through the implementation of XaaS services within the business model configurations adopted by the analyzed firms. This services-based analytical approach enables moving beyond normative assumptions regarding the sustainability potential of XaaS models, toward a more systematic understanding of how environmental improvements may be enabled in practice.

By systematically linking observable services to specific Environmental Value Drivers, the analysis provides an empirically grounded basis for identifying how XaaS configurations can be designed and managed to support environmental sustainability.

7.5.1 Overview of XaaS services across the case companies

Building on the empirical analysis aimed at identifying the XaaS services currently implemented within the offerings of the interviewed firms, this section examines how such services contribute to the representation of the Environmental Value Drivers (EVDs) introduced in Section 7.2. In particular, the services described by the companies included in the empirical investigation were analyzed in order to assess the extent to which different EVDs are reflected in practice through observable operational configurations.

The analysis reveals an uneven distribution of services associated with environmental sustainability improvements across the case companies. In particular, services supporting lifetime extension emerge as the most widely implemented mechanisms. Preventive or predictive maintenance programs, refurbishment activities, modular component replacement, and durable product design are adopted by the majority of the interviewed firms, including Turboden, Toyota Rental, Kaer, KUKA Rental, ABB, Prima Industrie, CGT, SEW, Henkelhausen, and STULZ CaaS. These services contribute to prolonging product operational life and delaying end-of-life disposal, thereby supporting EVDs associated with lifetime extension.

In contrast, services associated with recycling and reuse are implemented by a more limited subset of firms. These include remanufacturing activities, product take-back arrangements, and the inclusion

of second-hand equipment within service offerings, as observed in ABB, CGT, Kaer, Henkelhausen, Toyota Rental, Turboden, and KUKA Rental. While such services enable reverse logistics processes and multi-cycle asset utilization, their adoption appears less systematic across the analyzed XaaS configurations.

Similarly, services aimed at improving resource and energy efficiency, such as monitoring and optimization of resource consumption, are implemented in a relatively small number of cases, including Turboden, Kaer, CGT, Sandvik, and STULZ CaaS. These services rely on digital monitoring systems and data-driven functionalities to support operational optimization strategies aimed at reducing energy consumption and material usage during the use phase.

With respect to intensified product usage, services such as asset redeployment, multi-contract utilization, and shared usage arrangements are observed in several access-based XaaS models, including Toyota Rental, ABB, Kaer, CGT, Cavanna, and STULZ Rental. These services enable sequential or shared access to the same physical asset across multiple users, thereby increasing the functional output per installed unit and potentially reducing the need for additional product manufacturing.

Conversely, services supporting dematerialization and transparency, such as the monitoring and reporting of environmental performance data, are implemented in only a limited number of cases, most notably Turboden and Kaer. This suggests that while digital technologies are widely adopted to support operational optimization, their application for environmental transparency and sustainability reporting remains relatively underdeveloped.

Service	**EVD**	**Evidence (case companies)**
Maintenance and lifecycle support services (preventive, predictive, refurbishment)	Lifetime extension; Resource efficiency	Turboden; Kaer; ABB; CGT; KUKA Rental; Prima Industrie; SEW; Henkelhausen
Design and upgrade services (modularity, durability)	Lifetime extension	KUKA Rental; Prima Industrie; SEW; Henkelhausen; STULZ CaaS; Toyota Rental
Resource monitoring and optimization services	Resource efficiency; Dematerialization & transparency	Turboden; Kaer; CGT; Sandvik; STULZ CaaS
Product recovery services (take-back, remanufacturing, reuse)	Recycling & reuse	ABB; CGT; Kaer; Henkelhausen; Toyota Rental; Turboden; KUKA Rental
Asset sharing and utilization services (redeployment, multi-contract use, shared access)	Intensified usage	Toyota Rental; ABB; Kaer; CGT; Cavanna; STULZ Rental
Environmental data and reporting services	Dematerialization & transparency	Turboden; Kaer

Table 40 Mapping between XaaS services and Environmental Value Drivers (EVDs) across case companies

Table 40 provides a structured mapping between the XaaS services identified across the analyzed case companies and the Environmental Value Drivers they are expected to represent, integrating both theoretical grounding and empirical evidence. The table highlights not only the conceptual linkage between services and environmental mechanisms, but also the extent to which such mechanisms are actually operationalized in practice.

From an empirical perspective, a clear asymmetry emerges in the distribution of services across EVDs. In particular, services supporting lifetime extension represent the most widespread category, being implemented by the majority of the analyzed firms, including Turboden, Kaer, ABB, CGT, KUKA Rental, Prima Industrie, SEW, Henkelhausen, STULZ CaaS, and Toyota Rental. These services—such as preventive and predictive maintenance, refurbishment, modular upgrades, and durable product design—are deeply embedded within XaaS offerings and reflect a strong alignment between business model configurations and lifecycle optimization objectives.

In contrast, services associated with resource efficiency are more selectively implemented. Although digital monitoring and optimization functionalities are present in several cases (e.g., Turboden, Kaer, CGT, Sandvik, STULZ CaaS), their explicit use for minimizing resource or energy consumption appears to be limited to configurations where operational performance is directly linked to service outcomes. This suggests that the representation of resource efficiency mechanisms is contingent upon specific service designs and incentive structures, rather than being systematically embedded across all XaaS models.

A similar pattern can be observed for recycling and reuse mechanisms. Product recovery services—such as take-back arrangements, remanufacturing, and the use of second-hand equipment—are implemented by a subset of firms (ABB, CGT, Kaer, Henkelhausen, Toyota Rental, Turboden, KUKA Rental), primarily in configurations characterized by ownership retention and structured reverse logistics processes. This indicates that the activation of reuse-related EVDs depends on the ability of firms to manage product flows across multiple lifecycle stages.

Services enabling intensified product usage are relatively widespread in access-based configurations, with firms such as Toyota Rental, ABB, Kaer, CGT, Cavanna, and STULZ Rental implementing asset sharing, redeployment, and multi-contract utilization strategies. These services reflect a clear operationalization of usage intensification mechanisms, as they allow multiple users to access the same physical asset over time, thereby increasing utilization rates and reducing the need for additional product units.

Conversely, services associated with dematerialization and transparency are only marginally represented across the sample. Although digital monitoring technologies are widely adopted, their use for external reporting or environmental transparency purposes is limited to a few cases, notably Turboden and Kaer. In most configurations, data-related services are primarily used for internal optimization rather than for enabling customer-facing sustainability functionalities.

Overall, the empirical evidence suggests that the representation of Environmental Value Drivers within XaaS configurations is highly uneven and depends on the specific services embedded within the business model. While lifetime extension emerges as a dominant and systematically implemented mechanism, other EVDs, such as resource efficiency, recycling and reuse, and dematerialization, are only partially represented and appear to depend on more advanced or context-specific service configurations.

These findings highlight that the environmental sustainability potential of XaaS models is not uniformly realized across different implementations but is instead contingent upon the alignment between service design, operational practices, and the environmental mechanisms they are expected to activate. Overall, the mapping highlights that different Environmental Value Drivers are unevenly represented across XaaS configurations, depending on the specific services embedded within the business model. In particular, lifetime extension emerges as the most systematically represented EVD, supported by a broad set of services widely adopted across firms. In contrast, EVDs related to resource efficiency, recycling and reuse, and dematerialization are associated with more specific and less widely implemented service configurations. Importantly, no empirical evidence was identified regarding the implementation of services directly associated with product system substitution or with the reduction of pollution and hazardous material usage. This finding is consistent with the system-level nature of such mechanisms, which typically emerge from broader changes in consumption patterns rather than from firm-level service configurations.

Taken together, these findings suggest that the environmental sustainability potential of XaaS models is not inherently determined by the adoption of a service-based logic but rather depends on the extent to which specific services capable of activating Environmental Value Drivers are embedded within the business model configuration. Consequently, environmental improvements appear contingent upon the alignment between service design, operational practices, and the environmental mechanisms they are expected to enable.

7.6 Conclusions and implications for XaaS environmental sustainability

Taken together, the findings of this chapter provide a more nuanced understanding of the relationship between XaaS business models and environmental sustainability. While prior literature has frequently

emphasized the sustainability potential of service-based offerings, the analysis conducted in this study shows that such potential is neither automatic nor uniformly realized across different configurations. Both the literature review and the empirical evidence highlight that environmental improvements are mediated by specific lifecycle-oriented services and enabling conditions, rather than being an inherent consequence of the transition from ownership-based to service-based models. In particular, lifetime extension emerges as the most consistently represented Environmental Value Driver, supported by widely implemented services such as maintenance, refurbishment, and durable design. In contrast, other drivers, such as resource efficiency, recycling and reuse, and dematerialization, are more selectively activated and depend on more advanced service configurations, contractual arrangements, and operational capabilities.

At the same time, the presence of hindering mechanisms, including rebound effects, behavioural responses, and operational complexity, further reinforces the idea that XaaS adoption may generate both enabling and countervailing effects on environmental performance. As a result, the environmental sustainability of XaaS offerings appears to be contingent upon the alignment between service design, user behaviour, and lifecycle management practices.

From a theoretical perspective, these findings contribute to the ongoing debate on the sustainability implications of servitization by showing that Environmental Value Drivers provide a useful lens for disentangling the mechanisms through which XaaS models may influence environmental performance. From a managerial perspective, the results suggest that firms cannot rely on XaaS adoption per se to achieve sustainability improvements but must intentionally design and implement service configurations capable of activating specific environmental mechanisms across the product lifecycle.

8 CHAPTER VIII – DISCUSSION

8.1 In-depth interpretation of results

8.1.1 Conceptual fragmentation and definition

A first central issue emerging from the literature concerns the partial conceptual fragmentation surrounding advanced service-based business models. As highlighted in Chapter III, the systematic review shows that XaaS is situated within a landscape characterized by definitional overlap with pre-existing concepts rather than by a fully consolidated theoretical framework. Rather than converging toward a shared conceptualization, the literature reflects the coexistence of multiple, partially overlapping constructs, which may blur analytical boundaries and limit the development of cumulative knowledge.

In particular, Shen et al. (2023) explicitly describe the digital servitization domain as fragmented, marked by the proliferation of overlapping notions such as smart services, PSS, PaaS, EaaS, and platform-based offerings, often used interchangeably despite referring to structurally different configurations. Similarly, Kowalkowski and Ulaga (2024) show that subscription-based models in B2B markets vary substantially depending on the degree of integration between provider and customer and on whether the offering focuses on access or performance outcomes, further reinforcing the heterogeneity of advanced XaaS models. These studies underline diversity but do not establish clear analytical criteria to delimit XaaS as a distinct construct.

In parallel, Vandermerwe and Erixon (2023) conceptualize anything-as-a-service as an advanced stage of servitization in which customers access integrated bundles designed to generate value-in-use over time rather than acquiring ownership of physical assets. While this evolutionary interpretation situates XaaS within the broader servitization trajectory, it remains primarily descriptive and macro-level. It does not provide operational parameters through which XaaS configurations can be empirically identified and compared across firms.

Even where taxonomical efforts exist, such as the distinction among different sustainable servitization approaches discussed by Benedettini and Adrodegari (2026), the emphasis remains on categorizing orientations rather than on constructing a consolidated and operational definition of XaaS itself . Likewise, contributions examining gradual transitions from product-oriented to result-oriented offerings (Soellner et al., 2024) focus on transformation trajectories rather than on clarifying the structural core of XaaS configurations. As a result, the literature provides rich insights into evolutionary pathways and contractual logics, yet stops short of defining what constitutes XaaS in analytical terms.

This heterogeneity is further reflected by streams concentrating on specific elements of advanced service models, such as pricing mechanisms (Bertelli et al., 2024), lifecycle management practices (Nansubuga & Kowalkowski, 2021), or performance-based contracts (Ng and Nudurupati, 2010), without integrating these dimensions into a unified conceptual structure. While these studies significantly advance understanding of implementation dynamics, they implicitly assume rather than define the XaaS construct.

Against this background, the definitional work developed in this thesis directly addresses the conceptual ambiguity identified across these streams. Through a structured comparative analysis of established service-oriented models, the study isolates the foundational characteristics shared with PSS and servitization logics, such as integrated solutions, value-added services, relational continuity, and alternative revenue streams, and distinguishes them from elements that emerge as structurally distinctive within XaaS. In particular, the analysis highlights on-demand availability as a distinguishing element, while integrated solution logic and customer-centered value delivery are interpreted as foundational characteristics inherited from servitization and further operationalized within XaaS configurations.

This clarification responds directly to the analytical under-boundedness highlighted in the systematic review and to the heterogeneity highlighted in the literature. Unlike studies that focus predominantly on contractual typologies or subscription schemes, the proposed definition moves beyond pricing logic and centers the analysis on the structural characteristics of the offering itself, namely its integrated nature, on-demand availability, and value-added configuration.

Importantly, the empirical application of this definition to the 17 case studies demonstrates its operational robustness. XaaS configurations were not identified solely on the basis of recurring revenue logic, often emphasized in subscription or pay-per-X studies, but through the empirical verification of the defining elements articulated in Chapter IV: the provision of an integrated solution, the availability of the offering on demand, and the delivery of value through a value-added configuration designed to provide customers with precisely what they require at the moment of need. The case analysis shows that only those firms combining these elements in a coherent manner, integrating product and service components into a unified solution, enabling flexible and timely access, and structuring the offering around customer-specific value delivery, can be analytically categorized as XaaS. This multidimensional operationalization, grounded in the formal definition rather than in isolated contractual features, allows for a clearer differentiation between servitized offerings and XaaS models, thereby strengthening conceptual precision and enabling systematic cross-case comparison.

By consolidating dispersed conceptual streams into a coherent and empirically validated definition, the study enriches the literature in two interrelated ways. First, it enhances theoretical clarity by explicitly delineating the structural core of XaaS within manufacturing. Second, it creates the analytical foundation necessary for cumulative research development, addressing the definitional ambiguity and limited conceptual consolidation documented in prior research.

8.1.2 Integrative framework and configurational understanding of XaaS adoption

Beyond conceptual ambiguity, a second major limitation emerging from the literature concerns the absence of integrative analytical structures capable of systematically characterizing XaaS configurations. As highlighted in Chapter III, existing research predominantly focuses on isolated dimensions of advanced service-based models, such as technological adoption, pricing mechanisms, or lifecycle implications, without integrating them into a coherent and multidimensional framework. In particular, several contributions examine the determinants of digital service adoption through contextual lenses, emphasizing technological, organizational, and environmental readiness factors rather than the structural configuration of the business model itself. For example, studies applying the TOE framework to SaaS adoption focus on technological risks and benefits, organizational context, and environmental pressures (Rahman & Subriadi, 2022; Kim et al., 2017), while other analyses concentrate on data-related and governance challenges such as security, privacy, and interoperability (Ibrahim et al., 2023). Although these contributions provide valuable insight into adoption drivers and barriers, they do not explicitly conceptualize how value is created, structured, and captured within XaaS business models. Other studies concentrate on subscription logic and recurring revenue models, highlighting variations in pricing and contractual structure (Kowalkowski & Ulaga, 2024; Bertelli et al., 2024), yet without embedding these mechanisms within a broader architecture of value proposition, ownership configuration, resource deployment, and ecosystem coordination.

Similarly, research addressing the organizational transformation associated with servitization emphasizes capability development, lifecycle management, and customer engagement processes (Nansubuga & Kowalkowski, 2021; Soellner et al., 2024). While these studies significantly advance understanding of transformation dynamics, they tend to adopt a process-oriented perspective rather than providing a structural model through which implemented offerings can be systematically described and compared. As a result, the literature offers valuable insights into how firms move toward XaaS logics but provides limited tools to analyze how such logics are concretely configured at the level of the business model.

This heterogeneity is further evident in contributions focusing on performance-based contracts and incentive alignment (Ng & Nudurupati, 2010). Although these studies illuminate the complexity of

outcome-oriented arrangements, they examine contractual mechanisms in isolation from other interdependent dimensions, such as digital infrastructure, retained ownership, ecosystem structure, or sustainability implications. Consequently, value creation and value capture are often treated as analytically separable components rather than as structurally coupled elements within an integrated configuration.

Against this backdrop, the framework developed in this thesis responds directly to the lack of integrative analytical tools by proposing a multidimensional structure that encompasses value proposition, customers, ecosystem, organizational structure and culture, economic and financial mechanisms, resources, capabilities, and environmental sustainability. Unlike prior models that emphasize single dimensions, the proposed framework explicitly captures the interdependencies among ownership configuration, data-enabled monitoring, and lifecycle responsibility, thereby reflecting the structural complexity of XaaS business models.

The empirical application of this framework to the 17 case studies further strengthens its analytical relevance. Rather than merely describing individual firms' transition processes, the framework enables a systematic mapping of implemented offerings across multiple dimensions. This multidimensional characterization makes it possible to identify recurring configurations and to distinguish coherent archetypes of XaaS adoption. In doing so, the study moves beyond process narratives toward a configurational understanding of XaaS, where adoption is interpreted as the alignment of interdependent structural elements rather than as the presence of isolated service features.

Importantly, this configurational perspective also clarifies why firms adopting similar schemes or subscription mechanisms may nonetheless exhibit substantially different XaaS maturity levels. By simultaneously analyzing value proposition design, resource integration, capability development, and sustainability orientation, the framework reveals heterogeneity that would remain invisible under dimension-specific analyses. This directly addresses the limitation identified in prior research, which often relies on single-case studies that do not allow systematic cross-firm comparison.

In this sense, the framework does not merely classify business models but provides an analytical lens capable of capturing structural coherence and potential misalignment across dimensions. By embedding ownership, digital enablement, financial logic, and environmental sustainability within a unified structure, the study advances the analytical maturity of XaaS research and enriches the literature that has so far remained predominantly descriptive and fragmented.

8.1.3 Configurational archetypes, implementation challenges and best practices

A third stream of research examined focuses on the organizational and strategic complexity associated with the implementation of advanced service-based business models. Prior contributions emphasize that the transition toward subscription-based, access-based, or outcome-oriented configurations requires substantial modifications in pricing mechanisms, lifecycle cost structures, installed base management, and customer engagement processes (Bertelli et al., 2024; Nansubuga & Kowalkowski, 2021). Servitization is frequently described as a gradual transformation trajectory in which firms progressively move from product-oriented to use- and result-oriented offerings (Soellner et al., 2024). In parallel, the literature has highlighted several recurring implementation barriers. Misalignment between strategic intent and internal organizational structures may undermine expected financial returns, contributing to the well-documented service paradox (Alghisi & Saccani, 2015). Similarly, performance-based contractual schemes, central to many advanced XaaS configurations, introduce additional complexity, as linking remuneration to outcomes requires clearly defined performance metrics, reliable monitoring systems, and aligned stakeholder expectations (Ng & Nudurupati, 2010). While these studies convincingly identify implementation challenges, they predominantly treat them as generic features of servitization processes rather than as phenomena emerging from specific business model configurations.

The empirical findings of this study extend this literature by adopting a configurational perspective. By applying the multidimensional framework to the 17 manufacturing cases, the analysis reveals that XaaS adoption does not follow a uniform path. Instead, firms exhibit recurring structural patterns characterized by different combinations of value proposition orientation, ownership and risk allocation logic, digital resource integration, organizational capability maturity, and ecosystem involvement. These differentiated configurations are associated with distinct implementation dynamics.

Interpreting challenges through this configurational lens provides a more nuanced explanation of the tensions described in prior research. For instance, difficulties related to performance-based remuneration and incentive alignment (Ng & Nudurupati, 2010; Benedettini et al., 2015) are particularly evident in configurations where outcome-oriented value propositions are not supported by sufficiently developed monitoring capabilities or by clearly defined internal processes for data interpretation and risk management. In such cases, the shift toward performance-linked revenue logic amplifies uncertainty rather than stabilizing value capture.

Similarly, manifestations of the service paradox (Alghisi & Saccani, 2015) appear closely connected to structural misalignment across framework dimensions. When firms introduce recurring revenue schemes without adapting organizational structures, incentive systems, and cross-functional coordination mechanisms, the expected benefits of XaaS adoption remain unrealized. The empirical

evidence therefore suggests that financial underperformance is less a consequence of servitization per se than of incomplete or incoherent configuration.

Beyond challenges, the cross-case analysis also identifies recurring best practices that mitigate the risks documented in prior studies. First, firms exhibiting clearer alignment between value proposition design and capability development demonstrate greater stability in managing outcome-based or access-based offerings. This finding complements prior research highlighting the risks of strategic and organizational misalignment in servitization processes (Alghisi & Saccani, 2015; Soellner et al., 2024). Second, the integration of digital monitoring infrastructures with internal decision-making processes reduces uncertainty in performance measurement and facilitates more transparent customer relationships. This directly addresses the implementation tensions associated with performance-based contractual schemes, where clearly defined metrics and reliable monitoring systems are considered critical success factors (Nansubuga & Kowalkowski, 2021). Third, structured ecosystem coordination, particularly in cases involving third-party service providers or technology partners, supports more effective risk sharing and operational continuity. This observation extends prior concerns regarding incentive alignment and stakeholder coordination in advanced service models (Alghisi & Saccani, 2015) by demonstrating how coherent ecosystem design contributes to implementation stability.

Importantly, these practices are not isolated managerial tools but emerge as elements of coherent configurations. Successful XaaS implementations are characterized by structural consistency among value proposition, economic logic, resource deployment, and organizational culture. In contrast, configurations marked by partial adoption, such as introducing subscription pricing without redefining lifecycle responsibility or capability structures, tend to reproduce the tensions described in the servitization literature.

By linking recurring adoption patterns to differentiated challenges and mitigation practices, the study enriches the implementation literature in two interrelated ways. First, it shifts the analytical focus from linear transformation narratives to multidimensional configuration analysis, showing that implementation outcomes depend on the coherence of structural elements rather than on the mere adoption of service-based mechanisms. Second, it provides an empirical explanation for the heterogeneity of servitization outcomes documented in prior research, thereby advancing understanding of why similar initiatives may generate divergent results across manufacturing firms.

8.1.4 XaaS and environmental sustainability mechanisms

A fourth stream of literature examined concerns the potential relationship between advanced service-base business models and environmental sustainability. Several contributions suggest that access-

based and Product-as-a-Service configurations may generate environmental benefits by altering incentives related to ownership, lifecycle responsibility, and resource utilization. In particular, the retention of ownership by the provider is frequently associated with stronger incentives to extend product lifecycles, improve durability, and implement circular strategies such as reuse, refurbishment, and remanufacturing (Benedettini, 2025; Duberg & Sakao, 2024).

Analytical and modelling-based studies further indicate that PaaS arrangements may facilitate product take-back systems and increase component reuse at end-of-life stages, thereby improving resource efficiency (Kjaer et al., 2019; Moreno et al., 2016). Similarly, the integration of remanufacturing practices within service-based systems has been shown to reduce uncertainty in the availability of returned products ("cores"), supporting the development of closed-loop supply chains (Golinska-Dawson et al., 2025). While these contributions provide important insights into the sustainability potential of servitized configurations, much of the existing literature remains either conceptual or based on modelling assumptions rather than on systematic empirical mapping of implemented offerings.

Moreover, prior research emphasizes that different sustainable servitization approaches may generate environmental value through distinct mechanisms, such as lifecycle extension or operational efficiency improvements, and therefore require differentiated organizational practices and resource structures (Benedettini & Adrodegari, 2026). This suggests that sustainability outcomes cannot be assumed as automatic consequences of service-based transformation but depend on how specific business model elements are configured and governed.

The empirical findings of this study contribute to clarifying these mechanisms within manufacturing contexts. By analyzing the environmental sustainability dimension of the framework across the 17 cases, the study shows that environmental outcomes are closely linked to structural features of XaaS configurations. In particular, cases characterized by retained lifecycle responsibility and integrated monitoring capabilities exhibit stronger alignment between economic incentives and resource efficiency. In such configurations, the logic of providing value-in-use rather than transferring ownership encourages maintenance optimization, durability enhancement, and more controlled asset utilization over time.

Conversely, configurations in which service-based elements are introduced without fully integrating lifecycle responsibility or data-enabled monitoring display more limited environmental differentiation compared to traditional servitized offerings. This finding supports prior arguments that sustainable servitization requires coherent alignment between ownership logic, capability structures, and incentive systems (Benedettini & Adrodegari, 2026), and reinforces the idea that sustainability is not an inherent attribute of XaaS but a potential outcome contingent upon configuration.

Importantly, the cross-case analysis also highlights that environmental value drivers, such as resource efficiency, product lifetime extension, and circularitym are activated through specific structural mechanisms rather than through generic service orientation. This provides empirical grounding to theoretical claims regarding the sustainability potential of access-based and outcome-based models (Benedettini, 2025; Duberg & Sakao, 2024), and complements modelling-based evidence on closed-loop systems (European Commission JRC, 2025; Golinska-Dawson et al., 2025) by demonstrating how such mechanisms materialize in real manufacturing settings.

By linking environmental outcomes to identifiable configuration elements, the study advances the sustainability debate within XaaS research. Rather than assuming a deterministic relationship between servitization and sustainability, the findings suggest that environmental performance depends on the coherence of ownership structures, monitoring infrastructures, and economic incentives embedded in the business model. In this sense, the analysis moves beyond normative expectations and contributes empirical nuance to a literature that has so far remained predominantly conceptual and modelling-driven.

8.1.5 Synthesis of interpretative insights

Taken together, the analysis developed in this chapter demonstrates that the empirical findings of the study contribute to clarifying several ambiguities and structural limitations identified in the existing XaaS and servitization literature. The discussion has shown how definitional consolidation enhances conceptual clarity, how the proposed framework addresses the lack of integrative analytical tools, how a configurational perspective deepens understanding of implementation dynamics, and how environmental sustainability outcomes emerge from specific structural mechanisms rather than from generic service orientation.

Rather than positioning XaaS as a uniform or deterministic evolution of servitization, the findings highlight its multidimensional and configuration-dependent nature. Conceptual precision, structural coherence, and alignment across business model dimensions emerge as central elements in explaining both implementation performance and sustainability implications.

Building on these interpretative insights, the following chapter synthesizes the key findings of the thesis, explicitly addresses the research questions, and articulates the theoretical and managerial contributions, limitations, and avenues for future research.

9 CHAPTER IX – CONCLUSIONS

9.1 Summary of key findings

This thesis was motivated by four major research gaps identified in the existing literature on XaaS in manufacturing. The systematic review conducted in the early stages of the research revealed persistent conceptual fragmentation, the absence of integrative analytical frameworks, limited actionable guidance for implementation, and an underdeveloped empirical understanding of the relationship between XaaS and environmental sustainability.

First, the literature was characterized by definitional ambiguity and overlapping constructs. Advanced service-based models were frequently discussed under labels such as Product-as-a-Service, subscription models, digital servitization, or outcome-based contracts, without a shared and operationally grounded definition of XaaS. In response to this gap, the thesis developed a structured definition of XaaS grounded in the comparative analysis of established service-oriented models and validated it empirically within manufacturing contexts. This definition provides conceptual clarity by identifying XaaS as an integrated solution, available on demand, that delivers value through a value-added offering tailored to customer needs.

Second, prior research lacked integrative frameworks capable of systematically characterizing XaaS configurations. Existing contributions tended to focus on isolated dimensions, such as pricing logic, technological readiness, or lifecycle implications, without offering a multidimensional analytical structure. To address this limitation, the thesis proposed an eight-dimensional framework encompassing value proposition, customers, ecosystem, organizational structure and culture, economic and financial mechanisms, resources, capabilities, and environmental sustainability. The empirical application of this framework enabled a structured mapping of XaaS offerings in manufacturing and provided a coherent basis for cross-case comparison.

Third, the literature highlighted numerous implementation challenges associated with servitization and advanced service-based models, including organizational misalignment, contractual complexity, and capability gaps. However, these challenges were typically discussed at a general level and not systematically linked to specific business model configurations. Through the empirical analysis of 17 manufacturing firms, this study identified recurring configurational patterns of XaaS adoption and demonstrated how implementation challenges and best practices emerge from the alignment, or misalignment, across structural dimensions. This configurational perspective provides a more nuanced understanding of implementation dynamics than linear transformation narratives.

Finally, although several studies have suggested that access-based and outcome-based models may contribute to environmental sustainability, empirical evidence on the mechanisms through which such

benefits materialize has remained limited. By integrating an environmental sustainability dimension within the framework and examining its application across cases, the thesis clarified how environmental value drivers, such as resource efficiency, product lifetime extension, and circularity, are activated through specific structural configurations. The findings indicate that sustainability outcomes are not automatic consequences of XaaS adoption, but contingent upon coherent alignment between ownership structures, monitoring capabilities, and economic incentives.

Taken together, these findings demonstrate that XaaS in manufacturing should be understood as a multidimensional and configuration-dependent business model transformation. Conceptual precision, structural integration, and interdimensional coherence emerge as central elements in explaining both implementation performance and sustainability implications. The following section builds on these results by explicitly addressing the research questions and articulating the theoretical implications of the study.

9.2 Theoretical Implications

This section explicitly addresses the four research questions that guided the thesis and articulates the theoretical implications of the findings.

RQ1: *How can the XaaS model be defined across fragmented research streams and terminologies?*

The findings of this study demonstrate that XaaS can be rigorously defined as an integrated solution, available on demand, that, through a value-added offering, provides the customer with exactly what they want when they need it. This definition consolidates fragmented research streams by shifting the analytical focus from isolated contractual, technological, or pricing mechanisms toward the structural characteristics of the offering itself. Rather than equating XaaS with subscription logic, pay-per-use schemes, or digital extensions of servitization, the study conceptualizes XaaS as a business model configuration grounded in the integration of products and services, flexible accessibility, and value-in-use orientation. By empirically validating this definition within manufacturing contexts, the research reduces conceptual under-boundedness and establishes clearer analytical boundaries between advanced servitized offerings and fully developed XaaS configurations. Theoretically, this contributes to stabilizing the construct of XaaS, enhancing conceptual clarity, and enabling cumulative research across previously dispersed and partially overlapping terminologies.

RQ2: *What are the key aspects that characterize XaaS configurations in manufacturing, and how can they be integrated into an analytical framework that enables their systematic description and comparison?*

The study identifies eight interdependent dimensions that collectively characterize XaaS configurations in manufacturing: value proposition, customers, ecosystem, organizational structure and culture, economic and financial mechanisms, resources, capabilities, and environmental sustainability. These dimensions are not treated as isolated variables but as structurally interrelated components of a multidimensional business model architecture. By integrating these aspects into a coherent analytical framework, the thesis advances the field beyond dimension-specific analyses and descriptive taxonomies. The framework enables systematic mapping of implemented offerings and supports cross-case comparison, thereby facilitating a configurational understanding of XaaS adoption. Theoretically, this represents a shift from linear and process-oriented narratives of servitization toward a configuration-based perspective, in which business model coherence and interdimensional alignment become central explanatory mechanisms. The framework thus provides a structured foundation for future empirical and comparative research on advanced service-based models.

RQ3: *What best practices emerge from real-world XaaS implementations in the manufacturing sector, and how can such evidence be translated into managerial guidelines to support the transformation?*

The empirical findings reveal that XaaS implementation outcomes are strongly contingent upon the degree of structural alignment across business model dimensions. Recurring challenges, such as contractual complexity, performance measurement uncertainty, and organizational misalignment, emerge particularly in configurations where revenue logic, lifecycle responsibility, and capability development are only partially integrated. Conversely, best practices are associated with coherent configurations in which value proposition design, monitoring capabilities, financial logic, and ecosystem coordination are mutually reinforcing. Rather than identifying universal managerial prescriptions, the study demonstrates that effective practices are configuration-dependent and embedded within broader structural coherence. Theoretically, these findings refine implementation research by shifting the focus from generic transformation barriers toward configuration-specific alignment dynamics. This perspective provides a more nuanced explanation of the heterogeneous

outcomes observed in servitization initiatives and contributes to advancing theory on advanced service-based business model implementation.

RQ4: *Which environmental sustainability aspects are affected by XaaS models, what is the impact of XaaS adoption on sustainability performance, and how can the XaaS model be designed and leveraged to achieve environmental sustainability results?*

The study demonstrates that environmental sustainability outcomes in XaaS configurations are contingent upon specific structural mechanisms rather than automatically generated by service-based transformation. Environmental value drivers, such as resource efficiency, product lifetime extension, and circularity, are activated when ownership structures, monitoring capabilities, and economic incentives are coherently aligned within the business model. XaaS configurations that retain lifecycle responsibility and integrate data-enabled monitoring infrastructures exhibit stronger coupling between economic performance and environmental efficiency. In contrast, fragmented or partial configurations display limited sustainability differentiation. The findings therefore clarify that sustainability in XaaS is an emergent property of business model coherence rather than an inherent characteristic of access-based logic. Theoretically, this contributes to the sustainable servitization debate by operationalizing and empirically validating the mechanisms linking advanced service-based models to environmental performance. It moves the discussion beyond normative expectations and provides a configuration-based explanation of how environmental outcomes materialize in manufacturing contexts. Taken together, these responses demonstrate that XaaS in manufacturing represents a multidimensional and configuration-dependent transformation. By consolidating conceptual foundations, proposing an integrative analytical framework, empirically identifying configurational patterns, and clarifying sustainability mechanisms, this thesis advances theoretical understanding of advanced service-based business models and establishes a structured basis for future research development.

9.3 Practical Applications

Beyond its theoretical contributions, this thesis provides structured and actionable implications for managers operating in manufacturing contexts who are considering or currently implementing XaaS configurations.

First, the research offers a clarified and operational definition of XaaS that helps managers distinguish advanced service offerings from fully developed XaaS business models. In practice, this reduces the risk of superficial or partial transformations in which subscription mechanisms or digital add-ons are

introduced without a coherent redesign of the overall business model. By explicitly identifying XaaS as an integrated, on-demand, value-added solution, the study provides a clear reference point for managerial alignment.

Second, the eight-dimensional framework developed and empirically applied throughout the thesis functions as a diagnostic and interpretative tool. Consistent with the conclusions drawn in prior framework-based research, its value does not lie merely in descriptive classification but in its ability to make structural interdependencies explicit. Managers can use the framework to systematically map their current configuration, identify misalignments across dimensions (e.g., between pricing logic and monitoring capabilities, or between value proposition and internal competencies), and clarify which organisational areas require prioritised intervention.

In particular, the configurational evidence emerging from the cross-case analysis demonstrates that XaaS implementation challenges are rarely isolated problems. Rather, they stem from partial alignment across value proposition, economic mechanisms, resource base, and organisational capabilities. From a managerial perspective, this implies that transformation initiatives should not be approached through isolated functional projects (e.g., introducing pay-per-use pricing or installing IoT sensors), but through coordinated redesign across interdependent dimensions.

Third, the empirical findings on implementation challenges and best practices provide guidance for reducing transformation risk. The results indicate that firms achieving greater stability in XaaS adoption exhibit:

- coherence between value proposition design and capability development;
- integration of monitoring infrastructures with financial and contractual mechanisms;
- structured ecosystem coordination to distribute operational and financial risk.

These insights suggest that managers should prioritise capability-building in data management, lifecycle cost analysis, and risk assessment before extending advanced pricing schemes or outcome-based contracts. In line with evidence from the literature , structured frameworks can support this sequencing by clarifying readiness gaps and preventing premature business model commitments.

Fourth, the sustainability findings provide practical guidance for companies aiming to leverage XaaS for environmental improvement. The research demonstrates that environmental benefits are not automatic consequences of service-based transformation. Instead, they materialise when ownership retention, lifecycle responsibility, monitoring technologies, and revenue logic are coherently aligned. Managers seeking to achieve sustainability outcomes through XaaS must therefore intentionally design product-life extension strategies, reverse logistics processes, and performance-based incentives rather than assuming that access-based logic alone guarantees environmental improvement.

Finally, the framework offers particular value for small and medium-sized manufacturers or firms with limited internal experience in advanced service-based transformation. By structuring the transformation into clearly defined dimensions and variables, it reduces ambiguity, supports internal alignment across functions, and facilitates more informed strategic decision-making. In this sense, the framework acts not as a prescriptive model, but as a structured reasoning device that helps organisations approach XaaS adoption in an ordered and coherent manner, minimising the likelihood of fragmented or inconsistent implementation.

Overall, the practical contribution of this thesis lies in translating conceptual clarification and configurational evidence into a structured managerial support tool. By combining definitional precision, multidimensional analysis, and empirical validation, the study provides manufacturing firms with a coherent reference architecture for designing, assessing, and evolving XaaS business models.

9.4 Limitations of the study

As with any research endeavour, this study presents several limitations that should be acknowledged when interpreting its findings.

First, the empirical investigation is based on a multiple case study approach limited to 17 manufacturing firms. Although this number allows meaningful cross-case comparison and configurational analysis, the qualitative nature of the research design does not allow for statistical generalisation. The findings should therefore be interpreted as analytically generalisable within comparable manufacturing contexts rather than universally representative of all XaaS implementations.

Second, the study adopts a cross-sectional perspective. While the cases analysed provide insight into different stages of XaaS adoption, the research does not longitudinally track business model evolution over time. As a result, dynamic processes such as capability maturation, contractual renegotiation, or long-term sustainability performance improvements are inferred from structural configurations rather than directly observed across extended temporal horizons.

Third, although the proposed eight-dimensional framework integrates multiple structural elements of XaaS configurations, it necessarily represents a simplified abstraction of complex organisational realities. The framework captures the most recurrent and theoretically grounded variables emerging from the literature and empirical analysis; however, it does not exhaust all possible contextual contingencies. Industry-specific regulatory environments, macroeconomic conditions, and firm-level historical trajectories may influence XaaS adoption patterns beyond the scope of the present model.

Fourth, the sustainability analysis focuses on environmental dimensions embedded within the business model configuration. While this provides important insight into mechanisms such as resource efficiency, lifecycle extension, and circularity, the study does not quantitatively measure environmental performance outcomes. The assessment is therefore based on structural alignment and reported practices rather than on lifecycle assessment (LCA) data or environmental impact metrics.
Finally, the study is situated within the manufacturing sector and primarily examines business-to-business (B2B) contexts. The applicability of the findings to consumer markets or to purely digital XaaS environments may therefore be limited. The structural mechanisms identified in this research are grounded in asset-intensive, industrial settings and may require adaptation in other sectors.
These limitations do not undermine the contributions of the thesis but rather delimit its scope. They provide a foundation for identifying promising avenues for further investigation, which are outlined in the following section.

9.5 Suggestions for future research

Building upon the limitations identified above, several promising avenues for future research emerge. First, further empirical validation of the proposed framework through quantitative and mixed-method approaches would strengthen its generalisability. Large-scale surveys or configurational quantitative techniques could test the robustness of the eight-dimensional structure across broader samples of manufacturing firms. Such studies would allow examination of statistical relationships among dimensions and provide additional evidence regarding the performance implications of different XaaS configurations.
Second, longitudinal research designs would significantly enhance understanding of the dynamic evolution of XaaS business models. Future studies could track firms over extended periods to observe how capability development, organisational restructuring, contractual refinement, and ecosystem coordination evolve throughout the transformation process. This would allow scholars to move beyond structural snapshots and better capture path dependencies, sequencing effects, and capability maturation dynamics.
Third, the relationship between XaaS configurations and environmental sustainability outcomes warrants deeper investigation. While this study clarifies the structural mechanisms linking ownership retention, monitoring infrastructures, and revenue logic to sustainability potential, future research could integrate quantitative environmental performance measurements, such as lifecycle assessment (LCA), carbon footprint analysis, or material flow indicators. Such analyses would provide empirical validation of the environmental effects inferred from configurational alignment.

Fourth, comparative research across industries and market contexts would extend the scope of the findings. The present study focuses on manufacturing firms operating primarily in business-to-business settings. Future research could explore how XaaS configurations differ in consumer markets, in asset-light industries, or in purely digital service environments. Cross-sectoral comparisons would help determine which structural mechanisms are context-specific and which represent generalizable features of XaaS business models.

Fifth, future studies could further refine the configurational perspective by examining performance heterogeneity across different XaaS archetypes. The identification of recurring configuration patterns in this thesis opens the possibility of developing typologies that systematically link structural coherence to economic, relational, and environmental outcomes. Such research would advance understanding of why some XaaS transformations achieve sustained performance improvements while others struggle to stabilise.

Finally, additional research could explore the role of institutional and regulatory environments in shaping XaaS adoption. Financial regulation, accounting standards, environmental policy frameworks, and industry norms may influence the feasibility and attractiveness of ownership-retaining and outcome-based models. Incorporating these external dimensions would enrich the current framework and provide a more comprehensive understanding of XaaS diffusion dynamics.

Overall, future research should continue advancing from descriptive accounts of servitization toward analytically grounded, multidimensional, and empirically validated models of XaaS transformation. By combining configurational analysis, longitudinal evidence, and objective performance measurement, scholars can further consolidate the theoretical foundations of XaaS and support its responsible and sustainable development in manufacturing and beyond.

APPENDIX A - MAIN PRODUCT-SERVICE-ORIENTED DEFINITIONS

Object	Definitions + ref.	integrated solution	added value services	revenues streams	ownership transfer	revenue driver	risk assumption	customer involvement	partnership
PSS	a marketable set of products and services capable of jointly fulfilling a user's needs - A product service-system is a system of products, services, networks of "players" and supporting infrastructure that continuously strives to be competitive, satisfy customer needs and have a lower environmental impact than traditional business models (Goedkoop et al., 1999)-PSS is a system of products, services, supporting networks and infrastructure that is designed to be competitive, satisfy customers' needs and have a lower environmental impact than traditional business models (Mont, 2004)-A Product-Service System can be defined as the result of an innovation strategy, shifting the business focus from designing and selling physical products only, to selling a system o products and services which are jointly capable of fulfilling specific client demands (Manzini and Vezzoli, 2002)-A pure product system is one in which all property rights are transferred from the product provider to the client on the point of sale [..]. A pure service system is one in which all property rights remain with the service provider, and the clients obtain no other right besides consuming the service. A product-service system is a mixture [..] of the above. It requires that property rights remain distributed between client and provider, requiring more or less interaction over the life time of the PSS (Hockerts and Weaver, 2002)-A Product-Service System consists of tangible products and intangible services designed and combined so that they are jointly capable of fulfilling specific needs of customers - Product service (PS): a value proposition that consists of a mix of tangible products and intangible services designed and combined so that they are jointly capable of fulfilling integrated, final customer needs. Product-service system (PSS): The product-service including the network and infrastructure needed to 'produce' a product-service (Tukker and Tischner, 2006)-A Product-Service System (PSS) is an integrated bundle of products and services which aims at creating customer utility and generating value (Boehm and Thomas, 2013)-The term PSS includes the product-service itself, the enterprise network and the infrastructures needed (Peruzzini et al., 2013b)-A PSS consists of tangible products and intangible services, designed and combined so that they are jointly capable of fulfilling specific customer needs. Additionally PSS tries to reach the goals of sustainable development (Brandsotter, 2003)-'Product Service-Systems (PSS) may be defined as a solution offered for sale that involves both a product and a service element, to deliver the required functionality (Wong, 2004)-A product service-system is defined as a system of products, services, supporting networks and infrastructure that is designed to [be]: Competitive, Satisfy customer needs, & Have a lower environmental impact than traditional business models (ELIMA, 2005)-A PSS is an integrated product and service offering that delivers value in use. A PSS offers the opportunity to decouple economic success from material consumption and hence reduce the environmental impact of economic activity. The PSS logic is premised on utilizing the knowledge of the designermanufacturer to both increase value as an output (Baines et al., 2007)-A pre-designed system of products, supporting infrastructure and necessary networks that fulfil a users needs on the market, have a smaller environmental impact than separate product and services with the same function fulfilment and are self learning (Centre for Sustainable Design, 2002)-From a traditional marketing perspective, the notion of PSS originates from the shift of marketing focus from products (whose characteristics are related to its material components) to a more complex combination of products and services supporting production and consumption. From a service marketing perspective, the PSS represents the evolution of traditional generic and standardized services towards targeted and personalized ones. This perspective reflects the trend away from mass production that characterizes several production sectors. From a product management perspective, the notion of PSS refers to the extension of the service component around the product for business activities that are traditionally product-oriented or the introduction of a new service component marketed as a product for business activities that are usually service-oriented (Morelli, 2002)-Product service systems (PSSs) are marketable sets of products and services capable of jointly fulfilling users' needs. The PSS concept aims at minimization of environmental impacts with use of alternative production and consumption patterns (Komoto et al., 2005)-tangible artefacts and intangible services are conflated through design processes so that they are jointly capable of fulfilling specific customer needs (Cook et al., 2006)-innovation strategies where instead of focusing on the value of selling physical products, one focuses on the value of the utility of products and services throughout the product's life period (Tan et al., 2007)-The product-service system (PSS) proposition is an attempt to use existing industrial and commercial structures to create radically environmentally improved products by treating them as services (Evans et al., 2007)-Product-Service Systems are defined as customer life cycle-oriented combinations of products and services, realized in an extended value creation network, comprising a manufacturer as well as suppliers and service partners (Aurich et al., 2007)-We define PSSs as systems made up service units and physical objects. The physical objects are functional entities that carry out the elementary functions of the system, the service units are entities (mainly technical) that will ensure the smooth functioning of the whole system. These elements have relationships and interactions that lead to take into account the specificities of each ones during the design process (Maussang et al., 2009)-PSS combine physical products and services in a system to deliver required user functionality (Aurich et al., 2009)-Product-service system (PSS) has emerged as a concept to maintain the functionality of product for customers throughout the whole product lifecycle, which is supported by physical product	X	X		X	X		X	X

Object	Definitions + ref.	integrated solution	added value services	revenues streams	ownership transfer	revenue driver	risk assumption	customer involvement	partnership
	together with corresponding services (Geng et al., 2010) -we use the term product–service system (PSS) as a conceptual framework for the cooperative design and delivery of value bundles to take place in (Becker et al., 2010)-can be defined as customer life cycle-oriented combinations of products and services to provide a higher customer value (Meier et al., 2011)-The basic idea behind the Product–Service System concept is that it ensues from an innovation strategy, shifting the business focus from the design and sales of physical products to the design and sales of a system consisting of products, services, supporting networks and infrastructures, which are jointly capable of fulfiling specific client demands (Cavalieri & Pezzotta, 2012)-A PSS can be described as an integrated system of products, services and socio-economical stakeholders, designed to fulfil a specific client need, with the word system referring to both the system of products and services delivered to the customer, and the system of actors that produce and deliver the combination of products and services (Ceschin, 2013)-A product service system (PSS) is an integrated bundle of products and services which aims at creating customer utility and generating value (Boehm & Thomas, 2013)-Product-Service Systems (PSS) integrate product and service elements and thus are a basis for better differentiation from the competition, better fulfillment of customer demand and sustainability (Schenkl et al., 2014)-PSS are understood to comprise both products and services, which are combined to provide units of service which satisfy customer requirements for functionality (Cook, 2014)-"Product-Service Systems (PSS) incorporate a system of products, services and infrastructure to fulfill individual customer needs (Exner et al., 2016)-"PSS is a specific type of value proposition that offers a product in combination with a service. These products and services are delivered jointly to fulfill final customer needs. The delivery process needs to include not only the phase of use of the products and/or services, but also other customer activities (Kimita & Shimomura, 2014)-Product service systems (PSS) are bundles of physical technological elements and service elements that are integrated to solve customer problems (Berkovich et al., 2014)-A product-service consists of a mix of tangible products and intangible services designed and combined to increase the value for customers (Peruzzini & Germani, 2014)-a product-service system (PSS) is an integrated system in which the traditional functionality of a product is expanded by additional services. PSS shift the focus to the usage of the product, that is, the customer doesn't pay for the possession of a product, but for the use of the product or for the functionality he receives (Maisenbacher et al., 2014)-The product–service system (PSS) is an emerging manufacturing paradigm providing integrated product and service that delivers value in use, and it constitutes a basis of competitive strategy (Song et al., 2015)-The concept seeks to replace personal ownership and excess material consumption with alternative utilization options providing a mix of tangible products and intangible services that are more closely focused on the consumer's end desire (Armstrong et al., 2015)-Product–service systems (PSS) are not only 'a marketable set of products and services capable of jointly fulfilling a user's need' (Goedkoop et al., 1999), but equal a shift from designing physical products to designing a system of products and services. This in turn equals a shift from providing a product to selling satisfaction (Gelbmann & Hammerl, 2015)-PSS are defined as a marketable set of products and services that are capable of jointly fulfilling customers' needs in an economical and sustainable manner (Reim et al., 2015)-The PSS can be defined as a system that combines marketable products and services to meet customer demands (Chou et al., 2015)-the design of product-service systems – defined as a mix of products and services that have been designed and combined so that they are jointly capable of fulfilling final customer needs (Joore & Brezet, 2015)-combination of product and services to provide a performance (Azcárate-Aguerre et al., 2018)-PSS: a focus shift from selling just products to selling functions through a mix of products and services while fulfilling the same consumer demands with less environmental impact; selling the service that the customer needs rather than the product itself (Karaca et al., 2018)-a change process wherein manufacturing companies embrace service orientation and/or develop more and better services, with the aim to satisfy customer's needs, achieve competitive advantages and enhance firm performance (Kamal et al., 2020)-deliver functionality, rather than ownership (Bocken et al., 2014)-Whereas the concept of servitization tends to deal more with the manufacturer undergoing transformation to offer more services, the PSS field identifies specific ways in which services are bundled (and more importantly, integrated with) products to provide enhanced benefits to a given customer. In other words, it is more focused on the customer, and the way in which the manufacturer delivers an integrated service to them, rather than focusing solely on the manufacturer alone (Webb & Bil, 2011)-Product-Service-Systems (PSS) are a combination of products and services, whereby services can be digital. This makes smart services a subset of PSS. (Rabe et al., 2018)-PSS, as a special case of servitisation focuses on the combination of products and services to deliver customer value (Baxter et al., 2009)								
Servitization	the strategic innovation of organisations' capabilities and processes to shift from selling products to selling an integrated product and service offering, i.e., a Product-Service System (PSS) (Martinez et al., 2010)-Servitisation is considered as a position where product and service are inseparable (Baxter et al., 2009)-the increased offering of fuller market packages or 'bundles' of customer focussed combinations of goods, services, support, self-service and knowledge in order to add value to core product offerings (Vandermerwe and Rada, 1988)-A trend in which manufacturing firms adopt more and more service components in their offerings (Desmet et al., 2003)-The emergence of product-based services which blur the distinction between manufacturing and traditional service sector activities (Tellus institute, 1999)-Adding extra service components to core products (Verstrepen and Van Den Berg, 1999)-An integrated bundle of both goods and services (Robinson et al., 2002)-Any strategy that seeks to change the way in which a product functionality is delivered to its markets (Lewis et al., 2004)-Increasing the range of services offered by a manufacturer (Ward and graves, 2005)-A change process wherein manufacturing	X	X		X	X			

Object	Definitions + ref.	integrated solution	added value services	revenues streams	ownership transfer	revenue driver	risk assumption	customer involvement	partnership
	companies embrace servcie orientation and/or develop more and better services, with the aim to satisfy customer's needs, achieve competitive advantages and enhance firm performance (Ren and Gregory, 2007)-Generally, the term 'servitisation' in manufacturing refers to the delivery of value to a customer without the transfer of ownership of an asset (Buerkle et al., 2023)								
Advanced Service	complex value propositions whereby manufacturers focus on providing performance outcomes to customers - These outcomes often include: 1) revenue payments structured around product usage; 2) performance incentives—such as penalties for product failure when in service; 3) long-term contractual agreements, spanning 5, 10, or 15 years, and cost-down commitments; and 4) life cycle environmental improvements such as carbon footprints. Servitization is often presented as a decision taken by manufacturers choosing to expand their portfolio to include advanced services offerings (Schroeder et al., 2022)-Advanced Services would focus on the delivery of an outcome to a customer, resulting in customer support agreements or Outcome Based Contracts (OBCs). Advanced services represent the most advanced form of servitization and are what many companies aim for when transitioning to a service-based approach (Wood & Godsiff, 2021)-an integrated solution of product(s) and associated services - if the service relies on a product, that product may be material (e.g., an engine) or digital (e.g., a piece of software) - focuses on the delivery of a measurable customer-desired outcome - value comes from use and is determined by consumer - outcome forms the basis of a form of Outcome-Based-Contract (OBC) - performance incentives (including penalties) form part of the OBC - regular payment structure (whilst outcome is being delivered) - the actors that are involved will include, at minimum, the Operator (service provider) and Customer (service consumer) but may also include an OEM (service supplier) and intermediaries (additional agents required for service delivery e.g., for infrastructure) (Wood & Godsiff, 2021)-a capability delivered through product performance and often featuring: relationship over (an) extended life-cycle, extended responsibilities and regular revenue payments (Baines & Lightfoot, 2013)-advanced services intend to minimize the total cost of ownership and even to provide for a product's end-of-life (Rönnberg Sjödin et al., 2016)	X		X		X		X	X
Subscription Models	subscription models enable to focus on offering integrated bundles of products and services, a long-term business relation between supplier and customer, on a fulfilment of customer needs and benefits as well as a realization of Industry 4.0 potentials for their suppliers. A subscription model is defined by a continuous delivery of its value proposition for a periodic recurring fee. "Power-by-the-Hour" was introduced as a usage-based subscription model (Riesener et al., 2020) -Hansen distinguishes between six different types of use: unit-based, usage-based, user-based, unlimited, tiered and hybrid, as a combination of the further models. In unit-based subscription the customer receives a certain offer of a product for a fixed price. The main aspect of the usage-based subscription model is that costumers pay the price for the effective usage of the product. The user-based model focuses on the number of individual users. Within the traditional subscription model of Spotify and Netflix, the customer receives an unlimited access to products and services. In the tiered model, the customers get the opportunity to decide between different subscription options and services (Hansen, 2014)-car subscription models provide drivers with medium-term access to vehicles (usually from one to three years) through the payment of a monthly fee, which varies depending on the car model and the distance to be traveled. in subscription models, customers do not have the cost of ownership (except fuel), which includes the substantial upfront cost for acquisition and taxes. Moreover, the automaker is responsible for providing services such as maintenance, overhaul, spare part replacement, and insurance to guarantee the desired car availability, which generally differs from some leasing contracts. Therefore, car subscription businessmodels aremore complex than other use-oriented options (Smania et al., 2023)-The subscription-based structure generates continuous and predictable revenues and predictable costs (Häckel et al., 2022)	X		X		X		X	X
Use-oriented (PSS - business model - system)	Usage-based structures allow to only pay for their actual service use and avoid fixed costs (Häckel et al., 2022)-For use oriented Product–Service Systems ownership of the tangible product is retained by the service provider, who sells the functions of the product, via modified distribution and payment systems, such as sharing, pooling, and leasing (Neely, 2008)-Use-oriented: sale of products, since ownership of the good is not transferred to the customer. The product is made available to the customer in several ways, which pays for its use (Chiarot et al., 2022)-Use-oriented BMs combine products and services without transferring ownership of the underlying asset to the customers (Tukker, 2004)-PSS: an integrated combination of products and services in which suppliers, through a customised contract for availability (CfA), meet the requirements of the contractor - In a use-oriented PSS, there is a shift of ownership of the product, as the manufacturer or retailer retains ownership of it offering a functional "service unit" through leasing or renting the product to the user. Those business models based on offering product access and retaining ownership to internalise benefits of circular resource productivity mainly through a product-oriented PSS (i.e., products are sold to users, but additional services are added such as insurance or maintenance) or a use oriented PSS (i.e., products are leased or rented to the user) (Bech et al., 2019)-In this case the product is not owned by the customer anymore but is made available (e.g. through leasing) for customer-usage through the producer. High rates of usage as well as a long lifecycle of their products are the main goals for companies offering these product-service-systems (Kernschmid et al., 2016)-Use-oriented systems in which	X	X	X	X	X			

Object	Definitions + ref.	integrated solution	added value services	revenues streams	ownership transfer	revenue driver	risk assumption	customer involvement	partnership
	ownership of the product remains with the service-provider and the consumer purchases the product function through, for example, leasing systems (Costa et al., 2015)								
Result-oriented (PSS - business model - contact)	In result oriented Product–Service Systems, the PSS replaces services for products—e.g. voicemail service replacing answering machines (Neely, 2008)-Result-oriented: the customer and the supplier agree on a final result and there is no predefined product. It consists of the sale of a result or competence. Thus, the PSS provider also retains ownership of the product, being paid for the solution provided (Chiarot et al., 2022)-The plant remains in the ownership of the provider. The customer pays depending on the respective result. In the result-oriented business model, company is responsible for all phases of the life cycle of the plant (Rathmann et al., 2014)-This is the most complex type of a PSS, selling a desired result in place of a product (e.g. the offering of washed clothes instead of selling washing machines). The ownership as well as the decision of technology, maintenance, disposal etc. stays with the producer. Thus, the development of this PSS has to focus on the changed business model for which the consumer only pays per obtained output (Kernschmid et al., 2016)-Results-oriented PSS in which product sale is replaced by sale-of-service and the consumer may not encounter the tangible product (Costa et al., 2015)	X	X		X	X	X	X	
outcome-based contracts	contracting mechanism that allows the customer to pay only when the firm has delivered outcomes, rather than merely activities and tasks (Ng et al., 2009)-The service outcomes can be specified very broadly in terms of results, i.e. outcomes resulting from use, such as paying for every day that is incident-free in the security of a building, or they can be specified in terms of use, such as a bank of flying hours of a plane (Batista et al., 2017)-we define an OBC as 'an agreement between the provider and the customer that the provider provides total solutions and is paid based on the outcomes of the solutions or the outcomes of customer value in a continual use situation' (Hou & Neely, 2018) -Outcome-based contract: In an outcome-based contract2 (OBC), a manufacturer sells the outcome that a manufacturing process creates instead of the resources required for outcome creation (e.g., machinery, equipment), with payments based on the process outcome. we define an OBC as contract that incentivizes outcomes related to the customer's business processes instead of the resources required for these processes. contracted outcomes in a continual use situation, requires quantifiable indicators. These terms include 'performance-based contracting', 'usage-based pricing', 'performance-based logistics', 'pay-for-performance', 'pay-per-use', 'product-service systems', 'advanced services', 'procuring complex performance'. OBCs can be distinguished depending on the type of outcome considered: OBCs based on availability or OBCs based on economic results. Several design elements need to be specified in OBCs: (a) outcome measures, (b) payment and incentives, and (c) responsibilities (Schaefers et al., 2021)-outcome-based contracts include guaranteeing to deliver specific outcomes required by the customer and often involve combining diverse products and services to deliver the outcome (Visnjic et al., 2017)-the manufacturer can identify if a particular part performed in accordance with specification - The distinction is between outcomes based on availability (aOBCs) and outcomes based on economic results (eOBCs) (Grubic & Jennions, 2018)-"In the case of functional products, the customer pays only for a functional performance and does not buy the hardware … Since the customer pays only for the function …" (p. 537) (Alonso-Rasgado et al., 2004)-"'The essence of Performance Based Logistics is buying performance outcomes, not the individual parts and repair actions …" (p. 1843/1844) (Kim et al., 2007)-"[OBC] is a contracting mechanism that allows the customer to pay only when the firm has delivered outcomes, rather than merely activities and tasks. If one considers the famous quote from Levitt where 'the customer really doesn't want a drilling machine, he wants a hole-in-the-wall', outcome-based contracts considers the possibility of customers paying only for holes in walls … In essence, outcome-based contracts drives home the concept of value- in-use, where value is defined as the benefit the customer obtains through use …" (p. 377) - "In short, the buyer purchases the result of the product used (utilisation of service or performance outcomes) and not ownership of the product." (p. 380) (Ng et al., 2009)-"Under PBC (Performance based contract), compensation to a supplier is based on realized service outcomes such as equipment uptime or response time that are directly related to the value created by the customer through the operation of the system." (p. 1552) (Kim et al., 2010)-"… the basic idea of PBC is that the customer purchases performance instead of the capital goods themselves." (p. 648) (Hypko et al., 2010)-"OBC is a contracting mechanism that allows the customer to pay only when the firm has delivered outcomes, rather than for merely activities and tasks. OBC focuses on achieving required outcomes rather than performing to a set of prescribed specifications. In short, the buyer purchases the result of the product used (utilisation of service or outcome) and not ownership of the product." (p. 659) (Ng and Nudurupati, 2010)-"The performance-based contracting tends to focus on achieving a required outcome rather than a contract for the supply of a set of prescribed specifications. Thus, the buyer purchases the result of product use not ownership of the product … Performance-based contracts are an example of result-oriented industrial PSS." (p. 583) (Priya Datta and Roy, 2011)-"a new form of a support contract has emerged in recent years: performance-based contracts (PBC) … a supplier is paid based on the realized outcome of customer value." (p. 961) (Guajardo et al., 2012)-"There, the buyers no longer specify the individual components of a solution (e.g. a machine and related services) but rather the desired outcome (as the value expected from the solution), whereas the suppliers' compensation is tied to successfully achieving this outcome." (p. 185) (Kleemann and Essig, 2013)-"[OBC] based on the outcome of such activities in continual use situations i.e., the number of hours of engine in the air. This is analogous to the well-known story in marketing of being paid for holes-in-walls, rather than for the	X	X	X	X	X	X	X	

Object	Definitions + ref.	integrated solution	added value services	revenues streams	ownership transfer	revenue driver	risk assumption	customer involvement	partnership
	maintenance, repair and upkeep of the drill." (p. 731) (Ng et al., 2013)-In a result-oriented PSS the product's functional results are sold, that directly fulfil customer needs (type 3) (Van Ostaeyen et al., 2013)-"PBL can be viewed as a result-oriented PSS …" (p. 960) (Holmbom et al., 2014)-"PBC can be brieflydefined as the contractual approach of tying at least a portion of supplier payment to performance. The key characteristic of PBC is an emphasis on specification and evaluation of outputs or outcomes rather than required inputs, activities or processes." (p. 3505) (Selviaridis and Wynstra, 2015)-"The essence of outcome-based contracting is the buying of relevant business outcomes rather than resources (such as spare parts or repair actions) required for their provision." (p. 129) (Böhm et al., 2016)-"PBC is defined as a contract which provides incentives for business outcomes. This means that a service provider is compensated according to the contribution made to the business results of the service buyer and pricing depends (at least to a certain extend) on the service performance level that is actually rendered." (p. 5/6) (Essig et al., 2016)-"PBC 'is a results-oriented contracting method that focuses on the outputs, quality, or outcomes that may tie at least a portion of a contractor's payment, contract extensions, or contract renewals to the achievement of specific, measurable performance standards and requirements.'" (p. 40) (Liinamaa et al., 2016)-"Such outcome-based contracts focus on achieving required outcomes rather than meeting a set of prescribed service levels." (p. 133) (Batista et al., 2017)-"The service outcomes can be specified very broadly in terms of results, i.e. outcomes resulting from use …" (p. 134) (Batista et al., 2017)-"The outcome-based contracts include guaranteeing to deliver specific outcomes required by the customer and often involve combining diverse products and services to deliver the outcome." (p. 169) (Visnjic et al., 2017)-"we define an OBC as 'an agreement between the provider and the customer that the provider provides total solutions and is paid based on the outcomes of the solutions or the outcomes of customer value in a continual use situation'…" (p. 2) (Hou and Neely, 2018)-"Outcome delivery entails offering guarantees to deliver specific outcomes required by the customer …" (p. 2) (Visnjic et al., 2018)-"'advanced services'– 'services whose outcome focuses on capability delivered through product performance'" (p. 1) (Ziaee Bigdeli et al., 2018)-outcome-based contracts include guaranteeing to deliver specific outcomes required by the customer and often involve combining diverse products and services to deliver the outcome (Visnjic et al., 2017)-highly advanced services (e.g. outcome-based contracts) (Visnjic et al., 2018)								

APPENDIX B - RESEARCH PROTOCOL

B.1 Preliminary questionnaire

Company:
Name and surname:
Role:
Brief description of the company's XaaS offering:
ORGANIZATION
1. How would you rate the following aspects related to your company's service culture? (1= Absent; 2=Low; 3=Medium; 4=High; 5=Optimal)
Overall service orientation and culture of the organization
Top management commitment: drive change and establish a service culture
Service orientation and attitude of sales and marketing personnel
Willingness to maintain the product-ownership and take operational and financial risk
2. How would you rate the following aspects of the organizational structure delivering services within your company? (1= Absent; 2=Low; 3=Medium; 4=High; 5=Optimal)
Overall adequacy of the service structure and its linkages with other functions
Establishment of a distinct service function with responsibility for strategic service development
Establishment of distinct back-office and front-office roles to improve or balance the efficiency and effectiveness of service processes
Readiness of the current service organization to support the implementation of XaaS models
CAPABILITIES
3. How would you rate the following capabilities that support the development and sales of your services? (1= Absent; 2=Low; 3=Medium; 4=High; 5=Optimal)
Capability and methods for developing new services (design, engineering, standardization, ...)
Capability to formalize and standardize services/new service offering (procedure, responsibilities, documentation, contracts, …)
Capability to communicate and make tangible the service value to the customer
Product-service solution pricing capability
Capability to define reliable outcome expectations with the customer and define the corresponding metrics/parameters to evaluate the agreed outcome
Capability to evaluate operating and financial risk, to manage uncertainty, and to design and implement safeguarding mechanisms
Capability to estimate budget and forecast cash flow
4. How would you rate the following skills supporting the customer and the partner relationship management within your company? (1= Absent; 2=Low; 3=Medium; 4=High; 5=Optimal)
Relational skills of service personnel
Capability to analyse and interpret product, service, and customer process-related data
Capability to manage a customer portfolio and identify customer segments
Capability to support the composition of service contracts (business deal/agreement) with the customers
Capability to select and evaluate suppliers'/partners' performances over time and their achievement of targets/expectations
Capability to distribute risk to other network partners
Capability to collaborate with financial partners
PROCESS MANAGEMENT
5. How would you rate the procedures and practices implemented within your company to support the development and delivery of service offerings? (1= Absent; 2=Low; 3=Medium; 4=High; 5=Optimal)
Procedures and practices for managing the involvement of different business functions (i.e. techincal dep., service, sales) in the (re)design of the product to improve serviceability
Procedures for managing service delivery processes (e.g., maintenance interventions, helpdesk/customer support)
Procedures and practices for operating risk evaluation
Procedures and practices for financial risk evaluation
Procedures and practices for aligning incentives and rewards systems of sales and marketing personnel to strategic service objectives
Procedure for managing the End-Of-Life of the products (retrofit, refurbishment, decommissioning, reverse logistics, ..)
KPI and metrics to measure the operational performances of service activities (e.g., response time, quality, …)

KPI and metrics to measure the financial performance of service activities
TECHNOLOGY
6. How would you rate the following aspects that can support the service management? (1= Absent; 2=Low; 3=Medium; 4=High; 5=Optimal)
Monitoring technologies on your products/systems that support the collection of product and process-related data (e.g., product usage, performance,..)
ICT (cloud-based) solutions that support the interpretation and analysis of product, service, and process-related data
ICT systems/applications that support cost control reporting of service activities and financial analysis

B.2 Interview guideline

ID	Questions	Dimensions	Variables
1	Please describe your XaaS offering to your customers, including: a. Physical products and/or services included b. Degree of maturity (pilot or consolidated offering) c. Scope of the offering (applies to all products or only certain categories) Is the XaaS offering provided only upon the customer's explicit request, or is it systematically proposed as part of the standard commercial process? Who owns the product that is included in the XaaS offering?	Value proposition	• Offer Object • Maturity level of the service offering • Coverage of the offering • XaaS offering approach • Ownership
2	Who is the XaaS offering targeted at?	Customers	• Traget Customer segments • Customer segmentation strategy
3	At what level and in which areas can the customer personalize the offering (product, service, entire offering, payment terms, etc.)? Is there an opportunity for co-design of the offering with the customer?	Customers	• Offer customisation (level) • Offer customization (object) • Customer involvement
4	How do you communicate the offering, and who are the actors involved in this activity?	Value proposition	• Offer communication
5	What is the level of customer interest in the XaaS offering?	Customers	• Customer acceptance
6	Who are the main strategic partners directly involved in the product–service offering, at which stage are they engaged? Is the relationship with each partner coordinated (structured and execution-focused) or collaborative (flexible and co-design-focused)?"	Ecosystem	• Presence of strategic partners • Continuity of strategic partners' engagement • Alliance governance
7	What is the level of top management commitment to the XaaS offering?	Organization structure and culture	• Level of commitment of the top management of the provider
8	How strategically aligned is the XaaS offering with the company's overall objectives?	Organization structure and culture	• Service strategy
9	How is the XaaS offering organized within the company?	Organization structure and culture	• Internal organization
10	How are sales and service delivery coordinated in your XaaS offering, and to what extent do they work together throughout the contract lifecycle?	Organization structure and culture	• Sales–Service Integration level
11	How is your distribution structure organized? Is there also a digital channel?	Organization structure and culture	• Physical distribution channel • Digital Distribution channel

12	How is the product–service offering provided to your customers remunerated (e.g., one-time payment, monthly subscription, annual subscription, hybrid solution, etc.)?	Economic and finance	• Revenue model and mechanism
13	How is the XaaS offering priced (cost-plus, market-based, or value-based)?	Economic and finance	• Pricing
14	What are the main risks associated with your product–service offering, and how are they mitigated? Is there a formalized strategy for risk management?	Economic and finance	• Main risks • Risks mitigation mechanisms • Risks mitigation strategy
15	What are the main indicators (operational, economic/financial, environmental) that you monitor?	Economic and finance	• Profitability Measurement KPI
16	Is the product included in the offering connected? If yes, do you have full access to the customer's data? Which specific data are collected?	Resources	• Data connectivity • Customer Data accessibility • Data exploitation
17	Which technologies are used in your product–service offering? What is their primary function, and how do they support the XaaS offering?	Resources	• Technology role
18	Which of these internal capabilities, considered necessary for the development of XaaS, are present in your organization? How would you assess their level of maturity? - Data-analysis capabilities - Service design capabilities - Risk assessment capabilities - Human and relational capabilities (communication and sales capabilities, cross-functional coordination and managerial competencies, ability to sell and distribute integrated product–service offerings)	Capabilities	• Data-analysis capabilities • Service design capabilities • Risk assessment capabilities • Human and relational capabilities
19	Which of these services/practices do you offer to your customers? a. End-of-life/contract product collection b. Remanufacturing services c. Preventive and predictive maintenance programs d. Development of a durable product e. Modular upgrade or component replacement f. Reuse or lifetime extension throught refurbishment g. Measurements and optimization of resource, consumption (energy, materials..) h. Implementation of eco-efficient design or processes i. Monitoring and reporting of environmental data to customers j. Digital platforms supporting traceability and reporting k. Asset sharing among multiple users l. Optimization of asset use (maximized uptime, performance-based logic) m. Multi-contract asset utilization n. Single-use or customer-specific asset o. Inclusion of second-hand products in the aaS offering	Environmental sustainability	• End-of-life and reverse logistics strategies • Product-life extension strategy • Resource efficiency • Use and service intensity
20	Are there digital components in the XaaS offering that replace or reduce the need for manual intervention by the user or technician?	Environmental sustainability	• Dematerialization and transparency

21	Does your XaaS offering allow the customer to substitute the need for other products (which do not necessarily have to be the same)?	Environmental sustainability	• Product service substitution
22	What do you consider to be the main benefits of your offering for the customer? a. the reduction in initial investment b. the content and methods of service delivery (a fast and efficient service) c. minimization of operating costs d. risk minimization e. optimization of usage processes f. guaranteed access to the product at a cost known in advance g. guarantee of functionality h. the achievement of an expected result i. simplicity (removal of complications)	Value proposition	• Offer Value

APPENDIX C – CASE PROFILES

C.1 Turboden

Company and XaaS Offering Overview

Turboden is an Italian engineering company operating globally in the field of renewable and waste-energy power generation. Founded as a spin-off of the Politecnico di Milano and later becoming part of the Mitsubishi Heavy Industries Group, Turboden specializes in the design, engineering, and delivery of Organic Rankine Cycle (ORC) plants. These systems enable the conversion of renewable sources and industrial waste heat into electricity and useful heat and are deployed in applications such as biomass plants, waste-to-energy facilities, geothermal installations, and heat recovery from energy-intensive industries including cement, steel, and glass manufacturing. Turboden's technological offering is characterized by a very high level of engineering complexity and customization. ORC plants are typically designed on a project-by-project basis, tightly integrated into the customer's industrial process, and tailored to specific thermal streams, site constraints, and regulatory contexts. Investment values range from small-scale installations of around one million euros to large geothermal plants exceeding one hundred million euros. Operational lifetimes are long, often extending beyond twenty years, which makes reliability, performance stability, and lifecycle management central concerns for both the provider and the customer. Within this project-based and asset-intensive context, Turboden has historically developed a strong service orientation. Service activities were initially conceived as a natural extension of plant delivery, driven by the fact that customers generally lack the specialized competencies required to manage complex thermodynamic systems over time. Over the years, this service dimension has grown in scale and strategic relevance, leading recently to a formal organizational reconfiguration and the creation of a dedicated Service

After Sales business unit with its own commercial, technical, and financial responsibilities. The XaaS configuration analyzed in this study concerns a **pure service-based offering**, layered on top of customer-owned ORC plants. Physical assets are sold through traditional capital-expenditure models and remain under customer ownership, while value creation increasingly takes place through long-term, digitally enabled service contracts. These services are delivered according to an as-a-service logic and are structured around multi-year agreements, typically ranging from three to ten years, with very high penetration across the installed base. Turboden's service portfolio includes long-term service agreements (LTSAs), remote monitoring, predictive and preventive maintenance, performance optimization, and advanced monitoring-as-a-service solutions. All plants are connected to Turboden's central systems, enabling continuous data collection and performance supervision. Unlike many industrial equipment suppliers, Turboden has managed operational data from its installed base since the early 2000s, accumulating more than two decades of historical performance data. This data foundation supports both internal service efficiency and customer-facing value propositions. In recent years, the service offering has evolved beyond traditional remote assistance toward more advanced, analytics-driven configurations. Turboden has developed in-house algorithms and artificial intelligence models that compare real operating data with theoretical thermodynamic models of each plant. This allows early detection of deviations, degradation patterns, and performance losses, often months in advance of potential failures. These capabilities enable a shift from reactive or time-based maintenance toward predictive and performance-oriented service logic. The service offering is modular and tiered. Basic configurations focus on remote monitoring and technical support, while premium contracts include guarantees on availability or performance. In selected pilot cases, Turboden has experimented with mechanisms that partially resemble pay-per-performance logics, where extraordinary performance improvements beyond contractual baselines are shared between the provider and the customer. These configurations remain selective and are applied only to customers deemed suitable from both a technical and financial risk perspective. Strategically, Turboden's service-based XaaS offering serves multiple objectives. It stabilizes revenues through recurring contracts in a business otherwise dominated by cyclical project sales, strengthens long-term customer relationships, and leverages the company's unique system-level knowledge of ORC plant behavior. At the same time, it responds to growing customer expectations for operational reliability, cost predictability, and performance transparency in energy generation assets that are increasingly central to decarbonization strategies and energy self-sufficiency. Overall, Turboden represents a case in which XaaS does not emerge as a substitution of product ownership, but as a **deep lifecycle-oriented service model**, enabled by digital technologies and data analytics and tightly coupled to complex, long-lived, and highly customized physical assets.

Turboden framework-based analysis

- **Value proposition**

With respect to the object of the offering, **Turboden**'s XaaS configuration is centered entirely on the **service layer**, while the physical ORC plant remains outside the as-a-service logic and is owned by the customer. The service-based nature of the offering reflects both the high level of customization and the capital intensity of ORC plants, which make ownership-based sales the preferred and structurally dominant model for the physical asset. The service offering is currently positioned in a **pilot phase**, particularly with regard to its most advanced components. While long-term service agreements and remote monitoring are already well established across the installed base, more sophisticated digital services, such as AI-supported monitoring, predictive analytics, and performance-oriented contractual elements, are being tested with a limited number of selected customers. This pilot orientation reflects a deliberate and cautious approach, aimed at validating technical reliability, economic sustainability, and customer readiness before broader deployment. The coverage of the offering is **restricted to a specific product category**, namely ORC plants, and potentially large heat pumps in the future. This limitation is not driven by strategic exclusion, but by the need for deep system-specific knowledge and thermodynamic modeling capabilities, which are essential for delivering meaningful service value in highly complex energy systems. The XaaS offering is pursued with a **proactive approach**. Service contracts and digital services are systematically proposed as part of Turboden's standard commercial process, rather than being activated only upon explicit customer request. Services are positioned as an integral component of the overall value proposition, accompanying the plant throughout its operational lifecycle. Ownership of the physical asset remains firmly with the customer. This choice is consistent with Turboden's strategic decision not to pursue product-based XaaS models, given the long operational lifetimes of plants, their bespoke engineering, and the substantial financial exposure that full asset ownership would imply for the provider. From the customer's perspective, the value of the offering is primarily oriented toward the **achievement of an expected result**. Customers seek guaranteed availability, stable and optimized performance, and a reduction in unplanned downtime. These outcomes are particularly relevant because energy generation is typically not the customer's core business activity. By outsourcing monitoring, diagnostics, and performance optimization, customers reduce operational uncertainty and managerial burden while safeguarding the continuity of energy production. The offering exhibits a **high degree of customization**, applied at the service level rather than at the physical asset level. Service contracts are tailored to the specific characteristics of each plant and customer, with customization affecting contract duration, scope of services, performance guarantees, monitoring intensity, and the degree of provider involvement. This configurability allows Turboden

to adapt the service logic to heterogeneous operational contexts while maintaining a coherent overall service architecture. Finally, communication of the offering remains **limited and highly relational**. Services are primarily sold through direct interactions and negotiated engagements with customers, rather than through standardized marketing campaigns or dedicated digital channels. This reflects both the complexity of the offering and the central role of trust, technical credibility, and long-term relationships in the commercialization of service-based solutions for large-scale energy systems.

- **Customers**

Turboden's service-based XaaS offering is primarily addressed to **consolidated customers**, with whom the company maintains long-standing relationships that often extend over several years or even decades. These customers typically operate complex industrial or energy-generation systems and have accumulated substantial experience with Turboden's technologies over time. As a result, the service offering is embedded within established commercial and operational relationships, rather than being positioned as a tool for acquiring new or previously unserved customers. From a segmentation perspective, the service-based XaaS offering is **conceptually available to all customers** operating Turboden plants. The company does not adopt a formal or differentiated customer segmentation strategy, and service contracts are not designed around predefined customer categories. However, empirical evidence shows that the **effective applicability** of more advanced service configurations, such as premium monitoring solutions, AI-supported diagnostics, or performance-based contractual elements, is assessed on a **case-by-case basis**. Factors such as the customer's organizational maturity, internal technical capabilities, operational discipline, and openness to data sharing influence whether advanced service options are proposed or implemented. Despite this selectivity in practice, the offering itself remains undifferentiated in its formal structure. In terms of customer acceptance, the offering is characterized by **limited interest**, particularly with respect to the most advanced digital and performance-oriented service components. Customers generally acknowledge the potential value of remote monitoring, predictive maintenance, and performance optimization. However, adoption tends to be cautious and gradual. Interview evidence links this hesitation to concerns about data security, internal organizational readiness, and the perceived risk associated with outcome-based or availability-based service contracts, especially in contexts where energy generation is tightly coupled to core industrial processes. Customer involvement in the XaaS offering is **collaborative**. Customers actively participate by granting access to operational data, engaging in discussions to define service scopes, and aligning with Turboden on performance targets or contractual conditions. This involvement is necessary to enable effective monitoring and performance optimization. At the same time, the design, orchestration, and execution of the service remain largely under Turboden's

responsibility. The service logic is therefore provider-led, supported by structured interaction and mutual alignment rather than by full co-creation or customer-driven service design.

- **Ecosystem**

The XaaS offering developed by **Turboden** relies on a **selective and clearly structured ecosystem** of external partners, primarily operating in the financial and technological domains. Partner involvement is not broad or open-ended, but deliberately limited to functions that complement Turboden's internal competencies without undermining its control over core system knowledge and service architecture. Financial partners are involved mainly during the **development phase** of the offering. Their role is particularly relevant in the context of research and innovation initiatives supported by regional, national, or European funding schemes. These partnerships provide financial resources and institutional support for experimentation and pilot projects, especially those related to the development of new digital tools, advanced monitoring solutions, and data-driven service concepts. Financial partners therefore contribute to reducing the risk associated with early-stage exploration, rather than playing a direct role in service delivery or customer interaction. Technological partners play a more visible role during the **delivery phase** of the XaaS offering. While Turboden deliberately retains core technological competencies in-house, such as thermodynamic modeling, process engineering, monitoring logic, and data analysis, external partners support complementary activities related to software development, cloud infrastructure, and specific digital components. This configuration allows Turboden to maintain ownership of critical knowledge and decision-making logic, while leveraging external expertise to ensure robustness, scalability, and reliability of digital services. The **continuity of partner engagement** reflects this functional differentiation. Financial partners are typically engaged on a project basis, linked to development and innovation activities, whereas technological partners are involved more continuously during service delivery, supporting the operational functioning of digital platforms and monitoring systems. Alliance governance across the ecosystem is **coordinated and formalized**. Roles, responsibilities, interfaces, and deliverables are clearly defined through contractual arrangements, with particular attention to data security, service continuity, and alignment with Turboden's internal service processes. This governance approach reflects the critical nature of the service offering, where failures or disruptions could have significant operational and reputational consequences for both Turboden and its customers. Overall, the ecosystem configuration reinforces Turboden's position as the **central orchestrator** of the XaaS offering. External partners are integrated in a controlled and purpose-specific manner, supporting innovation and delivery without diluting responsibility, accountability, or control over the service value proposition.

- **Organization structure and culture**

Top management commitment to the XaaS offering at **Turboden** is **widespread and strategic**, and is reflected in concrete organizational decisions rather than in declarative intent alone. The most visible manifestation of this commitment is the formal reorganization of the company into distinct business units and, in particular, the establishment of a dedicated **Service After Sales business unit**. This structural change marks a clear step in recognizing services as a strategic domain with its own objectives, responsibilities, and resource allocation. The internal organization supporting the XaaS offering is therefore characterized by the presence of a **new, dedicated business unit or team** that is responsible for service development, contract management, and service delivery. This unit operates with a significant degree of autonomy, enabling focus and specialization, while maintaining close interaction with other organizational functions such as engineering, IT, automation, and R&D. These interactions are essential given the technical complexity of ORC systems and the tight coupling between plant design, operational performance, and service effectiveness. The service strategy is **partially aligned and integrated** with Turboden's overall corporate strategy. XaaS initiatives are clearly recognized as strategically important, particularly in terms of stabilizing revenues, strengthening customer relationships, and leveraging the installed base through data-driven services. At the same time, services remain embedded within a broader **product-centric business model**, rather than constituting a fully independent strategic trajectory. The physical asset sale continues to represent the core of value creation, with XaaS functioning as a complementary and reinforcing layer rather than as a substitute. The level of **sales–service integration** is high and can be characterized as integrated or unified. Commercial activities related to service contracts, technical service delivery, and ongoing contract management are closely coordinated. This integration supports continuity across the entire service lifecycle, from contract negotiation to execution and renewal, and reduces the risk of misalignment between commercial promises and operational delivery. From a distribution perspective, the XaaS offering is delivered through a **disintermediated physical channel**. Turboden maintains direct relationships with end customers, which is consistent with the complexity, criticality, and long-term nature of ORC plants and related services. There is no dedicated digital distribution channel for activating or purchasing services. Digital tools are used primarily to support service execution, monitoring, and performance supervision, rather than for commercialization or customer self-service. Overall, the Organizational dimension highlights a configuration in which strong managerial commitment and structural reorganization support the consolidation of service-based XaaS activities, while strategic integration remains partial, reflecting the continued centrality of product-based project delivery within Turboden's business model.

- **Economic and finance**

Turboden's XaaS revenue model is grounded primarily in **fixed-period subscription mechanisms**, typically structured as annual or multi-year service contracts. These contracts represent the economic backbone of the service-based offering and are widely adopted across the installed base. In more advanced or premium configurations, subscription fees are complemented by **performance- or availability-based components**, particularly when contractual guarantees related to plant uptime or performance levels are included. This hybrid structure reflects the gradual evolution of the offering from traditional service contracts toward more outcome-oriented service logics, without a full shift to pure pay-per-performance models. The economic configuration exposes Turboden to **financial risk**, which represents the most relevant risk dimension of the XaaS offering. Financial exposure arises from two main sources. First, revenues are distributed over time rather than realized upfront, creating a potential dilution effect compared to traditional project-based sales. Second, performance and availability guarantees embedded in premium contracts can generate additional financial exposure if plant performance deviates from contractual baselines. Turboden does not rely on a **formalized or standardized risk mitigation framework** for XaaS offerings. Instead, risk management is conducted on a **case-by-case basis**, combining careful customer selection with tailored contractual design. Advanced service configurations are typically proposed only to customers that are perceived as reliable from both an operational and organizational standpoint, and contractual terms are adjusted to reflect the specific characteristics and risk profile of each plant. A key implicit risk mitigation mechanism is **customer and portfolio diversification**. By operating across a wide range of industries, applications, and geographical markets, Turboden reduces dependency on individual contracts and limits the financial impact of potential underperformance in specific installations. Profitability is monitored through a **combination of financial economics KPIs and operational performance KPIs**. Financial indicators focus on service revenues, margins, and contract penetration, while operational KPIs track service delivery effectiveness, plant availability, and performance levels. This dual monitoring approach reflects the hybrid nature of the XaaS model, in which traditional financial control mechanisms coexist with service-oriented performance management. Overall, the Economic dimension highlights a configuration characterized by recurring revenues, selective exposure to performance-related risk, and pragmatic, experience-based approaches to economic control rather than fully formalized XaaS risk governance.

- **Resources**

Turboden's XaaS offering is underpinned by a **robust and long-established digital and technological resource base**, which has been developed progressively over time and is deeply embedded in the company's service operations. Unlike cases in which digital infrastructure is introduced only at later stages of servitization, Turboden has accumulated experience in plant

monitoring and data management for more than two decades, making digital resources a foundational element of its service model. All installed ORC plants are characterized by a **fully connected system**, enabling continuous or periodic transmission of operational data from the field to Turboden's infrastructure. This connectivity allows the company to remotely access plant information and monitor operating conditions throughout the entire lifecycle of the asset, independent of geographical location. Connectivity therefore functions as an enabling resource for both routine service activities and advanced analytics-based services. In terms of data exploitation, Turboden leverages a combination of **basic operational data**, such as machine status, alarms, and key operating parameters, and **performance and behavioral data** related to plant efficiency, deviations from expected operating conditions, and usage patterns. These data streams constitute the informational backbone of the XaaS offering. They support remote assistance, predictive maintenance, and performance optimization activities, enabling service engineers to intervene proactively rather than reactively. Over time, data collection and processing practices have evolved from manual or semi-automated analyses toward more **structured and increasingly automated approaches**. This evolution has been enabled by the introduction of advanced monitoring tools, proprietary analytics systems, and, more recently, AI-based models that compare real operating data with theoretical performance baselines. These developments enhance the scalability and reliability of service delivery while reducing dependence on purely manual interpretation. A critical resource for the delivery of the XaaS offering is Turboden's **full access to customer data**. This condition is facilitated by the specific role played by ORC plants within customers' production systems. In most cases, energy generation is ancillary to the customer's core business activities, which makes customers more willing to delegate performance analysis and optimization to the provider. As a result, Turboden can access and process detailed operational data without encountering significant restrictions, while remaining attentive to cybersecurity and data protection requirements. Digital technologies play a **central role** in the XaaS resource configuration. They support maintenance automation and operational continuity by enabling early detection of anomalies and reducing unplanned downtime. In parallel, technologies for real-time monitoring and analysis allow Turboden to continuously compare actual plant behavior with expected performance levels, generating alerts and actionable insights for service engineers. These technological resources form the backbone of the monitoring-as-a-service offering and enable the transition from traditional reactive service models toward more proactive and outcome-oriented service delivery.

- **Capabilities**

Turboden's XaaS offering is supported by a set of **advanced organizational, analytical, and relational capabilities** that have progressively evolved alongside the expansion of the service

business and the increasing digitalization of service delivery. Unlike cases in which service capabilities remain peripheral, at Turboden they represent a core element of the value creation logic associated with long-term service contracts. With respect to **data-analysis capabilities**, the company demonstrates a high level of maturity. Turboden has developed the ability to collect, process, and interpret large volumes of operational and performance data generated by installed plants over extended time horizons. These capabilities are enabled by the integration of deep domain-specific engineering knowledge, particularly in thermodynamic cycle design, with data analytics and artificial intelligence tools. The company has internalized key competencies related to data modeling, algorithm development, and anomaly detection, allowing it to move beyond purely descriptive monitoring toward **predictive and prescriptive service solutions** that anticipate failures and performance degradation. In terms of **service design capabilities**, Turboden exhibits a strong orientation toward continuous innovation. New service offerings are developed iteratively within the Service After Sales business unit, building on accumulated experience with existing customers and progressively incorporating advanced digital components. Service design activities are closely connected to operational feedback from the field and to the specific characteristics of highly customized plants. As a result, service configurations tend to be tailored to individual installations rather than standardized across the entire customer base. While customer involvement is present, particularly during contract definition and the alignment on performance targets, the overall service architecture remains largely provider-driven. Regarding **risk assessment capabilities**, Turboden's approach can be characterized as based on **basic risk control**. Risk evaluation is conducted primarily on a qualitative and case-by-case basis, relying on managerial judgment, detailed knowledge of customers and plants, and accumulated historical experience. Formalized or standardized risk management frameworks play a limited role. This approach reflects both the bespoke nature of the offerings and the financial and operational exposure associated with performance- and availability-based service contracts. Finally, Turboden displays well-developed **human and relational capabilities**, particularly at the managerial and organizational level. The company has established cross-functional coordination mechanisms that involve service engineering, IT, automation, and commercial functions, enabling effective integration of technical and service-related activities. In parallel, the organization has developed hybrid selling capabilities that support the commercialization of complex service-based value propositions. These capabilities allow Turboden to articulate service value in terms of technical performance, operational continuity, and long-term customer support, reinforcing trust and facilitating the adoption of advanced XaaS configurations.

- **Environmental sustainability**

Environmental sustainability represents a **structurally embedded dimension** of Turboden's XaaS offering and is closely intertwined with the service logic adopted across the lifecycle of ORC plants. Sustainability is not treated as an ancillary or symbolic element, but emerges as a direct consequence of long-term service responsibility, continuous monitoring, and performance-oriented maintenance practices. A first pillar of the environmental configuration concerns **end-of-life and reverse logistics strategies**. Turboden adopts articulated procedures for managing plants and components at the end of their operational life or contractual duration. These activities include the collection of systems, the recovery of components, and their reintegration into service operations where technically feasible. In parallel, the company offers **remanufacturing services**, aimed at restoring components or subsystems to extend their usability. These practices enable reuse, reduce material waste, and limit the environmental impact associated with the production of new components. Closely related to this logic, Turboden actively pursues **product-life extension strategies**. Preventive and predictive maintenance programs, modular upgrades, and refurbishment activities are central elements of the service offering. By continuously monitoring plant conditions and intervening before critical failures occur, the company maximizes asset lifetime, preserves efficiency over time, and adapts existing installations to evolving technical and regulatory standards. This long-term orientation is coherent with the extended operational lifetimes of ORC plants, which often exceed twenty years. **Resource efficiency** represents another relevant sustainability dimension. Through continuous measurement and optimization of energy and material flows, supported by monitoring systems and data analytics tools, Turboden seeks to improve plant efficiency and reduce losses. Monitoring enables the identification of deviations from expected performance levels, supporting corrective actions that enhance overall energy conversion efficiency. These improvements are particularly significant given that ORC plants are often deployed to recover waste heat or exploit renewable energy sources. The XaaS offering does not involve **product–service substitution**, as the physical asset remains central to value creation and cannot be replaced by purely digital or outcome-based services. However, sustainability is further reinforced through **dematerialization and transparency initiatives**. Digital monitoring and reporting tools allow environmental and performance data to be shared with customers, supporting transparency and informed decision-making regarding plant operation and optimization. Finally, the service-based model promotes **increased use and service intensity**. By maximizing uptime and optimizing performance through long-term service contracts, Turboden enhances asset utilization and reduces the environmental footprint per unit of energy generated. Sustainability outcomes therefore arise not from isolated initiatives, but from the overall architecture of the XaaS model, in which long-term responsibility, data-driven optimization, and lifecycle thinking are structurally embedded.

DIMENSIONS	VARIABLES	CODING
Value proposition	Offer object	Service
Value proposition	Maturity Level of the Service Offering	Pilot
Value proposition	Coverage of the Offering	Specific category
Value proposition	XaaS Offering Approach	Proactive
Value proposition	Ownership	Customer
Value proposition	Value for the customers	the achievement of an expected result
Value proposition	Offer costumization (level)	Customizable offer
Value proposition	Offer Customization (object)	Service
Value proposition	Offer communication	Limited or absent communication
Customers	Traget Customer segments	consolidated customers
Customers	Customer segmentation strategy	Undifferentiated
Customers	Customer acceptance	Limited interest
Customers	Customer involvement	Collaborative
Ecosystem	Presence of strategic partners	Financial
Ecosystem	Presence of strategic partners	Technological
Ecosystem	Continuity of strategic partners' engagement	Financial _development
Ecosystem	Continuity of strategic partners' engagement	Technological _delivery
Ecosystem	Alliance governance	Financial_coordinated
Ecosystem	Alliance governance	Technological _coordinated
Organization structure and culture	Level of commitment of the top management of the provider	Widespread and strategic commitment
Organization structure and culture	Internal organization	New, dedicated business unit or team
Organization structure and culture	Service strategy	Partially aligned / Integrated
Organization structure and culture	Sales–Service Integration level	Integrated / Unified
Organization structure and culture	Physical distribution channel	Disintermediated
Organization structure and culture	Digital Distribution channel	Absent
Economic and finance	Revenue model and mechanism	Fixed period / subscription (payment per period)
Economic and finance	Revenue model and mechanism	Payment per performance / per availability
Economic and finance	Main Risk	Financial risk
Economic and finance	Risk mitigation strategy	No formal strategy
Economic and finance	Risk mitigation mechanisms	Customer and/or portfolio diversification
Economic and finance	Profitability Measurement KPI	financial economics KPI
Economic and finance	Profitability Measurement KPI	operational performance KPI

Resources	Data connectivity	Fully connected system
Resources	Data Exploitation	Basic operational data
Resources	Data Exploitation	Performance and behavioral data
Resources	Customer Data accessibility	Full access
Resources	Technology role	Maintenance automation and/or operational continuity
Resources	Technology role	Real-time monitoring and/or analysis
Capabilities	Data-analysis capabilities	Advanced
Environmental sustainability	End-of-life and reverse logistics strategies	End-of-life/contract product collection
Environmental sustainability	End-of-life and reverse logistics strategies	Remanufacturing services offered
Environmental sustainability	Product-life extension strategy	Preventive and predictive maintenance programs
Environmental sustainability	Product-life extension strategy	Modular upgrade or component replacement
Environmental sustainability	Product-life extension strategy	Reuse or lifetime extension throught refurbishment
Environmental sustainability	Resource efficiency	Measurements and optimization of resource, consumption (energy, materials..)
Environmental sustainability	Product service substitution	No substitution
Environmental sustainability	Dematerialization and transparency	Monitoring and reporting of environmental data to customers
Environmental sustainability	Dematerialization and transparency	Digital platforms supporting traceability and reporting
Environmental sustainability	Use and service intensity	Optimization of asset use (maximized uptime, performance-based logic)

Table 41 Turboden coding results

C.2 Toyota Handling Material

Company description

Toyota Material Handling (TMH) is a global leader in the design, production, and provision of material handling solutions, operating as part of the Toyota Industries Corporation. The company specializes in forklifts, warehouse equipment, and integrated logistics solutions, serving a broad range of industries including manufacturing, logistics, retail, and distribution. TMH is widely recognized for its focus on quality, reliability, and continuous improvement, reflecting the broader Toyota Production System (TPS) philosophy. In Europe, Toyota Material Handling operates through a structured network of sales companies, direct branches, and independent dealers. In Italy, Toyota

Material Handling Italia is headquartered in Casalecchio di Reno (Bologna) and represents one of the most important national subsidiaries within the European organization. The company combines a strong direct presence, through multiple branch offices, with an extensive and long-established dealer network, enabling capillary market coverage. From a business model perspective, Toyota Material Handling has progressively shifted from a predominantly transactional product-sales logic toward a use- and service-oriented model, in which rental, leasing, and service-based solutions play a central role. Long-term rental has become the dominant mode of market engagement, particularly among large and multinational customers, while short-term rental is widely used to address temporary needs such as seasonal peaks, inventory surges, or exceptional operational conditions. Sales remain relevant, especially among small and medium-sized enterprises, but represent a declining share of overall volumes. A distinctive characteristic of Toyota Material Handling's positioning is its end-to-end lifecycle responsibility for equipment. The company manages large rental fleets and retains control over maintenance, refurbishment, redeployment, resale, and end-of-life processes. Remanufacturing and second-life strategies are systematically embedded in fleet management practices, enabling the reuse of equipment across multiple rental cycles and customer segments. This lifecycle-oriented approach supports both economic performance and environmental objectives, while reinforcing customer reliance on the provider. In parallel, Toyota Material Handling has expanded its service portfolio beyond traditional maintenance and repair. Digital solutions for fleet management, remote monitoring, diagnostics, and usage tracking have been progressively introduced, alongside advanced service offerings such as full-service contracts, extended warranties, training services, and diagnostic tools provided on a subscription basis. These services are delivered both to end customers and to the dealer network, contributing to the standardization and scalability of service quality across the market. Within this context, Toyota Material Handling has developed two distinct XaaS configurations, which constitute two separate units of analysis within the proposed framework:

1. **Rental (Noleggio)**, in which material handling equipment is provided to customers under short- or long-term rental contracts, with Toyota Material Handling retaining ownership of the assets and assuming responsibility for maintenance, refurbishment, and lifecycle management.
2. **Service-as-a-Service**, encompassing **training-as-a-service and diagnostic-as-a-service** offerings, in which customers retain ownership of the equipment while training and diagnostic services delivered through recurring contracts and digital tools.

These two configurations differ significantly in terms of object of the offering, asset ownership, risk allocation, digital intensity, and organizational implications, while being embedded within the same

corporate and operational context. As such, they provide a suitable basis for within-firm comparison and for examining how different XaaS logics coexist within a mature servitized manufacturing organization.

Toyota Handling Material Rental XaaS Offering Overview

The rental offering of Toyota Material Handling is centered on providing material handling equipment under time-based access contracts, in which customers use forklifts and warehouse vehicles without acquiring ownership of the physical assets. Rental represents a core and consolidated access mode within the company's business model, rather than a peripheral or experimental solution, and is articulated through both short-term and long-term rental contracts. Long-term rental constitutes the dominant configuration and is typically adopted by medium and large customers seeking stable access to equipment over extended periods. Under this arrangement, Toyota Material Handling retains full ownership of the equipment and assumes responsibility for its operational availability, maintenance, and lifecycle management. Short-term rental, by contrast, is used to address temporary operational needs, such as seasonal demand peaks, extraordinary workload fluctuations, or specific short-duration projects. Both configurations are managed within the same overarching rental logic, differing mainly in contractual duration and usage context. Operationally, the rental offering is structured as a standardized solution, with predefined equipment configurations and contractual terms. While customers can select among different vehicle types and capacities, the rental model does not rely on extensive customization at the contractual level. The focus is instead on ensuring rapid availability, operational reliability, and predictable cost structures. A defining feature of Toyota Material Handling's rental offering is its integration with internal fleet management practices. The company manages large rental fleets and systematically controls equipment allocation, redeployment, refurbishment, and resale. Equipment used in rental contracts is maintained according to standardized procedures and, upon contract termination, can be refurbished and reassigned to new customers or applications. This enables Toyota Material Handling to extend asset lifetimes and optimize utilization across multiple rental cycles. Service activities are inherently embedded within the rental offering. Maintenance and repair are not provided as optional add-ons but are integral components of the rental contract, ensuring continuous operability of the equipment throughout the rental period. Customers therefore access not only the physical equipment, but also a bundle of supporting services that reduce operational risk and internal maintenance requirements. Overall, Toyota Material Handling's rental offering can be characterized as a product-based XaaS configuration, in which value is created through temporary access to equipment combined with lifecycle-oriented service support. The offering emphasizes cost predictability, operational continuity, and flexibility for customers, while

allowing the provider to retain control over assets and to optimize their economic and operational performance over time.

Toyota Handling Material Rental framework-based analysis

- **Value proposition**

The value proposition of Toyota Material Handling's **rental** offering is centered on providing customers with **reliable and continuous access to material handling equipment** without requiring ownership of the physical assets. Within the framework, the **object of the offering** is coded as a **product-based solution**, as forklifts and warehouse vehicles remain central to value creation, while access is enabled through time-based contractual arrangements. The **maturity level** of the rental offering is **consolidated**, reflecting its long-standing role as a core pillar of Toyota Material Handling's business model. Rental is not positioned as an experimental or complementary option, but rather as a standard and widely adopted alternative to product sales, particularly among medium and large customers. The **coverage** of the offering spans a **broad portion of the product range**, encompassing different categories of forklifts and warehouse equipment suitable for diverse operational contexts. The **approach** is predominantly **proactive**, as rental solutions are actively proposed to customers as a preferred mode of access to equipment. Rental is integrated into the company's commercial narrative and is presented as a stable and flexible solution for managing material handling needs over time. **Offer communication** is therefore structured and embedded within existing sales and service channels. **Ownership** of the equipment is retained by the **provider**, and this ownership structure is a fundamental element of the value proposition. By maintaining ownership, Toyota Material Handling assumes responsibility for asset performance, maintenance, and lifecycle management, thereby relieving customers from capital investment, depreciation concerns, and end-of-life management. In the specific case of long-term rental arrangements, ownership of the asset may also be transferred to or held by a financial institution, while the service provider remains responsible for service delivery and operational performance. Customer value is articulated primarily in terms of **minimization of operating costs** and **optimization of usage processes**. Rental enables customers to transform capital expenditure into predictable operating expenses, reducing financial rigidity and improving cost visibility. At the same time, the integration of maintenance and service within the rental contract reduces operational risk and internal management complexity, allowing customers to focus on core logistics and production activities. The rental offering is characterized by **limited customization** at the contractual level. While customers can choose equipment types and rental durations, the overall structure of the rental solution remains standardized. This standardization supports efficiency, scalability, and rapid deployment, which are

critical to the value proposition. Customization is therefore primarily operational rather than contractual. Overall, the value proposition of Toyota Material Handling's rental offering can be characterized as **access-oriented, lifecycle-based, and risk-reducing**. The as-a-service logic lies in the provider's assumption of ownership and responsibility over the equipment, enabling customers to access reliable material handling solutions with high operational continuity and reduced financial and operational uncertainty.

- **Customers**

The customer dimension of Toyota Material Handling's **rental** offering reflects the **mainstream and widely institutionalized nature** of this access model within the material handling sector. Within the framework, **target customer segments** are coded as **no distinction**, indicating that rental solutions are not formally restricted to specific industries or customer categories. Rental is applicable across a broad spectrum of sectors, including manufacturing, logistics, retail, and distribution, wherever material handling activities are required. At the same time, the **segmentation strategy** is coded as **segment-oriented**, capturing the fact that different rental configurations are practically aligned with different customer needs and organizational profiles. Long-term rental is predominantly adopted by medium-sized and large customers seeking stable, predictable access to equipment over extended periods, while short-term rental is more frequently used to address temporary or exceptional operational requirements, such as seasonal peaks or short-duration projects. This differentiation emerges from practice rather than from explicit segmentation policies. Customer **acceptance** of the rental model is coded as **high**, reflecting the fact that rental has become a standard and preferred mode of access to equipment for many customers. Interview material indicates that customers are generally familiar with rental contracts and perceive them as a reliable and low-risk solution for managing material handling needs. The widespread diffusion of rental in the market reduces uncertainty and lowers barriers to adoption. Customer **involvement** is coded as **passive**, as customers do not actively participate in the co-design of the rental model. The offering is largely provider-defined and standardized, with customers selecting among predefined options rather than shaping the structure of the service. Interaction with customers primarily concerns the selection of equipment types, contract duration, and operational coordination, rather than collaborative innovation or customization of the business model. Overall, the customer dimension highlights that Toyota Material Handling's rental offering functions as a **mature and normalized XaaS configuration**, characterized by broad applicability, high acceptance, and limited customer involvement in design. Customers engage with the rental model pragmatically, valuing its predictability, flexibility, and integration of service responsibilities, while relying on the provider to manage asset-related complexity.

- **Ecosystem**

The ecosystem supporting Toyota Material Handling's **rental** offering is characterized by a **structured and mature configuration**, reflecting the centrality of rental within the company's business model and the operational complexity associated with managing large fleets of material handling equipment. Within the framework, the presence of strategic partners is primarily associated with **service delivery and logistics**, rather than with financial or purely technological roles. A key element of the ecosystem is represented by Toyota Material Handling's **dealer and branch network**, which plays an essential role in delivering rental services at the local level. Dealers and direct branches are responsible for customer interfacing, equipment delivery, routine maintenance, and on-site interventions, operating within standardized procedures and quality requirements defined by the central organization. This network enables capillary coverage and rapid response times, which are critical to the effectiveness of rental solutions. Partner engagement is **continuous**, as rental contracts require ongoing coordination throughout their duration. Equipment availability, maintenance scheduling, and fleet redeployment depend on sustained interaction between Toyota Material Handling's central fleet management functions and local operational units. The ecosystem therefore supports both the development and delivery phases of the offering, ensuring consistency and reliability across different geographical areas. **Ecosystem governance** follows a **coordinated and provider-led logic**. Toyota Material Handling retains full control over asset ownership, contract definition, pricing structures, and lifecycle management policies. Partners operate as executors of predefined processes rather than as independent value orchestrators. This governance structure allows Toyota Material Handling to maintain strategic control over the rental model while leveraging external and semi-autonomous actors for operational execution. Unlike more experimental XaaS configurations, the rental ecosystem does not rely on financial partners for asset ownership or risk sharing. While a group-internal financial entity may hold ownership of the assets in the case of long-term rental arrangements, this role remains confined within the corporate group and does not alter the fundamentally industrial logic of the offering**.** Assets remain on Toyota Material Handling's balance sheet, and the ecosystem is designed to support efficient utilization and lifecycle extension rather than financial engineering. Similarly, while digital tools support fleet management and coordination, technology partners do not emerge as dominant ecosystem actors within the rental configuration. Overall, the ecosystem dimension highlights that Toyota Material Handling's rental offering is supported by a **robust, operationally focused, and tightly governed ecosystem**, optimized for scale, reliability, and lifecycle control. The ecosystem reinforces the maturity of the rental model and underpins its role as a stable and standardized XaaS configuration within the company's portfolio.

- **Organization structure and Culture**

The organizational structure underpinning Toyota Material Handling's **rental** offering reflects a **high degree of maturity and institutionalization**, consistent with the central role that rental plays within the company's overall business model. Within the framework, **top management commitment** is coded as **widespread and strategic**, indicating that rental is fully embedded in the firm's long-term strategic orientation and supported at the highest organizational levels. The **internal organization** of the rental offering is based on **dedicated and well-established structures**, integrated within the broader commercial and operational organization. Rental activities are managed through a combination of central fleet management functions and local operational units, including branches and dealers. This structure enables Toyota Material Handling to balance strategic control—particularly over asset ownership, fleet sizing, and lifecycle policies—with operational flexibility at the local level. The **service strategy** associated with rental is coded as **fully integrated and strategically driven**. Rental is not treated as a standalone access option, but as a comprehensive solution combining equipment availability, maintenance, and lifecycle management. Service activities are therefore inseparable from the rental offering and are managed as a core organizational competence rather than as ancillary support functions. **Sales–service integration** is coded as **integrated/unified**, reflecting the close coordination required between commercial roles and service operations. Sales personnel are responsible for proposing rental solutions and defining contractual terms, while service and technical teams ensure equipment availability, maintenance execution, and operational continuity throughout the rental period. This integration supports consistent value delivery and reinforces the reliability of the rental model. With regard to channels, the **physical distribution channel** is **intermediated**, as equipment delivery, maintenance, and on-site support are largely executed through branches and dealers. At the same time, coordination and control are maintained centrally through standardized procedures and fleet management systems. The **digital distribution channel** plays a supportive role, enabling coordination and monitoring, but does not fundamentally alter the organizational configuration of the rental offering. From a cultural perspective, the rental model aligns closely with Toyota Material Handling's **process-oriented and reliability-driven culture**, rooted in the principles of standardization, continuous improvement, and operational discipline. The organization demonstrates a strong orientation toward long-term customer relationships and lifecycle responsibility, which supports the sustained delivery of rental services over extended contractual periods. Overall, the organization structure and culture dimension highlights that Toyota Material Handling possesses a **high level of organizational readiness** for rental-based XaaS configurations. The offering leverages established structures, integrated service logics, and a

supportive organizational culture, enabling scalable and reliable delivery without requiring disruptive organizational change.

- **Economic and Finance**

The economic and financial configuration of Toyota Material Handling's **rental** offering is grounded in a **time-based revenue logic**, in which revenues are generated through periodic payments linked to the duration of equipment use rather than to ownership transfer or output performance. Within the framework, the **revenue model** is coded as a **fixed-period payment**, typically structured on a monthly basis over the agreed rental term. Rental enables Toyota Material Handling to transform high upfront capital investments in equipment into **stable and recurring revenue streams** over the asset lifecycle. The economic logic of the model relies on long-term utilization of assets across multiple rental cycles, allowing the company to amortize equipment costs progressively and to extract value through sequential deployment, refurbishment, and redeployment. This lifecycle-oriented revenue logic is particularly evident in long-term rental contracts, which represent the dominant configuration. From a cost structure perspective, Toyota Material Handling assumes responsibility for **maintenance, repair, and asset management costs**, which are embedded within the rental fee. This shifts operational and technical risk away from the customer and onto the provider. As a result, effective fleet management, maintenance efficiency, and asset utilization rates become critical determinants of profitability. The **main risk** associated with the rental model is coded as **asset-related and operational risk**. Toyota Material Handling bears the risk of equipment downtime, unexpected maintenance costs, and fluctuations in utilization rates. Additionally, residual value risk is inherent to the model, as the economic performance of rental assets depends on their ability to be refurbished, redeployed, or resold at the end of each rental cycle. Risk mitigation is coded as **formalized**, reflecting the presence of structured asset management and lifecycle control mechanisms. Standardized maintenance procedures, preventive service schedules, and refurbishment processes are used to preserve asset condition and extend usable life. The company's ability to manage second-life deployment and resale further reduces exposure to residual value risk. Profitability is monitored through a combination of **financial and operational KPIs**, including utilization rates, maintenance cost per asset, contract duration, and fleet turnover. Rather than focusing on transaction-level margins, economic performance is assessed at the portfolio and lifecycle level, consistent with the long-term orientation of the rental model. Overall, the economic and financial dimension highlights that Toyota Material Handling's rental offering represents a **capital-intensive but economically mature XaaS configuration**. The model prioritizes predictable

recurring revenues and long-term asset value extraction, while requiring strong operational discipline and sophisticated fleet management capabilities to manage risk and sustain profitability.

- **Resources**

The resource base supporting Toyota Material Handling's **rental** offering is centered on a **large and diversified fleet of material handling equipment**, which constitutes the core physical resource of the XaaS configuration. Forklifts and warehouse vehicles are owned by the provider and deployed across multiple rental cycles, making asset availability, condition, and redeployability critical resources for value creation. A key enabling resource is the company's **fleet management infrastructure**, which allows Toyota Material Handling to monitor asset allocation, utilization, maintenance status, and lifecycle progression. This infrastructure supports decisions related to equipment deployment, refurbishment, and reassignment, enabling efficient use of assets across different customers and usage contexts. While digital tools are employed to support these activities, the system is coded as **partially connected**, reflecting a focus on operational coordination rather than on advanced data-driven optimization. Data exploitation is primarily oriented toward **basic operational and usage data**, such as hours of operation, maintenance needs, and equipment status. These data support preventive maintenance planning, fleet availability management, and cost control. However, data are not systematically exploited for advanced analytics or predictive optimization at the business model level. Their role remains supportive of operational reliability rather than transformative of the value proposition. **Customer data accessibility** is limited and functional. Customers interact with the rental resources mainly through service interfaces and contractual arrangements, without direct access to detailed fleet or lifecycle data. Information exchange is oriented toward ensuring transparency regarding equipment availability and service execution, rather than enabling shared monitoring or co-optimization of asset performance. Technology plays an important role in enabling **maintenance automation and operational continuity**. Standardized maintenance tools, diagnostic equipment, and service management systems support the execution of service activities embedded within rental contracts. These technological resources are integrated into the broader service organization and are essential to sustaining the reliability promised by the rental offering. Beyond physical and digital resources, the rental model relies heavily on **logistics and refurbishment infrastructures** as key resources. Facilities and capabilities dedicated to inspection, refurbishment, and preparation of equipment for redeployment enable Toyota Material Handling to extend asset lifetimes and extract value across multiple rental cycles. These resources are central to both the economic and environmental performance of the rental model. Overall, the resource dimension highlights that Toyota Material Handling's rental offering is **asset-intensive and lifecycle-**

oriented, relying on a combination of owned equipment, fleet management systems, service infrastructures, and logistics resources. These resources support the scalability and maturity of the rental XaaS configuration, while anchoring value creation firmly in the effective management of physical assets over time.

- **Capabilities**

The capability base underpinning Toyota Material Handling's **rental** offering is characterized by a **high degree of operational, organizational, and lifecycle management capabilities**, reflecting the maturity and scale of rental as a core business model. Within the framework, capabilities are primarily coded as **managerial and organizational skills**, supported by **basic data-handling capabilities** oriented toward execution and control. A central capability lies in the company's ability to **manage large rental fleets across multiple lifecycle stages**. Toyota Material Handling demonstrates strong competence in allocating equipment to customers, monitoring usage, planning maintenance, and coordinating refurbishment and redeployment activities. This lifecycle orchestration capability enables the company to maximize asset utilization and extend equipment life across successive rental contracts. Another key capability concerns **maintenance execution and service coordination**. The rental model requires the provider to ensure high equipment availability and reliability over time. Toyota Material Handling has developed standardized maintenance routines, preventive service schedules, and rapid intervention procedures that allow it to manage downtime risk and sustain operational continuity. These capabilities are deeply embedded in the organization and supported by trained service personnel and established service processes. The rental offering also relies on strong **logistics and operational coordination capabilities**. Delivering, collecting, redeploying, and refurbishing equipment requires precise coordination between central fleet management functions and local branches or dealers. The ability to synchronize these activities across geographically dispersed operations is a critical enabler of the rental model's scalability. From a commercial perspective, Toyota Material Handling possesses the capability to **sell and manage long-term rental contracts** as standardized solutions. Sales personnel are skilled in positioning rental as a preferred access mode, articulating its economic and operational benefits, and managing contract renewals over time. This capability reinforces customer retention and supports the stability of recurring revenue streams. By contrast, **advanced analytical and predictive capabilities remain limited**. Although operational data are collected and used to support maintenance planning and fleet coordination, there is no evidence of systematic use of advanced analytics to optimize pricing, predict asset failure at scale, or dynamically adapt rental conditions. Data-driven capabilities support execution rather than strategic transformation. Overall, the capability dimension highlights that Toyota Material Handling's

rental offering is supported by **strong execution-oriented and lifecycle management capabilities**, which enable reliable, scalable, and economically sustainable delivery of rental services. These capabilities underpin the maturity of the rental XaaS configuration, while also defining its boundaries in terms of innovation intensity and digital sophistication.

- **Environmental sustainability**

Environmental sustainability in Toyota Material Handling's **rental** offering is embedded structurally in the **asset ownership and lifecycle management logic** of the business model, rather than being articulated as a standalone or explicitly marketed objective. Within the framework, sustainability emerges as a systemic outcome of the provider's responsibility for equipment throughout its entire lifecycle. A primary sustainability mechanism lies in the **extension of asset lifetimes** enabled by rental. By retaining ownership of forklifts and warehouse vehicles, Toyota Material Handling manages maintenance, refurbishment, and redeployment activities in a coordinated and standardized manner. Equipment is used across multiple rental cycles and reassigned to different customers and applications, reducing the need for frequent production of new assets and lowering the overall material and energy footprint per unit of use. The rental model also supports **optimization of asset utilization**. Centralized fleet management allows Toyota Material Handling to allocate equipment efficiently, avoid underutilization, and balance demand across customers and time periods. Higher utilization rates contribute to improved resource efficiency, as the same physical assets generate more functional output over their lifecycle. Maintenance activities embedded within rental contracts further contribute to sustainability outcomes. Preventive maintenance and standardized service routines help preserve equipment condition, reduce unexpected failures, and limit premature disposal. While these practices are primarily motivated by economic and operational considerations, they indirectly support environmental objectives by reducing waste and extending usable life. The model facilitates **remanufacturing and second-life strategies**, as equipment returning from rental contracts can be refurbished and redeployed or resold. These practices are systematically integrated into fleet management processes and represent an important sustainability lever, even though they are not explicitly framed as such within the rental value proposition. The rental offering does not emphasize **environmental transparency** toward customers, nor does it include formal sustainability reporting or environmental performance indicators as part of the contractual arrangement. Sustainability benefits are therefore implicit and operational, rather than explicitly communicated or monetized. Overall, environmental sustainability in Toyota Material Handling's rental offering can be characterized as **lifecycle-driven and structurally embedded**. The provider's assumption of ownership and responsibility over assets enables more efficient use of resources, extended asset

lifetimes, and reduced waste, positioning rental as an environmentally supportive XaaS configuration even in the absence of explicit sustainability-oriented value propositions.

DIMENSIONS	VARIABLES	CODING
Value proposition	Offer object	Product
Value proposition	Maturity Level of the Service Offering	Consolidated
Value proposition	Coverage of the Offering	Specific category
Value proposition	XaaS Offering Approach	proactive
Value proposition	Ownership	Offer Provider
Value proposition	Ownership	Third parties
Value proposition	Value for the customers	the content and methods of service delivery (a fast and efficient service)
Value proposition	Value for the customers	minimization of operating costs
Value proposition	Value for the customers	risk minimization
Value proposition	Value for the customers	guarantee of functionality
Value proposition	Offer costumization (level)	Configurable offer
Value proposition	Offer Customization (object)	sales channel
Value proposition	Offer communication	Integration into existing channels
Customers	Traget Customer segments	No distinction
Customers	Customer segmentation strategy	Segment-Oriented
Customers	Customer acceptance	High interest
Customers	Customer involvement	Passive
Ecosystem	Presence of strategic partners	Financial
Ecosystem	Presence of strategic partners	Technological
Ecosystem	Continuity of strategic partners' engagement	Financial _both
Ecosystem	Continuity of strategic partners' engagement	Technological _delivery
Ecosystem	Alliance governance	Financial_collaborative
Ecosystem	Alliance governance	Technological _coordinated
Organization structure and culture	Level of commitment of the top management of the provider	Widespread and strategic commitment
Organization structure and culture	Internal organization	Existing functions or business units (es. Sales service)
Organization structure and culture	Service strategy	Partially aligned / Integrated
Organization structure and culture	Sales–Service Integration level	Separated
Organization structure and culture	Physical distribution channel	hybrid/intermediate
Organization structure and culture	Digital Distribution channel	Disintermediated

Economic and finance	Revenue model and mechanism	Fixed period / subscription (payment per period)
Economic and finance	Main Risk	Financial risk
Economic and finance	Risk mitigation strategy	Formalized risk management model
Economic and finance	Risk mitigation mechanisms	Financial company
Economic and finance	Profitability Measurement KPI	financial economics KPI
Economic and finance	Profitability Measurement KPI	operational performance KPI
Economic and finance	Profitability Measurement KPI	life cycle KPI
Resources	Data connectivity	Fully connected system
Resources	Data Exploitation	Basic operational data
Resources	Data Exploitation	Performance and behavioral data
Resources	Customer Data accessibility	Limited/conditional access
Resources	Technology role	Real-time monitoring and/or analysis
Capabilities	service design capabilities	Basic design:
Capabilities	Risk assessment capabilities	Financial & operational integration
Capabilities	Human and relational capabilities	Managerial & organizational skills
Capabilities	Human and relational capabilities	Hybrid selling & distribution skills
Environmental sustainability	End-of-life and reverse logistics strategies	End-of-life/contract product collection
Environmental sustainability	Product-life extension strategy	Preventive and predictive maintenance programs
Environmental sustainability	Product-life extension strategy	development of a durable product
Environmental sustainability	Resource efficiency	Implementation of eco-efficient design or processes
Environmental sustainability	Product service substitution	No substitution
Environmental sustainability	Dematerialization and transparency	Digital platforms supporting traceability and reporting
Environmental sustainability	Use and service intensity	Asset sharing among multiple users
Environmental sustainability	Use and service intensity	Optimization of asset use (maximized uptime, performance-based logic)
Environmental sustainability	Use and service intensity	Multi-contract asset utilization
Environmental sustainability	Use and service intensity	Inclusion of second-hand products in the aaS offering

Table 42 Toyota Handling Material Rental coding results

Toyota Handling Material Service XaaS Offering Overview

The service-based XaaS offering of Toyota Material Handling is centered on the provision of **training and diagnostic services delivered under recurring contractual arrangements**, while customers

retain full ownership of the material handling equipment. In this configuration, value creation is decoupled from both asset access and traditional maintenance activities, focusing instead on **capability development and condition assessment** as ongoing services. The offering combines **Training as a Service** and **Diagnostic as a Service** within a modular service logic. Training services are designed to enhance the competencies of operators and customer personnel, supporting safe, efficient, and standardized use of material handling equipment. Training activities are delivered through structured programs that can be periodically renewed, allowing customers to continuously update skills in response to operational changes, workforce turnover, or regulatory requirements. Diagnostic services complement training by providing **systematic assessments of equipment condition, usage patterns, and operational behavior**. Through diagnostic activities, Toyota Material Handling supports customers in identifying potential issues, inefficiencies, or risks associated with equipment usage. Diagnostic insights are used to inform customers about the state of their fleet and to support decision-making regarding operational practices and future interventions. Operationally, the service offering is structured through **recurring service contracts**, typically defined on an annual basis. These contracts specify the scope and frequency of training and diagnostic activities, providing customers with predictable access to services and stable cost structures. The offering is applicable both to customers operating Toyota Material Handling equipment and, in certain cases, to mixed fleets, reinforcing its positioning as a service-oriented solution rather than a product-dependent add-on. Digital tools play a supporting role, particularly within the diagnostic component of the offering. Data collected from equipment and operational environments are used to support diagnostic assessments, although the service does not rely on fully automated or autonomous analytics systems. Instead, digital information is leveraged by service and training personnel to contextualize diagnostics and tailor training interventions. A defining feature of this service-based XaaS configuration is its **independence from asset ownership and maintenance responsibility**. Toyota Material Handling does not assume responsibility for equipment performance or availability, but rather provides knowledge-based and diagnostic support aimed at improving how customers operate and manage their assets. This positions the offering as a complementary layer to both rental and ownership-based models. Overall, Toyota Material Handling's **Training as a Service and Diagnostic as a Service** offering can be characterized as a **knowledge- and insight-driven XaaS configuration**, in which value is delivered through continuous access to expertise, diagnostics, and structured learning rather than through physical assets or direct operational execution. The as-a-service logic lies in the repeatability, continuity, and contractualization of services that traditionally would have been delivered on a one-off basis.

Toyota Handling Material Service framework-based analysis

- **Value proposition**

The value proposition of Toyota Material Handling's **Training as a Service and Diagnostic as a Service** offering is centered on providing customers with **continuous access to expertise, knowledge, and operational insight**, rather than on the provision or operation of physical assets. Within the framework, the **object of the offering** is coded as a **pure service**, as value creation is based entirely on intangible activities related to capability development and condition assessment, while equipment ownership remains with the customer. The **maturity level** of the offering is coded as **pilot**, reflecting the fact that these service-based configurations are less established and less standardized than rental solutions within Toyota Material Handling's portfolio. Interview material suggests that training and diagnostic services are still evolving in terms of scope, packaging, and commercialization, and are often proposed selectively rather than as default options. In terms of **coverage**, the offering is applied to **specific service domains**, namely operator training and equipment diagnostics. The **approach** is **proactive**, as Toyota Material Handling actively proposes these services to customers in order to enhance operational performance, safety, and awareness, rather than responding solely to explicit customer requests. **Ownership** is not a relevant dimension in this configuration, as the offering does not involve physical assets. Instead, value is framed around access to **knowledge and diagnostic insight** over time. Customers retain full control over their equipment and operations, while benefiting from external expertise delivered on a recurring basis. Customer value is articulated primarily in terms of **optimization of usage processes** and **risk reduction**. Training services support safer and more efficient operation of equipment, reducing the likelihood of misuse, accidents, and operational inefficiencies. Diagnostic services provide visibility into equipment condition and usage patterns, enabling customers to identify potential issues and to make informed decisions regarding maintenance, replacement, or process adjustments. The offering allows for **limited customization**, as training and diagnostic activities are delivered within predefined service packages. Customization occurs mainly in the selection of training modules or diagnostic focus areas, rather than through bespoke contractual structures. **Offer communication** is integrated into existing sales and service interactions and relies heavily on consultative discussions rather than standardized marketing messages. Overall, the value proposition of Toyota Material Handling's Training as a Service and Diagnostic as a Service offering can be characterized as **knowledge-intensive, insight-driven, and complementary**. The as-a-service logic lies in the contractualization and continuity of services that enhance customer capabilities and awareness, without transferring operational responsibility or asset-related risk to the provider.

- **Customers**

The customer dimension of Toyota Material Handling's **Training as a Service and Diagnostic as a Service** offering reflects the **selective and capability-oriented nature** of this service-based XaaS configuration. Within the framework, **target customer segments** are coded as **no distinction**, as the services are not formally limited to specific industries or firm sizes. In practice, however, adoption is more likely among customers with structured operational environments and a clear interest in improving internal competencies and process awareness. The **segmentation strategy** is coded as **segment-oriented**, capturing the fact that training and diagnostic services are primarily proposed to customers for whom operator behavior, safety, and equipment usage quality represent critical performance levers. These include customers with complex logistics operations, high equipment utilization, or significant workforce turnover, where structured training and diagnostics can generate tangible benefits. Customer **acceptance** is coded as **moderate interest**. Interview material suggests that while customers generally recognize the value of training and diagnostic services, these offerings are not perceived as essential in the same way as rental or maintenance-related solutions. Adoption often depends on managerial awareness, regulatory pressure, or specific operational incidents that highlight the need for improved skills or diagnostics. Customer **involvement** is coded as **collaborative**, particularly in the definition of training content and diagnostic focus areas. Although the overall structure of the service offering is provider-defined, effective delivery requires interaction with customer representatives to align services with operational contexts, workforce profiles, and equipment usage patterns. Customers therefore play an active role in tailoring service delivery within predefined boundaries. Overall, the customer dimension highlights that Toyota Material Handling's service-based offering targets **customers willing to invest in capability development and operational insight**, rather than those seeking asset access or outsourcing of operational responsibility. Customer readiness, managerial commitment, and organizational maturity are key factors influencing adoption and sustained engagement with Training as a Service and Diagnostic as a Service solutions.

- **Ecosystem**

The ecosystem supporting Toyota Material Handling's **Training as a Service and Diagnostic as a Service** offering is characterized by a **relatively simple and internally driven configuration**, reflecting the knowledge-intensive nature of the services and their limited reliance on external actors. Within the framework, the presence of strategic partners is coded as **low**, as value creation is primarily based on internal expertise and organizational capabilities rather than on multi-actor collaboration. A central role in the ecosystem is played by Toyota Material Handling's **internal service and training units**, which are responsible for the design and delivery of training programs and diagnostic activities.

These units operate in close coordination with local branches and dealers, which act as interfaces with customers and facilitate access to operational contexts where services are delivered. However, dealers primarily support execution rather than acting as autonomous ecosystem partners. For diagnostic services, the ecosystem includes **technological enablers** that support data collection and analysis, such as monitoring tools and diagnostic interfaces embedded in equipment. These technologies are integrated into Toyota Material Handling's service infrastructure and do not constitute independent ecosystem actors. As a result, technological partners do not emerge as strategic players within the ecosystem, but rather as background enablers of service delivery. Partner engagement is **episodic to continuous**, depending on the service component. Training activities often involve periodic interactions aligned with contract schedules, workforce turnover, or regulatory requirements, while diagnostic services may require more continuous interaction to monitor equipment conditions and usage patterns. In both cases, ecosystem interactions remain largely bilateral between Toyota Material Handling and the customer. **Ecosystem governance** is coded as **provider-led and coordinated**. Toyota Material Handling defines service scope, methodologies, pricing, and delivery standards, while customers participate by granting access to personnel, equipment, and operational data where required. There is no evidence of shared governance mechanisms, revenue-sharing arrangements, or co-investment structures typical of more complex service ecosystems. Overall, the ecosystem dimension highlights that Toyota Material Handling's Training as a Service and Diagnostic as a Service offering is supported by a **closed and internally orchestrated ecosystem**, optimized for consistency, control, and knowledge transfer rather than for innovation through external collaboration. This configuration aligns with the pilot and complementary nature of the service offering within the company's broader XaaS portfolio.

- **Organization Structure and Culture**

The organizational configuration underpinning Toyota Material Handling's **Training as a Service and Diagnostic as a Service** offering reflects a **partial and evolving integration** of service-based logics within the company's established organizational structure. Within the framework, **top management commitment** is coded as **selective**, indicating that while service-based offerings are recognized as strategically relevant, they do not yet enjoy the same level of institutionalization as rental solutions. The **internal organization** supporting training and diagnostic services relies primarily on **existing service, technical, and training functions**, rather than on a dedicated or autonomous XaaS unit. Responsibility for these services is distributed across specialized training teams, technical experts, and local service units, which operate within the broader service organization. This distributed structure enables flexibility but also reflects the non-core and pilot

nature of the offering. The **service strategy** is coded as **integrated but not dominant**, as training and diagnostic services complement the company's core rental and product-based business models rather than redefining them. These services are positioned as value-adding layers that enhance customer relationships and operational outcomes, without displacing existing revenue logics or organizational priorities. **Sales–service integration** is coded as **partially integrated**. While sales personnel are involved in proposing training and diagnostic services, these offerings are often introduced through consultative interactions rather than through standardized sales processes. Service and training teams play a significant role in shaping the offering during customer engagement, reflecting the knowledge-intensive nature of the services. Regarding channels, both **physical and digital channels** are used to deliver training and diagnostic services. Physical channels include on-site training sessions and diagnostic visits, while digital channels support diagnostics, data sharing, and, in some cases, remote training activities. However, digital channels remain supportive rather than transformative, and do not fundamentally alter organizational roles or responsibilities. From a cultural perspective, the service offering aligns with Toyota Material Handling's **continuous improvement and safety-oriented culture**, which values skill development, standardization, and operational discipline. At the same time, the selective adoption of Training as a Service and Diagnostic as a Service indicates a **cautious organizational attitude** toward expanding pure service-based XaaS models, favoring incremental development over radical transformation. Overall, the organization structure and culture dimension suggests that Toyota Material Handling possesses the **foundational organizational capabilities** required to deliver training and diagnostic services as recurring offerings, while these services remain **organizationally peripheral and complementary**. Their future evolution depends on the extent to which service-based logics are further institutionalized and integrated into the company's core strategic and organizational framework.

- **Economic and Finance**

The economic and financial configuration of Toyota Material Handling's **Training as a Service and Diagnostic as a Service** offering is grounded in a **service-based and recurring revenue logic**, which differs substantially from the asset-intensive and lifecycle-driven economics of the rental model. Within the framework, the **revenue model** is coded as a **fixed-period subscription**, typically structured on an annual basis and linked to predefined service packages. Revenues are generated through **periodic fees** that grant customers access to training programs and diagnostic activities over the contractual period. Pricing is not linked to asset usage, output, or performance outcomes, but rather to the **availability and continuity of service provision**. This reflects a conservative and predictable economic logic, aimed at ensuring revenue stability while limiting exposure to operational

and performance-related risks. The **cost structure** of the offering is primarily driven by **personnel-related costs**, including trainers, technical experts, and service staff involved in diagnostic activities. Unlike rental, there is no capital tied up in physical assets, and financial exposure related to depreciation or residual value is absent. As a result, the economic sustainability of the offering depends largely on the efficient allocation of human resources and on achieving sufficient scale across customers. The **main risk** associated with this service-based XaaS configuration is coded as **market and demand risk**. Because training and diagnostic services are not perceived as mission-critical by all customers, demand may fluctuate depending on managerial priorities, regulatory pressure, or specific operational incidents. The risk is therefore related to customer willingness to pay for intangible and preventive services rather than to technical execution failures. Risk mitigation is coded as **informal**, reflecting the absence of dedicated financial hedging or contractual mechanisms. Instead, risk is managed through selective targeting of customers, bundling of services within broader commercial relationships, and leveraging existing service infrastructures to limit incremental costs. Training and diagnostic services are often positioned as complementary offerings, reducing standalone revenue dependency. Profitability is monitored through **service-level financial indicators**, such as contract margins and personnel utilization rates, rather than through lifecycle or outcome-based KPIs. The economic evaluation focuses on balancing service delivery costs with recurring revenues, reinforcing the interpretation of the offering as financially lightweight but also limited in scalability. Overall, the economic and financial dimension highlights that Toyota Material Handling's Training as a Service and Diagnostic as a Service offering represents a **low-capital, low-risk XaaS configuration**, characterized by predictable revenues and limited financial exposure. At the same time, its economic impact remains modest compared to asset-based models, reinforcing its role as a complementary and exploratory service offering within the company's broader XaaS portfolio.

- **Resources**

The resource base supporting Toyota Material Handling's **Training as a Service and Diagnostic as a Service** offering is primarily **intangible and knowledge-intensive**, reflecting the service-centric nature of the XaaS configuration. Unlike rental-based models, value creation does not rely on physical asset ownership, but on the availability and effective deployment of expertise, methodologies, and diagnostic tools. A central resource is represented by **specialized human capital**, including certified trainers, technical experts, and service professionals with deep knowledge of material handling equipment, operational safety, and usage practices. These professionals constitute the core enabling resource of the offering, as training and diagnostic services are delivered through direct interaction,

assessment, and knowledge transfer rather than through automated systems. The offering is supported by **standardized training programs and diagnostic methodologies**, which function as organizational resources enabling consistency and repeatability. Training modules, instructional materials, and assessment frameworks allow Toyota Material Handling to deliver services in a structured manner across different customer contexts, while maintaining quality standards. These resources are periodically updated to reflect regulatory requirements, technological evolution, and best practices. Digital technologies play a **supportive but non-central role**. Diagnostic services leverage data collected from equipment and operational environments to inform assessments and recommendations. However, within the framework, the system is coded as **partially connected**, as data exploitation remains limited to basic operational and condition-related information. Advanced analytics, automated diagnostics, or AI-driven insights do not constitute core resources of the offering. **Customer data accessibility** is selective and purpose-driven. Customers provide access to operational information and equipment data to enable diagnostics, while Toyota Material Handling processes these data internally to generate insights. Data sharing is functional and bounded, aimed at supporting service delivery rather than enabling continuous co-monitoring or shared data platforms.

Physical resources play a marginal role and are mainly associated with **training facilities, demonstration equipment, and diagnostic tools** used during service delivery. These resources support execution but do not represent strategic assets within the XaaS configuration. Overall, the resource dimension highlights that Toyota Material Handling's Training as a Service and Diagnostic as a Service offering is **light in physical assets but rich in human and organizational resources**. Value creation depends on the effective mobilization of expertise, standardized knowledge, and supportive digital tools, reinforcing the characterization of the offering as a knowledge- and insight-driven XaaS configuration rather than a technology-intensive one.

- **Capabilities**

The capability base underpinning Toyota Material Handling's **Training as a Service and Diagnostic as a Service** offering is predominantly oriented toward **knowledge deployment, capability development, and interpretative skills**, rather than toward operational execution or asset management. Within the framework, capabilities are primarily coded as **managerial and organizational skills**, complemented by **basic analytical capabilities** related to diagnostics and assessment. A core capability lies in Toyota Material Handling's ability to **translate technical expertise into structured and repeatable service offerings**. The company demonstrates competence in designing training programs and diagnostic services that can be delivered on a recurring basis, transforming what would traditionally be one-off interventions into contractualized

services. This requires the ability to codify knowledge, standardize methodologies, and adapt content to different customer contexts while preserving consistency. Another critical capability concerns **interpretative and advisory skills**. Diagnostic services do not rely on automated decision-making systems, but on the capacity of service personnel to analyze operational data, observe usage behaviors, and interpret equipment conditions. The value delivered to customers depends on the ability to contextualize diagnostic findings and to translate them into actionable recommendations, rather than on the mere availability of data. The offering also relies on strong **training delivery and facilitation capabilities**. Trainers must not only possess technical knowledge, but also be able to effectively transfer skills to customer personnel, address heterogeneous competence levels, and adapt training approaches to operational realities. These capabilities are central to ensuring that training services lead to tangible improvements in safety, efficiency, and equipment usage. From an organizational perspective, Toyota Material Handling demonstrates the capability to **coordinate service delivery across local and central units**, ensuring that training and diagnostic services are aligned with broader service standards while remaining responsive to local customer needs. This coordination supports scalability, even though the offering remains selectively applied. By contrast, **advanced digital and analytical capabilities are limited**. While data are used to support diagnostic assessments, there is no evidence of systematic exploitation of advanced analytics, predictive models, or automated insights. Capabilities remain human-centered and experience-based, reinforcing the service's advisory and knowledge-driven character. Overall, the capability dimension highlights that Toyota Material Handling's Training as a Service and Diagnostic as a Service offering is supported by **strong human-centric and interpretative capabilities**, enabling the delivery of value through expertise, assessment, and learning. These capabilities underpin the offering's potential to enhance customer competencies, while also defining its boundaries in terms of scalability and digital intensity.

- **Environmental Sustainability**

Environmental sustainability within Toyota Material Handling's **Training as a Service and Diagnostic as a Service** offering is addressed **indirectly and supportively**, emerging as a consequence of improved operational practices rather than as an explicit objective of the service model. Within the framework, sustainability effects are primarily linked to **behavioral change, operational awareness, and more efficient use of existing assets**. A key sustainability mechanism lies in the **improvement of equipment usage practices** enabled by training services. By enhancing operator skills and awareness, training contributes to safer and more efficient handling of equipment, reducing misuse, excessive wear, and avoidable damage. These effects support longer equipment lifetimes and lower resource consumption over time, even though they are not explicitly framed as

environmental outcomes within the service offering. Diagnostic services further contribute to sustainability by enabling **early identification of inefficiencies and abnormal usage patterns**. Diagnostic assessments provide insights into how equipment is used in practice, allowing customers to recognize behaviors or conditions that may lead to premature degradation or energy inefficiency. This supports more informed decision-making and encourages corrective actions that indirectly reduce waste and unnecessary resource use. Unlike rental-based configurations, the service offering does not involve **provider responsibility for asset lifecycle management**, nor does it include refurbishment, redeployment, or end-of-life strategies as part of the contractual scope. Equipment ownership remains with the customer, and sustainability impacts depend largely on how customers act upon the insights and recommendations provided through training and diagnostics. The offering does not include **formal environmental metrics, reporting tools, or sustainability KPIs** communicated to customers. Environmental benefits are therefore implicit and contingent, arising from improved practices rather than from contractual obligations or performance guarantees. Similarly, there is no product–service substitution or dematerialization effect, as the service complements existing equipment rather than replacing physical assets. Overall, environmental sustainability in Toyota Material Handling's Training as a Service and Diagnostic as a Service offering can be characterized as **capability-driven and awareness-based**. Sustainability benefits emerge through improved human behavior and operational discipline, positioning the service as an enabling mechanism for more sustainable equipment use rather than as a sustainability-driven XaaS model in its own right.

DIMENSIONS	VARIABLES	CODING
Value proposition	Offer object	Service
Value proposition	Maturity Level of the Service Offering	Pilot
Value proposition	Coverage of the Offering	Entire product range
Value proposition	XaaS Offering Approach	proactive
Value proposition	Ownership	Customer
Value proposition	Value for the customers	the content and methods of service delivery (a fast and efficient service)
Value proposition	Value for the customers	minimization of operating costs
Value proposition	Value for the customers	risk minimization
Value proposition	Value for the customers	guarantee of functionality
Value proposition	Offer costumization (level)	Customizable offer
Value proposition	Offer Customization (object)	Product
Value proposition	Offer Customization (object)	Service

Value proposition	Offer communication	Integration into existing channels
Customers	Traget Customer segments	consolidated customers
Customers	Customer segmentation strategy	Segment-Oriented
Customers	Customer acceptance	High interest
Customers	Customer involvement	Co-creative
Ecosystem	Presence of strategic partners	Technological
Ecosystem	Continuity of strategic partners' engagement	Technological _delivery
Ecosystem	Alliance governance	Technological _coordinated
Organization structure and culture	Level of commitment of the top management of the provider	Widespread and strategic commitment
Organization structure and culture	Internal organization	Existing functions or business units (es. Sales service)
Organization structure and culture	Service strategy	Partially aligned / Integrated
Organization structure and culture	Sales–Service Integration level	Separated
Organization structure and culture	Physical distribution channel	hybrid/intermediate
Organization structure and culture	Digital Distribution channel	Absent
Economic and finance	Revenue model and mechanism	Fixed period / subscription (payment per period)
Economic and finance	Main Risk	Financial risk
Economic and finance	Risk mitigation strategy	Formalized risk management model
Economic and finance	Risk mitigation mechanisms	Financial company
Economic and finance	Profitability Measurement KPI	operational performance KPI
Resources	Data connectivity	Fully connected system
Resources	Data Exploitation	Basic operational data
Resources	Data Exploitation	Performance and behavioral data
Resources	Customer Data accessibility	Limited/conditional access
Resources	Technology role	Maintenance automation and/or operational continuity
Resources	Technology role	Real-time monitoring and/or analysis
Capabilities	service design capabilities	Basic design:
Capabilities	Risk assessment capabilities	Financial & operational integration
Capabilities	Human and relational capabilities	Managerial & organizational skills
Capabilities	Human and relational capabilities	Hybrid selling & distribution skills
Environmental sustainability	Product-life extension strategy	development of a durable product

Environmental sustainability	Resource efficiency	Implementation of eco-efficient design or processes
Environmental sustainability	Product service substitution	No substitution
Environmental sustainability	Dematerialization and transparency	Digital platforms supporting traceability and reporting
Environmental sustainability	Use and service intensity	Multi-contract asset utilization

Table 43 Toyota Handling Material Service coding results

C.3 Kaer

Company and XaaS Offering Overview

Kaer is a Singapore-based company operating in the cooling and air-conditioning industry, with a long-standing presence in Southeast Asia. Founded over seventy years ago, the company has evolved from an initial role as a distributor of HVAC equipment into a system integrator and, more recently, into a fully service-oriented provider. Kaer currently operates primarily in Singapore, India, Indonesia, and Malaysia, serving a wide range of customers including office buildings, shopping malls, educational campuses, data centers, and mixed-use developments. Kaer's business model is centered on **Cooling-as-a-Service (CaaS)**, which represents a radical shift from traditional product-based HVAC solutions. Under this model, Kaer designs, builds, owns, operates, and maintains cooling systems on behalf of customers, while customers pay exclusively for the cooling output consumed (e.g., per ton-hour). The physical assets remain fully owned by Kaer, and customers are relieved from capital expenditures, operational responsibilities, and performance risks. The offering covers the **entire product range** and is delivered through a long-term, outcome-oriented contractual arrangement.

Kaer framework-based analysis

- **Value proposition**

Kaer's XaaS offering is configured as a **product-based as-a-service model**, in which the as-a-service logic fully encompasses the physical cooling infrastructure together with all associated activities across the system lifecycle. Cooling-as-a-Service (CaaS) is not positioned as an add-on to a traditional product offering, but rather as the firm's **core and dominant business model**, following a strategic transition completed in 2018. This consolidated maturity level is reflected not only in the longevity of the offering, but also in the company's accumulated operational experience across multiple geographies, sectors, and building typologies. The **object of the offering** is therefore not a specific piece of equipment, but the continuous delivery of cooling performance. Customers do not purchase chillers, plants, or technical solutions; instead, they purchase a predefined cooling output, measured in standardized units (e.g., dollars per ton-hour), comparable to the way utilities such as electricity or

water are consumed. This framing fundamentally redefines the nature of value exchange, shifting attention away from assets and toward outcomes. The **coverage of the offering** extends to Kaer's **entire product range**, as the CaaS model is applicable across different cooling technologies, system configurations, and customer applications, including offices, shopping malls, data centers, educational campuses, and industrial facilities. The interview evidence highlights that the offering is deliberately designed to be adaptable across sectors, with differences addressed through service-level specifications rather than through changes to the core product architecture. Kaer adopts a clearly **proactive XaaS offering approach**. CaaS is actively promoted as a strategic alternative to ownership-based cooling solutions, rather than being proposed reactively in response to customer requests. This proactive stance is closely linked to the firm's explicit positioning of cooling as a non-core, yet mission-critical function for building owners and operators. The offering narrative consistently emphasizes that customers should invest capital and managerial attention in their core business activities, while outsourcing cooling complexity entirely to Kaer. A defining element of the value proposition is **ownership retention** by the offer provider. Kaer designs, builds, owns, operates, and upgrades the cooling systems over time, assuming full responsibility for system performance, availability, efficiency, and lifecycle management. Ownership is not presented merely as a contractual detail, but as a foundational mechanism that enables Kaer to optimize operations, continuously improve efficiency, and internalize the incentives associated with energy consumption and maintenance decisions. The **primary value for customers** is articulated as **simplicity**, understood as the comprehensive removal of technical, financial, and organizational complexity associated with cooling systems. Customers are deliberately shielded from decisions related to technology selection, system design, operation, optimization, maintenance, and regulatory compliance. As emphasized in the interview, customers "do not like air conditioning"; they require cooling to operate their buildings, but do not perceive it as a strategic area in which to invest time or expertise. By transforming cooling into a utility-like service, Kaer enables customers to access reliable and efficient cooling without engaging in asset ownership, performance optimization, or long-term planning. The offering is **customizable**, but customization is applied **exclusively at the service level**, rather than at the level of the physical product. Customers specify desired outcomes and service levels—such as temperature ranges, redundancy requirements (e.g., N+1 or N+2), availability, response times, and on-site staffing—while all technical and operational decisions remain under Kaer's control. This output-based customization allows the firm to accommodate heterogeneous customer needs without relinquishing control over system design, technology choices, or operational practices. In some cases, customer constraints (e.g., preferred equipment brands or regulatory requirements) are accommodated, but these are explicitly reflected in pricing adjustments, reinforcing the transparency

of the value exchange. Finally, the **communication of the offering** is integrated into Kaer's existing channels and relies heavily on **direct, high-level interactions** with top management roles on the customer side, including CEOs, CFOs, asset owners, and portfolio managers. This reflects the strategic nature of the decision to adopt CaaS, which is framed not as a technical procurement choice but as a business model decision affecting capital allocation, risk exposure, sustainability performance, and long-term operational responsibility. Technical discussions are deliberately minimized in favor of conversations centered on liquidity, risk, ESG performance, and organizational focus. Overall, Kaer's value proposition represents a highly mature and coherent XaaS configuration, in which outcome-based value delivery, ownership retention, service-level customization, and radical simplification for the customer are tightly integrated into a single offering logic.

- **Customers**

Kaer's XaaS offering is addressed to customers operating across different sectors and application contexts, without the adoption of a formal customer segmentation logic. Accordingly, the **target customer segments** are coded as **no distinction**, and the **customer segmentation strategy** is classified as **undifferentiated**. Cooling-as-a-Service is proposed through a consistent value proposition that does not vary according to industry, building typology, or customer category, suggesting that Kaer conceptualizes cooling as a transversal infrastructural need rather than as a sector-specific solution. Despite differences in customer contexts, the same CaaS logic is systematically applied, with variation managed at the level of service specifications rather than through differentiated customer strategies. This approach reflects the firm's emphasis on standardizing the underlying business model while allowing flexibility in output levels and service conditions, as already reflected in the customization logic described in the Value Proposition dimension. **Customer acceptance** of the offering is characterized by **high interest**. Interview evidence indicates that customers perceive Cooling-as-a-Service as particularly attractive due to the removal of capital expenditure requirements, the outsourcing of operational and technical complexity, and the alignment between cost predictability, performance delivery, and sustainability objectives. Cooling is consistently framed by customers as a non-core yet mission-critical activity: while it is essential for the functioning of buildings and operations, it is not considered an area in which customers wish to invest managerial attention or internal expertise. This perception underpins customers' readiness to adopt an as-a-service solution and to delegate responsibility to the provider. In terms of **customer involvement**, the configuration is clearly **passive**. Customers are involved in defining the required service outputs and performance levels, such as cooling capacity, availability, and redundancy, but they do not participate in system design, technology selection, operational

decisions, or optimization activities. Responsibility for all technical and operational aspects remains fully with Kaer. Interaction between the parties is therefore centered on the achievement of agreed performance outcomes, rather than on technical details or asset-related decisions. Overall, the Customers dimension highlights a configuration in which Kaer addresses a broad and undifferentiated customer base, characterized by high acceptance of the XaaS logic and limited involvement in service delivery. The customer role is primarily that of a performance recipient rather than a co-designer or co-operator, reinforcing the outcome-oriented and provider-driven nature of the Cooling-as-a-Service model.

- **Ecosystem**

Kaer's Cooling-as-a-Service model is supported by a **broad and heterogeneous ecosystem** comprising **financial, technical, and technological partners**, whose roles and relative importance have evolved in parallel with the company's transition toward a service-based business model. **Financial partners** play a fundamental role within Kaer's ecosystem, reflecting the capital-intensive nature of the CaaS model. Because Kaer retains ownership of the cooling assets and directly finances their design, installation, and operation, access to external financial resources is essential to enable both initial investments and long-term service delivery. Financial partners—including banks and investors—are therefore involved across **both the development and delivery phases** of the offering. Their engagement is characterized by a **collaborative governance model**, reflecting shared exposure to long-term financial performance and asset-related risks inherent in outcome-oriented and pay-per-use arrangements. **Technical partners** primarily consist of traditional HVAC equipment suppliers, including providers of chillers, cooling towers, pumps, and control components. These relationships remain largely anchored in conventional supply logics. Governance with technical partners is **coordinated and transactional**, with equipment procured through standard purchasing arrangements rather than through service-based or performance-oriented contracts. Engagement with these partners is concentrated mainly in the **development phase**, particularly during system design, engineering, and installation activities, after which their role becomes more limited. **Technological partners** have assumed an increasingly central position within Kaer's ecosystem as the company has scaled and consolidated its CaaS offering. These partners support a range of digital functionalities, including software development, data analytics, visualization, scheduling, billing, and ESG reporting. Kaer combines externally developed digital solutions—such as platforms for data visualization, ticketing, scheduling, and financial management—with internally developed systems, most notably **Kaer Connect**. The engagement with technological partners spans **both development and delivery phases**, reflecting the ongoing need for system integration, data reliability, and continuous platform

operation throughout the service lifecycle. Alliance governance varies by partner type but follows a **consistent and structured logic**. Relationships with financial partners are governed through **collaborative arrangements**, while governance with technical and technological partners is **coordinated**, with clearly defined roles, interfaces, and contractual boundaries. Despite the multiplicity of partners involved, Kaer deliberately maintains a **single contractual interface with customers**, retaining full responsibility for orchestrating the ecosystem internally. Customers interact exclusively with Kaer, without direct exposure to suppliers, financiers, or technology providers. This ecosystem configuration reinforces Kaer's role as the sole provider accountable for service outcomes, while simultaneously enabling the firm to mobilize complementary external resources and capabilities. By internalizing ecosystem complexity and shielding customers from multi-actor coordination, Kaer aligns its ecosystem structure with the core value proposition of simplicity and outcome-based service delivery.

- **Organizational structure and Culture**

Kaer's transition to Cooling-as-a-Service is underpinned by a **widespread and strategic commitment from top management**, which has driven a profound reconfiguration of the company's organizational structure and operating logic. The adoption of CaaS is not presented as an incremental extension of the existing product business, but as a deliberate shift away from a product-centric logic toward a service-dominant business model. This strategic orientation is reflected in the company's decision to focus almost exclusively on as-a-service offerings, with only a limited number of legacy turnkey projects still remaining. From an organizational perspective, Kaer has established **new, dedicated business units and teams** specifically designed to support the requirements of the CaaS model. A central structural feature of this reconfiguration is the **separation between asset development and asset operation**. Design and construction activities are managed by a dedicated asset development function, which is responsible for engineering and delivering cooling systems that meet predefined technical, performance, and quality standards. Asset operation and management are instead assigned to a separate team responsible for the continuous delivery of cooling performance, including maintenance, monitoring, and optimization activities throughout the contract duration. This internal separation increases clarity of roles and accountability, reducing the risk that technical or design-related issues are transferred unresolved into the operational phase. By clearly distinguishing responsibilities across the asset lifecycle, Kaer aligns its internal organization with the long-term performance obligations embedded in the CaaS model. In parallel, Kaer has created a **dedicated Customer Success function**, which plays a central role in managing customer relationships after contract signature. This function supports customers during the transition from product ownership to

service consumption, helping them adapt internal processes and expectations to the logic of outcome-based cooling. The Customer Success team also acts as an interface between customers and Kaer's internal operational teams, ensuring alignment between contractual performance commitments and delivered outcomes over time. The **service strategy** is fully integrated and strategically driven. Cooling-as-a-Service is embedded at the core of Kaer's business model rather than positioned as an ancillary or complementary service offering. This strategic integration is consistent with the company's organizational investments and with the central role assigned to service delivery, asset management, and customer relationship management. Despite this strong service orientation, the **sales–service integration level** is coded as **separated**. This reflects the recognition that selling long-term, outcome-based service contracts requires distinct competencies from those needed for day-to-day service delivery and operational management. Sales activities are primarily oriented toward strategic decision-makers on the customer side, such as CEOs, CFOs, and portfolio owners, and focus on issues related to financial structure, risk allocation, and long-term value. Service and operations teams, by contrast, concentrate on performance execution, reliability, and continuous optimization once the contract is in place. While coordinated, these activities remain organizationally distinct. Both **physical and digital distribution channels** are **disintermediated**. Kaer maintains direct relationships with customers throughout the entire lifecycle of the offering, from initial engagement and contract negotiation to service delivery, monitoring, and reporting. Digital platforms, such as *Kaer Connect*, support transparency, data access, and performance reporting, but they complement rather than replace direct organizational interfaces between Kaer and its customers. Overall, Kaer's organizational structure and culture reflect a high degree of alignment with the requirements of a consolidated XaaS model. Strategic commitment from top management, dedicated organizational units, clear separation of lifecycle responsibilities, and direct customer relationships collectively support the long-term delivery of outcome-based cooling services.

- **Economic and Finance**

Kaer's Cooling-as-a-Service offering is characterized by a **pure pay-per-use revenue model**, under which customers pay exclusively for the actual cooling output consumed. Consumption is typically measured in **ton-hours**, and the pricing mechanism does not include fixed fees, minimum consumption thresholds, penalties, or lock-in periods. Customers are therefore charged only when cooling is effectively used, with payments scaling linearly with consumption. This structure reflects Kaer's explicit intention to align the commercial model with the logic of utilities such as electricity or water, while operating within a service-based contractual framework. Pricing is **market-based** and reflects both competitive benchmarks and the specific configuration of the service requested by the

customer. While customers do not participate in technical design decisions or asset selection, they can choose among different **service levels**, such as redundancy requirements, on-site presence, or the inclusion of backup generators. These choices are directly incorporated into the final price. As a result, customization affects pricing **indirectly**, through service-level differentiation rather than through variations in the physical assets deployed. From a **cost structure** perspective, Kaer identifies four main cost components: capital expenditure, utilities, operations, and maintenance and optimization activities. Capital expenditure represents a significant upfront investment, as Kaer retains ownership of all cooling assets. Utility costs, primarily electricity and water, account for a substantial share of total costs, approximately half of the overall service cost. Operational and maintenance costs cover service labor, repairs, system optimization, and upgrades over time, reflecting Kaer's ongoing responsibility for performance delivery throughout the contract duration. The **main risk** associated with the CaaS model is **operational risk**, stemming from Kaer's full responsibility for system availability, efficiency, and performance. This risk is explicitly absorbed by the provider rather than transferred to customers. Kaer addresses this exposure through a **formalized risk management model**, supported by extensive data availability, historical operational data, and continuous performance monitoring across a diversified portfolio of sites. **Risk mitigation mechanisms** include both contractual and portfolio-based approaches. Contractually, Kaer applies pass-through mechanisms for utility price fluctuations: variations in electricity and water tariffs are transferred directly to customers through predefined pricing formulas. This ensures that Kaer is neither incentivized nor penalized by external changes in energy prices, maintaining neutrality with respect to utility cost volatility. At the same time, portfolio diversification across different building types, usage profiles, and geographical markets reduces dependency on individual sites or demand patterns, contributing to overall risk balancing. Finally, **profitability measurement** relies on a combination of **financial economics KPIs** and **operational performance KPIs**, all normalized per unit of cooling output. Examples include margin per ton-hour, efficiency per ton-hour, and maintenance intensity per ton-hour. This output-based measurement logic reinforces alignment between economic performance, operational efficiency, and service delivery, and is fully consistent with the pay-per-use structure of the offering. By anchoring both revenues and costs to the same output metric, Kaer ensures coherence between value creation and value capture mechanisms.

- **Resources**

Kaer's Cooling-as-a-Service model is strongly enabled by a set of **digital and data-related resources** that support continuous monitoring, operational continuity, and service customization throughout the lifecycle of the offering. At the foundation of the resource configuration lies a **fully connected system**

architecture. All cooling assets deployed within the CaaS model are equipped with connectivity solutions that allow continuous data transmission from the field. This full connectivity enables Kaer to collect real-time information on system status, usage, and performance, forming the technological backbone of the pay-per-use and outcome-oriented service logic. In terms of **data exploitation**, Kaer leverages multiple layers of data. **Basic operational data** are systematically collected and used across all installations to monitor system functioning and ensure availability. In addition, **performance and behavioral data** are exploited to assess efficiency levels, usage patterns, and deviations from expected performance. Beyond these layers, Kaer also integrates **system-level and customer-related data**, enabling a more comprehensive view of asset behavior within its operational and contractual context. The coexistence of these three data categories indicates a relatively advanced data exploitation configuration compared to more basic monitoring-oriented XaaS models. Consistently with this approach, Kaer has **full access to customer data** relevant to service delivery. This access supports continuous performance tracking, reporting, and optimization activities, and allows Kaer to manage cooling systems in line with contractual commitments and service-level agreements. Data accessibility is therefore not episodic or conditional, but structurally embedded in the service relationship. The **role of technology** within the CaaS offering is multifaceted. First, technology supports **real-time monitoring and analysis**, enabling Kaer to continuously track system performance and respond promptly to deviations or anomalies. Second, technology plays a key role in **maintenance automation and operational continuity**, supporting preventive and predictive maintenance activities aimed at ensuring reliability and minimizing downtime. Finally, technology enables a **high level of service customization**, allowing Kaer to tailor output levels, service conditions, and performance parameters to customer requirements without altering the underlying asset architecture. These technological resources are integrated through a combination of internally developed and externally sourced digital solutions. Internally, platforms such as *Kaer Connect* provide centralized visibility and coordination, while external tools support complementary functionalities related to data visualization, scheduling, billing, and reporting. Together, these resources allow Kaer to manage complex service operations at scale while maintaining consistency and transparency in service delivery. Overall, the Resources dimension highlights a configuration in which full connectivity, multi-layer data exploitation, and digitally enabled monitoring and maintenance are essential enablers of the CaaS model. These resources support Kaer's ability to deliver cooling as a measurable, controllable, and continuously optimized service, reinforcing the alignment between operational execution, economic logic, and customer value creation.

- **Capabilities**

Kaer's Cooling-as-a-Service model relies on a set of **organizational and managerial capabilities** that directly support the design, delivery, and continuous improvement of the service offering. As highlighted in the interview material, the capabilities discussed by the company reflect those considered critical for enabling the CaaS model, rather than a comprehensive mapping of all existing organizational competences. A central capability underpinning Kaer's XaaS configuration is its **service design capability**, which is characterized by **continuous innovation**. Rather than treating Cooling-as-a-Service as a fixed or standardized solution, Kaer continuously refines and adapts its service offering over time, incorporating operational learning, performance data, and customer feedback. This capability supports the evolution of service features, contractual structures, and operational practices, ensuring that the offering remains aligned with customer expectations and performance requirements as conditions change. In parallel, Kaer demonstrates **structured risk assessment and management capabilities**, which are particularly critical given the company's full ownership of assets and responsibility for long-term performance. Risk assessment is not handled in an ad hoc manner, but is embedded in a **structured risk management framework** that integrates financial and operational considerations. This capability is supported by the availability of historical operational data and by continuous performance monitoring across Kaer's portfolio of sites, enabling the firm to assess risks proactively and to manage exposure at both project and portfolio level. Human and relational capabilities also play a key role in enabling the CaaS model. Kaer places strong emphasis on **hybrid selling and distribution skills**, which combine technical understanding with financial, contractual, and relational competences. These skills are essential for engaging with high-level customer stakeholders, such as CEOs, CFOs, and asset owners, and for communicating the value of outcome-based, pay-per-use service contracts. Hybrid capabilities allow Kaer's teams to bridge technical performance considerations with business-level discussions around cost predictability, risk allocation, and long-term value. Together, these capabilities support Kaer's ability to operate Cooling-as-a-Service as a consolidated XaaS model. Continuous service innovation enables adaptation and scalability, structured risk management underpins economic sustainability, and hybrid relational skills facilitate the commercialization and long-term management of service relationships. Rather than being evenly distributed across all possible capability categories, Kaer's capabilities are selectively developed in areas that are directly aligned with the requirements of outcome-based cooling service delivery.

- **Environmental Sustainability**

Environmental sustainability constitutes a **structural pillar** of Kaer's Cooling-as-a-Service model and is closely interwoven with both the operational and economic dimensions of the offering. Rather

than being treated as a secondary or ancillary benefit, the environmental impact of cooling systems, particularly in terms of electricity consumption and associated carbon emissions, is explicitly addressed through the design of the service model itself. Kaer actively implements **end-of-life and reverse logistics strategies**, adapted to the specific characteristics of cooling assets. At the end of contracts, equipment is systematically collected whenever feasible, enabling controlled asset recovery and redeployment. A central element of this approach is the extensive use of **second-hand and refurbished chillers**, which are reintegrated into the XaaS offering, often as standby or backup units. Although these assets may no longer represent the highest available energy-efficiency standards, they remain highly reliable and well suited for non-continuous operation. Their reuse allows Kaer to significantly extend asset lifetimes while reducing the need for new equipment production. Product-life extension is further supported through **intensive preventive and predictive maintenance programs**. Because Kaer retains ownership and operational responsibility for all cooling assets, the company is directly incentivized to maximize asset reliability and longevity while minimizing performance degradation over time. Maintenance, refurbishment, and selective component replacement are therefore integral elements of the service offering, embedded within the operational logic rather than treated merely as cost-containment activities. **Resource efficiency**, particularly with respect to energy and water consumption, represents a core operational objective. Since Kaer directly bears utility costs, continuous optimization of resource use is embedded in daily operations. System efficiency is monitored in real time, and deviations from expected performance are promptly identified and addressed to limit waste and inefficiencies. In parallel, Kaer adopts **eco-efficient design and operational practices**, including modular system configurations and adaptive capacity management, which allow cooling assets to be scaled up or down in response to changing demand conditions. The offering does not involve **product–service substitution**, as physical cooling assets remain essential to service delivery. However, Kaer actively promotes **dematerialization and transparency** through the use of digital platforms. Customers are provided with continuous access to environmental performance data—such as energy consumption and carbon emissions—through dashboards and reporting tools. This enables customers to integrate cooling-related metrics into their broader ESG and sustainability reporting frameworks, enhancing visibility and accountability. Finally, the inclusion of second-hand assets and the **dynamic reallocation of equipment across sites** contribute to increased **use and service intensity**. By optimizing asset utilization across multiple contracts and operational contexts, Kaer reduces the environmental footprint per unit of cooling delivered, reinforcing the sustainability logic embedded in the Cooling-as-a-Service model.

DIMENSIONS	VARIABLES	CODING
Value proposition	Offer object	Product

Value proposition	Maturity Level of the Service Offering	Consolidated
Value proposition	Coverage of the Offering	Entire product range
Value proposition	XaaS Offering Approach	Proactive
Value proposition	Ownership	Offer Provider
Value proposition	Value for the customers	simplicity (removal of complications)
Value proposition	Offer costumization (level)	Customizable offer
Value proposition	Offer Customization (object)	Service
Value proposition	Offer communication	Integration into existing channels
Customers	Traget Customer segments	No distinction
Customers	Customer segmentation strategy	Undifferentiated
Customers	Customer acceptance	High interest
Customers	Customer involvement	Passive
Ecosystem	Presence of strategic partners	Financial
Ecosystem	Presence of strategic partners	Technical
Ecosystem	Presence of strategic partners	Technological
Ecosystem	Continuity of strategic partners' engagement	Financial _both
Ecosystem	Continuity of strategic partners' engagement	Technical _development
Ecosystem	Continuity of strategic partners' engagement	Technological _both
Ecosystem	Alliance governance	Financial_collaborative
Ecosystem	Alliance governance	Technical _coordinated
Ecosystem	Alliance governance	Technological _coordinated
Organization structure and culture	Level of commitment of the top management of the provider	Widespread and strategic commitment
Organization structure and culture	Internal organization	New, dedicated business unit or team
Organization structure and culture	Service strategy	Fully integrated / Strategically driven
Organization structure and culture	Sales–Service Integration level	Separated
Organization structure and culture	Physical distribution channel	Disintermediated
Organization structure and culture	Digital Distribution channel	Disintermediated
Economic and finance	Revenue model and mechanism	Pay-per-use
Economic and finance	Main Risk	Operational risk
Economic and finance	Risk mitigation strategy	Formalized risk management model
Economic and finance	Risk mitigation mechanisms	Contractual clauses
Economic and finance	Risk mitigation mechanisms	Customer and/or portfolio diversification

Economic and finance	Profitability Measurement KPI	financial economics KPI
Economic and finance	Profitability Measurement KPI	operational performance KPI
Economic and finance	Pricing	Market-based
Resources	Data connectivity	Fully connected system
Resources	Data Exploitation	Basic operational data
Resources	Data Exploitation	Performance and behavioral data
Resources	Data Exploitation	Integrated system & customer data
Resources	Customer Data accessibility	Full access
Resources	Technology role	Maintenance automation and/or operational continuity
Resources	Technology role	Real-time monitoring and/or analysis
Resources	Technology role	High level of customization
Capabilities	service design capabilities	Continuous innovation:
Capabilities	Risk assessment capabilities	Structured risk management
Capabilities	Human and relational capabilities	Hybrid selling & distribution skills
Environmental sustainability	End-of-life and reverse logistics strategies	End-of-life/contract product collection
Environmental sustainability	Product-life extension strategy	Preventive and predictive maintenance programs
Environmental sustainability	Resource efficiency	Measurements and optimization of resource, consumption (energy, materials..)
Environmental sustainability	Resource efficiency	Implementation of eco-efficient design or processes
Environmental sustainability	Product service substitution	No substitution
Environmental sustainability	Dematerialization and transparency	Digital platforms supporting traceability and reporting
Environmental sustainability	Use and service intensity	Inclusion of second-hand products in the aaS offering

Table 44 Kaer coding results

C.4 Kuka Robotics

Company description

KUKA Robotics is a global automation specialist and one of the world's leading manufacturers of industrial robots and automated production systems. Headquartered in Augsburg, Germany, KUKA operates worldwide through an extensive network of subsidiaries and service centers, serving industries such as automotive, electronics, metal and plastic processing, consumer goods, e-commerce, and healthcare. Over decades, the company has built a strong reputation for German engineering quality, advanced robotics technology, and system integration capabilities. Beyond its

core product business, KUKA has developed a highly structured and globally standardized Customer Service organization, which represents a strategic pillar of the company's value creation logic. KUKA Global Customer Services provides lifecycle-oriented support ranging from planning and system design to installation, programming, maintenance, refurbishment, and reuse of robots. This service-oriented infrastructure constitutes the organizational foundation upon which KUKA's XaaS initiatives are developed. Within this context, KUKA has experimented with two distinct XaaS configurations:

1. a **robot rental model**, in which robots are provided as product-based solutions under subscription contracts;
2. a **service-based XaaS model**, in which customers retain ownership of robots while accessing advanced services delivered in an as-a-service logic.

These two configurations represent **two distinct units of analysis** within the proposed framework.

Kuka Robotics Rental XaaS Offering Overview

KUKA's robot rental offering is conceived as a temporary access model to industrial robots, designed to address specific and time-bounded customer needs rather than to replace traditional ownership-based sales. The offering allows customers to use robotic equipment for a defined contractual period without purchasing the asset, thereby lowering entry barriers to automation and increasing flexibility in capacity management. Rental contracts are typically activated in response to concrete customer requests and are negotiated on a case-by-case basis. The offering is therefore not yet fully standardized, nor embedded in a formalized commercial portfolio, but operates as an adaptive solution tailored to situational requirements. The rental configuration is currently framed as a pilot, and KUKA is actively exploring a transition toward a more structured operating lease model. This prospective evolution involves the participation of an external financial partner, which would acquire ownership of the robot and lease it to the customer through KUKA. Such an arrangement is explicitly discussed in the interview as a potential way to reduce internal financial exposure while maintaining flexibility for customers. However, at the time of the study, this model remains under evaluation and has not yet been fully implemented. From an operational perspective, the rental offering typically involves the provision of a standardized robot configuration, with limited or no customization. This standardization supports rapid deployment and aligns with the temporary nature of the offering. Service components associated with the rental remain basic and are primarily oriented toward ensuring operability over the rental period, rather than delivering advanced lifecycle or performance-based guarantees. Overall, KUKA's robot rental offering can be characterized as an access-enabling, product-centered XaaS configuration, aimed at reducing customers' upfront investment and

increasing short-term flexibility, while allowing KUKA to experiment with alternative revenue and asset management logics without fundamentally disrupting its core product business.

Kuka Robotics Rental framework-based analysis

- **Value proposition**

The value proposition of KUKA's robot rental offering is centered on providing **temporary access to industrial robots** without requiring customers to commit to full ownership or long-term capital investment. Within the framework, the **object of the offering** is clearly the **product**, as the physical robot remains the core element of value creation, even though access is mediated through a rental contract. The **maturity level** of the offering is coded as **pilot**, reflecting the exploratory and non-standardized nature of the rental solution. Interview evidence confirms that the rental model is not yet fully structured or institutionalized, and that KUKA is still evaluating alternative contractual and financial arrangements, including a potential shift toward an operating lease model managed in collaboration with a financial partner. As a result, the value proposition is not yet crystallized into a single, stable configuration, but remains flexible and adaptive. In terms of **coverage**, the rental offering is limited to a **specific category of robots** rather than the entire portfolio. This reflects a deliberate choice to restrict the model to selected use cases where temporary access is particularly valuable, such as short-term capacity needs, pilot applications, or transitional production phases. The **offering approach** is therefore **reactive**, as the rental solution is typically activated in response to explicit customer requests rather than proactively proposed as a standard alternative to product sales. **Ownership** of the physical asset is retained by **third parties**, consistent with the involvement of external financial partners in the rental logic. This ownership structure allows KUKA to decouple robot usage from asset ownership, thereby enabling customers to access robotic capacity without absorbing balance-sheet exposure or depreciation risk. The **value for customers** is articulated along two closely related dimensions. First, the rental model supports the **minimization of operating costs** by eliminating large upfront investments and transforming capital expenditure into time-bound operating expenses. Second, it enables **optimization of usage processes**, as customers can align robot availability more closely with actual production needs, avoiding underutilization or overcapacity once the rental period ends. The rental offering is characterized by **no customization**, indicating that robots are delivered in a standardized configuration rather than being tailored to individual customer specifications. This standardization supports simplicity and speed of deployment, which are consistent with the temporary and pilot-oriented nature of the offering. Finally, **offer communication** is coded as **limited or absent**, reinforcing the interpretation of robot rental as a non-core,

supplementary solution that is not actively promoted within KUKA's mainstream commercial narrative, but rather leveraged selectively to address specific customer situations.

- **Customers**

The customer dimension of KUKA's robot rental offering reflects the **exploratory and situational nature** of the model. Within the framework, **target customer segments** are coded as **no distinction**, indicating that the rental solution is not formally restricted to a specific industry or customer type. However, empirical evidence suggests that the offering is activated primarily in contexts where customers face **temporary or uncertain automation needs**, rather than as a standardized alternative to ownership-based procurement. The **segmentation strategy** is coded as **segment-oriented**, which captures the fact that, while no explicit segmentation is institutionalized, the rental model is practically relevant only for a subset of use cases. These include short-term production increases, pilot projects, or transitional phases in which customers are testing automation solutions without committing to long-term investments. In these situations, rental becomes a viable option to reduce commitment and risk, even though it is not systematically promoted across the entire customer base. Customer **acceptance** of the rental offering is coded as **moderate interest**. Interview evidence indicates that customers generally perceive the rental solution as attractive in principle, particularly due to its ability to lower entry barriers and reduce upfront costs. At the same time, interest is tempered by uncertainty regarding contractual conditions, asset availability, and the long-term implications of rental compared to purchase. This ambivalence is consistent with the pilot status of the offering and with its activation primarily upon request. Customer **involvement** is coded as **passive**, reflecting the fact that customers do not actively participate in the design or customization of the rental model. The offering is largely provider-defined, with standardized configurations and limited room for negotiation beyond basic contractual terms. Customer interaction is therefore confined to acceptance and use of the rented robot, rather than co-creation of the service or joint definition of performance metrics. Overall, the customer dimension reinforces the interpretation of KUKA's robot rental as a **complementary access mechanism** rather than a fully developed market-facing XaaS solution. Customers engage with the model pragmatically and selectively, using it to address specific operational needs while continuing to rely on traditional ownership-based arrangements for long-term automation strategies.

- **Ecosystem**

The ecosystem supporting KUKA's robot rental offering is structured around the presence of **strategic financial partners**, whose role is central to the feasibility of the rental logic. Within the framework, partners are coded as **financial**, with **continuous engagement** across both the

development and delivery phases of the offering, and with **collaborative governance**. Interview evidence highlights that the rental model is closely linked to discussions with external financial institutions, which are expected to assume ownership of the robotic assets within an operating rental or leasing configuration. This arrangement is explicitly described as a way to manage the high capital intensity of industrial robots and to reduce KUKA's direct exposure to asset ownership risks. As such, financial partners are not peripheral actors, but rather **structural enablers** of the rental model. The governance of the ecosystem is collaborative in nature. KUKA retains responsibility for the customer relationship, the definition of the offering, and the coordination of service and operational aspects, while financial partners contribute capital and asset management capabilities. This division of roles reflects a complementary logic: KUKA leverages its technological and market expertise, while delegating financial ownership and depreciation risks to specialized partners. At the same time, the ecosystem configuration remains **relatively narrow**. There is no evidence of broader technological or service delivery partnerships specifically developed to support the rental model. Service activities associated with the rented robots are managed primarily within KUKA's existing service infrastructure, rather than through external partners. This reinforces the interpretation of robot rental as an extension of existing business practices rather than as a fully reconfigured ecosystem-based XaaS model. Overall, the ecosystem dimension underscores that KUKA's robot rental offering is **financially enabled rather than technologically orchestrated**. The success and scalability of the model depend largely on the stability of partnerships with financial institutions and on KUKA's ability to integrate these partners into its commercial and contractual architecture, rather than on the development of a complex multi-actor service ecosystem.

- **Organization structure and culture**

The organizational configuration underlying KUKA's robot rental offering reflects the **experimental and non-institutionalized** nature of the model. Within the framework, **top management commitment** is coded as **widespread and strategic**, indicating that the exploration of alternative access and revenue models is supported at a high level within the organization. This strategic openness provides legitimacy to experimentation with rental solutions, even in the absence of a fully developed service strategy. Despite this high-level commitment, the **internal organization** of the rental offering remains anchored in **existing functions and business units**. There is no dedicated organizational unit or team responsible exclusively for the development and scaling of robot rental. Instead, the offering is managed through established commercial and service structures, which are primarily oriented toward traditional product sales and project-based delivery. This organizational choice limits the degree of focus and specialization that can be devoted to the rental model. The

service strategy is coded as **absent or not aligned**, reflecting the fact that robot rental is not embedded within a broader, coherent servitization or XaaS roadmap. The rental model is treated as an additional commercial option rather than as a strategic pivot, and it does not yet benefit from clearly articulated objectives, performance metrics, or long-term organizational planning. **Sales–service integration** is coded as **partially integrated**. While sales and service functions collaborate to ensure the operability of rented robots, their interaction remains shaped by existing roles and incentives. Sales activities continue to be predominantly oriented toward product transactions, and the rental model does not fundamentally alter sales responsibilities or compensation structures. Service functions provide operational support, but are not positioned as co-owners of the rental offering. Regarding channels, the **physical distribution channel** is **disintermediated**, as KUKA maintains direct relationships with customers in rental negotiations and delivery. In contrast, the **digital distribution channel** is coded as **absent**, indicating that there are no dedicated digital tools or platforms for configuring, ordering, or managing rental contracts. This absence reinforces the interpretation of the rental offering as a manually managed, case-specific solution rather than a standardized, scalable XaaS model. From a cultural perspective, the organizational context remains strongly influenced by a **product-centric mindset**. The rental model coexists with, rather than challenges, the dominant logic of product sales. As a result, robot rental functions more as a pragmatic response to specific customer situations than as a catalyst for deeper cultural transformation toward service-based value creation.

- **Economic and Finance**

The economic and financial configuration of KUKA's robot rental offering reflects the **experimental character** of the model and the centrality of asset-related considerations. Within the framework, the **revenue model** is coded as a **fixed-period subscription**, with customers paying a recurring fee for access to the robot over a predefined contractual period. This payment logic allows KUKA to shift revenues from a one-off transaction to a time-distributed stream, while preserving a relatively simple pricing structure. Interview evidence indicates that the rental model is closely linked to discussions around **operating lease arrangements**, in which an external financial partner would acquire ownership of the robot and lease it to the customer through KUKA. This prospective structure highlights the importance of financial engineering in enabling the rental offering, particularly in light of the high capital value of industrial robots. At the time of the study, this configuration remains under evaluation and has not yet been fully implemented, reinforcing the pilot status of the offering. The **main risk** associated with the rental model is coded as **financial risk**. This risk stems from uncertainty regarding asset utilization, contract duration, and residual value, especially in a context

where rental demand is still sporadic and case-specific. Capital exposure and cash flow timing are therefore critical concerns, influencing both pricing decisions and partner selection. Risk mitigation is addressed through a **formalized risk management model**, primarily based on collaboration with **financial companies**. By delegating asset ownership and depreciation risks to specialized partners, KUKA aims to limit its direct financial exposure while maintaining the ability to offer rental solutions to customers. Contractual arrangements play an important role in defining responsibilities, usage conditions, and payment obligations, even though these arrangements are still being refined. Profitability assessment is coded through **operational performance KPIs**, rather than through lifecycle or outcome-based metrics. This reflects the early stage of the rental model, in which performance is evaluated primarily in terms of utilization, contract fulfillment, and short-term financial balance, rather than through long-term value creation or systemic transformation of the revenue model. Overall, the economic and financial dimension underscores that KUKA's robot rental offering is **financially cautious and risk-aware**, prioritizing controlled experimentation and partner-based risk sharing over rapid scaling or radical reconfiguration of the company's core business model.

- **Resources**

The resource configuration underlying KUKA's robot rental offering is **limited and only partially aligned with a data-driven XaaS logic**, reflecting the experimental nature of the model and its positioning as a complementary access solution rather than as a digitally enabled service system. Within the framework, the rented robots are coded as **disconnected products**. This indicates that connectivity and digital integration are not systematically embedded in the rental configuration. While the robots are technically capable of generating operational data, such data are not structurally leveraged as a core resource for the rental offering. As a result, the rental model does not rely on continuous data flows to deliver value, monitor usage in real time, or support advanced service features. Data exploitation is therefore limited to **basic operational data**, and **customer data accessibility is absent**. This implies that neither KUKA nor the customer systematically accesses or exploits usage data as part of the rental contract. The absence of structured data access reinforces the interpretation of the rental offering as primarily contractual and asset-based, rather than data-enabled. Digital resources do not play a central role in differentiating or scaling the offering. The role of technology within the rental configuration is coded as **real-time monitoring and/or analysis**, but this role remains marginal and non-systematic. Technology is used, where necessary, to ensure basic operability and to support internal checks, rather than to provide continuous monitoring, predictive insights, or performance-based guarantees. There is no evidence of dedicated digital platforms, dashboards, or analytics tools specifically designed to support the rental model. From a broader

resource perspective, the rental offering relies mainly on **physical assets (robots)** and on KUKA's existing **commercial and service infrastructure**, rather than on new digital or informational resources. The absence of proprietary digital platforms or structured data exploitation limits both scalability and standardization, but at the same time allows KUKA to deploy the rental model with relatively low organizational disruption. Overall, the resource dimension confirms that KUKA's robot rental offering is a **low-digital-intensity XaaS configuration**, where value is generated primarily through temporary access to a high-value physical asset, supported by existing organizational resources, rather than through the creation and exploitation of new digital or data-driven resources.

- **Capabilities**

The capability base supporting KUKA's robot rental offering is primarily oriented toward **managerial and organizational coordination**, rather than toward advanced digital or analytical competencies. Within the framework, capabilities are coded as **managerial and organizational skills**, with **basic data-analysis capabilities**, a configuration that is consistent with the low level of digital integration observed in the resource dimension. A core capability underpinning the rental model lies in KUKA's ability to **manage contractual and operational arrangements** for temporary asset provision. This includes coordinating internal commercial units, interfacing with service functions to ensure basic operability during the rental period, and aligning contractual terms with customer-specific requirements. These capabilities allow KUKA to activate rental solutions pragmatically, even in the absence of a standardized or scalable service architecture. Another critical capability concerns **partner coordination**, particularly with financial institutions involved in the prospective operating lease configuration. Interview evidence suggests that KUKA is developing the organizational ability to interact with external financial partners, negotiate asset ownership structures, and integrate these arrangements into its commercial processes. While this capability is still emerging, it is central to enabling the rental logic without exposing the company to excessive financial risk. By contrast, **digital and analytical capabilities remain limited**. The rental model does not require sophisticated data interpretation, predictive analytics, or performance-based monitoring. As a result, KUKA has not developed dedicated analytical routines or digital service competencies specifically for this offering. Data, where available, are not used as a strategic input for value creation, but remain peripheral to the rental logic. From a sales and market-facing perspective, capabilities are also constrained by the **dominant product-centric mindset** of the organization. Selling rental solutions requires a different commercial narrative compared to traditional product sales, yet the interview material indicates that sales capabilities have not been fundamentally reconfigured to support this

shift. Rental contracts are therefore handled as exceptions within existing sales practices, rather than as outcomes of a dedicated capability set. Overall, the capability dimension reinforces the interpretation of KUKA's robot rental as a **low-capability-intensity XaaS configuration**, relying on existing managerial competencies and organizational flexibility rather than on newly developed service, digital, or analytical capabilities. This configuration supports experimentation and responsiveness, but limits the scalability and transformative potential of the rental model within KUKA's broader business system.

- **Environmental Sustainability**

Environmental sustainability within KUKA's robot rental offering is articulated in a **structured but indirect manner**, emerging primarily as a consequence of asset utilization and lifecycle management practices rather than as an explicit objective of the XaaS model. Within the framework, sustainability-related practices are more developed in this unit of analysis than in other pilot XaaS configurations, reflecting KUKA's broader service-oriented approach to robotics assets. A key sustainability mechanism is the provision of **remanufacturing and refurbishment services**, which allow rented robots to be recovered, inspected, upgraded, and redeployed after the end of a rental period. This approach supports **product-life extension**, enabling robots to remain in use across multiple customers and applications rather than being prematurely replaced. The rental logic is therefore aligned with the development of **durable products**, designed to withstand repeated use and multiple lifecycle phases. The rental model also contributes to **optimization of asset use**. By enabling temporary access to robots, KUKA can increase utilization rates across its asset base, reducing idle time and overcapacity. Higher utilization intensity per asset translates into more efficient use of materials and embedded energy over the robot's lifetime, even though these effects are not explicitly measured or communicated as sustainability outcomes. In addition, the coding indicates the presence of **eco-efficient processes and design practices**, which are consistent with KUKA's broader approach to engineering and service delivery. While the rental offering itself does not introduce new eco-design features, it leverages existing product characteristics and service processes that support efficiency and longevity. Digital platforms supporting **traceability and reporting** are also referenced in the sustainability coding. In the context of the rental offering, these platforms enable internal tracking of assets across rental cycles, maintenance interventions, and redeployment phases. However, this traceability is primarily internal and operational; there is no evidence of structured environmental reporting or sustainability metrics being shared with customers as part of the rental contract. The rental configuration does not involve **product–service substitution**, as physical robots remain central to value creation. Sustainability benefits arise from **how** robots are used and managed, rather than

from replacing physical assets with digital or outcome-based services. Similarly, there are no explicit initiatives focused on reducing energy consumption during robot operation through the rental model itself. Overall, environmental sustainability in KUKA's robot rental offering can be characterized as **utilization-driven and lifecycle-oriented**, embedded in asset management and refurbishment practices rather than strategically framed or market-facing. Sustainability outcomes are thus real but implicit, supporting efficiency and circularity without being positioned as a primary driver of the XaaS value proposition.

DIMENSIONS	VARIABLES	CODING
Value proposition	Offer object	Product
Value proposition	Maturity Level of the Service Offering	Pilot
Value proposition	Coverage of the Offering	Specific category
Value proposition	XaaS Offering Approach	reactive (Upon request)
Value proposition	Ownership	Third parties
Value proposition	Value for the customers	minimization of operating costs
Value proposition	Value for the customers	optimization of usage processes
Value proposition	Offer costumization (level)	No customization
Value proposition	Offer communication	Limited or absent communication
Customers	Traget Customer segments	No distinction
Customers	Customer segmentation strategy	Segment-Oriented
Customers	Customer acceptance	Moderate interest
Customers	Customer involvement	Passive
Ecosystem	Presence of strategic partners	Financial
Ecosystem	Continuity of strategic partners' engagement	Financial _both
Ecosystem	Alliance governance	Financial_collaborative
Organization structure and culture	Level of commitment of the top management of the provider	Widespread and strategic commitment
Organization structure and culture	Internal organization	Existing functions or business units (es. Sales service)
Organization structure and culture	Service strategy	Absent / Not aligned
Organization structure and culture	Sales–Service Integration level	Partially integrated
Organization structure and culture	Physical distribution channel	Disintermediated
Organization structure and culture	Digital Distribution channel	Absent
Economic and finance	Revenue model and mechanism	Fixed period / subscription (payment per period)
Economic and finance	Main Risk	Financial risk

Economic and finance	Risk mitigation strategy	Formalized risk management model
Economic and finance	Risk mitigation mechanisms	Financial company
Economic and finance	Profitability Measurement KPI	operational performance KPI
Resources	Data connectivity	Disconnected product
Resources	Data Exploitation	Basic operational data
Resources	Customer Data accessibility	No specific data
Resources	Technology role	Real-time monitoring and/or analysis
Capabilities	Data-analysis capabilities	Basic
Capabilities	Human and relational capabilities	Managerial & organizational skills
Environmental sustainability	End-of-life and reverse logistics strategies	Remanufacturing services offered
Environmental sustainability	Product-life extension strategy	development of a durable product
Environmental sustainability	Resource efficiency	Measurements and optimization of resource, consumption (energy, materials..)
Environmental sustainability	Resource efficiency	Implementation of eco-efficient design or processes
Environmental sustainability	Product service substitution	No substitution
Environmental sustainability	Dematerialization and transparency	Digital platforms supporting traceability and reporting
Environmental sustainability	Use and service intensity	Optimization of asset use (maximized uptime, performance-based logic)

Table 45 Kuka Robotics Rental coding results

Kuka Robotics Service XaaS Offering Overview

KUKA's service-based XaaS offering consists of delivering a **comprehensive portfolio of customer services** in an as-a-service logic, while **ownership of the robotic systems remains with the customer**. The offering is rooted in KUKA's long-established Global Customer Service organization and builds on standardized service contracts rather than on temporary asset access or outcome-based guarantees. Interview evidence indicates that service activities are articulated through different contractual logics depending on the nature of the service. Certain activities, such as robot programming or specific interventions, are provided on a **one-off basis**, while other services, most notably maintenance and availability-oriented services, are structured through **recurring contracts**, typically with **annual payments** and multi-year durations. This hybrid structure reflects the coexistence of transactional and subscription-based elements within the service portfolio. The service offering encompasses preventive and corrective maintenance, availability support, spare parts logistics, technical assistance, and programming support. As highlighted in the customer service

materials, these services are designed to ensure **high system availability**, reduce unplanned downtime, and support stable operation throughout the robot's lifecycle. Service levels and contractual terms can vary depending on customer needs, production criticality, and installed system complexity, but the overall architecture of the offering is standardized and globally coordinated. From an operational perspective, the service XaaS model does not replace existing sales-based relationships but rather **complements product ownership** by extending KUKA's involvement across the lifecycle of installed robots. Customers retain full control and responsibility over the asset, while KUKA assumes responsibility for defined service activities under contractual agreements. The offering is therefore not framed as a radical business model innovation, but as a **structured formalization of service delivery through recurring contractual arrangements**. Overall, KUKA's service-based XaaS offering can be characterized as a **consolidated, service-centric configuration**, in which value is created through continuous support, maintenance, and operational assistance rather than through asset provision. The as-a-service logic primarily concerns **how services are contracted and delivered**, rather than a transformation of asset ownership or performance risk allocation.

Kuka Robotics Service framework-based analysis

- **Value proposition**

The value proposition of KUKA's service-based XaaS offering is centered on providing **continuous operational support** for installed robotic systems, with the objective of ensuring system availability, reliability, and stable performance over time. Within the framework, the **object of the offering** is clearly coded as **service**, as value is generated through the delivery of maintenance, support, and technical assistance rather than through access to or ownership of physical assets. The **maturity level** of the offering is coded as **consolidated**, reflecting the fact that service contracts represent a well-established and institutionalized component of KUKA's business model. Service offerings are not experimental or ad hoc, but are embedded within a structured global portfolio and supported by standardized processes and contractual templates. In terms of **coverage**, the service XaaS offering spans the **entire product range**, applying to all robotic systems installed by KUKA across different industries and applications. The **approach** is **proactive**, as services are actively proposed to customers as an integral part of the lifecycle strategy, rather than being activated only upon request. Service communication is **integrated into existing channels**, including direct sales interactions and customer service touchpoints, reinforcing the perception of services as a core element of KUKA's value proposition. **Ownership** of the robotic systems remains with the **customer**, and the service offering is designed to complement, rather than substitute, traditional product sales. Customer value is articulated primarily in terms of **minimization of operating costs** and **optimization of usage**

processes. By ensuring preventive maintenance, rapid response, and technical support, KUKA enables customers to reduce unplanned downtime, extend asset lifetimes, and stabilize production performance. The service offering is **configurable**, with customization applied at the **service level**. Customers can select different service packages, maintenance levels, and contractual durations based on their operational requirements and criticality of the robotic systems. This configurability allows KUKA to address heterogeneous customer needs while maintaining a standardized service architecture. Overall, the value proposition of KUKA's service-based XaaS offering can be characterized as **lifecycle-oriented and reliability-driven**, focusing on sustaining the performance of customer-owned assets through recurring service contracts. The as-a-service logic lies in the **contractual and relational continuity** of service provision, rather than in a transformation of asset ownership or risk allocation.

- **Customers**

The customer dimension of KUKA's service-based XaaS offering reflects the **broad and transversal relevance** of services within the company's installed base. Within the framework, **target customer segments** are coded as **no distinction**, indicating that the service offering is conceived as applicable to all customers operating KUKA robotic systems, regardless of industry, size, or application context. Consistently, the **segmentation strategy** is coded as **undifferentiated**. Service contracts are not designed around narrowly defined customer niches, but rather around the universal need to ensure availability, reliability, and continuity of robotic operations. While different industries and applications may require different service levels, this differentiation is handled through configurable service packages rather than through formal segmentation strategies. Customer **acceptance** of the service XaaS offering is coded as **moderate interest**. Interview evidence suggests that customers generally recognize the importance of maintenance and support services, yet the decision to adopt recurring service contracts depends on factors such as internal maintenance capabilities, perceived criticality of downtime, and cost considerations. As a result, service adoption is widespread but not uniform, and customers may selectively activate contracts based on their operational priorities. Customer **involvement** is coded as **passive**, reflecting the fact that the service offering is largely provider-designed. Customers do not typically participate in the co-creation or redesign of service architectures, but instead choose among predefined service options. Interaction with customers primarily occurs during contract negotiation, service execution, and issue resolution, rather than through continuous collaborative innovation processes. Overall, the customer dimension highlights that KUKA's service-based XaaS offering functions as a **standardized lifecycle support solution** for a diverse customer base. Customers engage with the offering pragmatically, selecting service

contracts as a means to stabilize operations and reduce risk, without fundamentally reshaping their relationship with the provider or actively contributing to service design.

- **Ecosystem**

The ecosystem supporting KUKA's service-based XaaS offering is structured around **strategic service delivery partners**, whose role is to ensure continuity, coverage, and responsiveness of service activities across geographically distributed customer sites. Within the framework, partners are coded as **service delivery partners**, with **continuous engagement** primarily focused on the delivery phase of the offering, and governed through **collaborative arrangements**. Unlike the rental configuration, where financial partners play a central enabling role, the service-based XaaS model relies on an ecosystem oriented toward **operational execution rather than financial structuring**. Service partners support activities such as on-site maintenance, emergency interventions, and technical assistance, complementing KUKA's internal service organization. These partnerships are particularly relevant in contexts where rapid response times are critical or where customer locations are distant from KUKA's main service hubs. Governance of the ecosystem is collaborative but clearly provider-led. KUKA retains full control over customer relationships, service standards, and contractual terms, while partners operate within predefined procedures and quality requirements. The ecosystem is therefore designed to extend KUKA's service reach without fragmenting responsibility for service outcomes or diluting the provider's role as the primary service orchestrator. The continuity of partner engagement reflects the **long-term nature of service relationships**. Rather than being activated for isolated projects, service partners are embedded into KUKA's ongoing service delivery structure, supporting recurring maintenance contracts and long-term customer support. This stability is essential to ensure consistency of service quality across different regions and customer contexts. Overall, the ecosystem dimension highlights that KUKA's service-based XaaS offering is supported by a **relatively mature and operationally focused ecosystem**, aligned with the objective of ensuring availability and reliability of customer-owned robotic systems. The ecosystem does not aim to enable radical service innovation, but rather to reinforce scalability, geographic coverage, and execution capacity within an established service model.

- **Organization structure and Culture**

The organizational configuration underlying KUKA's service-based XaaS offering reflects the **long-standing institutionalization of service activities** within the company, combined with a partial misalignment with a fully developed XaaS logic. Within the framework, **top management commitment** is coded as **widespread and strategic**, indicating that services are recognized as a core component of KUKA's value creation model and are supported at the highest organizational levels.

The **internal organization** of the service offering is anchored in **existing functions and business units**, particularly within the Global Customer Service organization. Service activities are not managed as an experimental or peripheral initiative, but rather as an established organizational domain with dedicated roles, standardized procedures, and global coordination mechanisms. This structural stability supports consistent service delivery across regions and customer segments. Despite this consolidation, the **service strategy** is coded as **absent or not fully aligned** with the XaaS framework. This coding reflects the fact that, although services are strategically important, they are not explicitly framed as part of a broader transformation toward outcome-based or fully servitized business models. Service contracts coexist with traditional product sales, but do not fundamentally challenge the dominant product-centric logic of the organization. **Sales–service integration** is coded as **partially integrated**. Sales and service functions collaborate in proposing and delivering service contracts, yet they remain governed by distinct objectives, incentives, and routines. Sales activities continue to prioritize product transactions, while service units focus on operational execution and contract fulfillment. This partial integration limits the potential for a fully unified commercial approach to XaaS offerings. Regarding channels, the **physical distribution channel** is **disintermediated**, as KUKA maintains direct relationships with customers for service contracting and delivery. The **digital distribution channel** is coded as **absent**, indicating that, despite the presence of digital service touchpoints (e.g., customer portals and support tools), there is no dedicated digital channel specifically designed to configure, sell, or manage service XaaS contracts end-to-end. From a cultural perspective, the organization exhibits a **strong service execution culture**, oriented toward reliability, responsiveness, and technical excellence. However, this culture is primarily operational rather than transformational. Services are viewed as a necessary and valuable complement to products, but not yet as the primary driver of business model innovation. As a result, while KUKA demonstrates high maturity in delivering services, the cultural shift toward a fully service-dominant or outcome-oriented logic remains partial.

- **Economic and Finance**

The economic and financial configuration of KUKA's service-based XaaS offering reflects a **stable and consolidated revenue logic**, grounded in recurring service contracts rather than in asset ownership or performance-based remuneration. Within the framework, the **revenue model** is coded as a **fixed-period subscription**, with customers paying periodic fees for access to defined service packages over an agreed contractual duration. Interview evidence clarifies that service revenues are generated through a combination of **one-off payments** and **recurring contracts**, depending on the nature of the service provided. Activities such as robot programming or specific technical

interventions are typically invoiced on a transactional basis, while maintenance and availability-oriented services are structured through **annual payments**, often within multi-year contractual agreements. This hybrid configuration allows KUKA to balance revenue stability with flexibility in service provision. The **main risk** associated with the service XaaS model is coded as **technological risk**. This risk relates to KUKA's responsibility for service performance, system reliability, and response times, rather than to capital exposure or asset utilization. Service failures, delays, or insufficient support could directly impact customer operations, making technical competence and service quality critical risk factors. Risk mitigation is coded as **no formal strategy**, reflecting the absence of explicit financial or contractual instruments designed specifically to hedge technological risk within the XaaS framework. Instead, risk is managed operationally through standardized service procedures, preventive maintenance protocols, trained service personnel, and rapid response mechanisms. These operational safeguards are embedded in the service architecture but are not formalized as distinct risk management tools in the coding. Profitability is monitored through **operational performance KPIs**, such as service response times, system availability, and contract fulfillment, rather than through lifecycle or outcome-based metrics. This focus on operational indicators is consistent with the service offering's objective of ensuring reliability and continuity rather than delivering quantifiable production outcomes. Overall, the economic and financial dimension underscores that KUKA's service-based XaaS offering is **financially mature but conservative**, prioritizing predictable recurring revenues and operational control over experimentation with more advanced outcome-based or performance-linked pricing mechanisms.

- **Resources**

The resource base supporting KUKA's service-based XaaS offering is **more developed and structured** than in the rental configuration, yet it remains **moderate in digital intensity** when assessed through the lens of the proposed framework. Within the framework, the service system is coded as a **partially connected system**, reflecting the presence of digital tools and connectivity without full integration into a comprehensive, data-driven service platform. KUKA's service offering exploits **basic operational data**, primarily related to robot status, faults, alarms, and maintenance needs. These data are used to support service delivery activities such as troubleshooting, preventive maintenance planning, and response prioritization. However, the exploitation of data remains largely operational and descriptive, rather than predictive or prescriptive. Advanced analytics, automated decision-making, or outcome-based performance monitoring do not constitute core resources of the service XaaS configuration. **Customer data accessibility** is coded as **no specific customer data**, indicating that customers do not systematically access or control service-related data as part of the

XaaS offering. While customers may receive information through service reports, support interactions, or digital touchpoints, data access is not structured as a shared resource enabling co-monitoring or co-optimization of system performance. Technology plays a relevant role in enabling **maintenance automation and operational continuity**, as well as **real-time monitoring and analysis**. Digital tools support fault diagnostics, service ticketing, and technical support, allowing KUKA to coordinate service interventions across its installed base. Customer service materials reference the use of digital platforms and knowledge systems to assist both service personnel and customers, reinforcing the role of technology as an enabler of service efficiency and responsiveness. At the same time, the service XaaS offering does not rely on a dedicated digital platform designed specifically for service monetization or outcome tracking. Digital resources are embedded within the broader service infrastructure rather than configured as strategic assets driving business model innovation. As a result, scalability and differentiation of the service offering are achieved primarily through organizational reach and standardized procedures, rather than through intensive use of digital or data-driven resources. Overall, the resource dimension highlights that KUKA's service-based XaaS offering is **operationally robust but digitally conservative**. Resources are sufficient to ensure reliable service delivery across a global installed base, yet they do not fundamentally transform services into a data-centric or outcome-oriented XaaS model.

- **Capabilities**

The capability base underpinning KUKA's service-based XaaS offering is **structurally more mature and institutionalized** than that observed in the rental configuration, reflecting the long-standing role of services within the company's business model. Within the framework, capabilities are coded as **managerial and organizational skills**, supported by **basic data-analysis capabilities**, a configuration that is consistent with a service organization focused on reliable execution rather than on advanced analytics-driven innovation. A core capability lies in KUKA's ability to **design, standardize, and deliver complex service portfolios** at scale. The company has developed routines, procedures, and training systems that allow service activities, such as preventive maintenance, troubleshooting, spare parts management, and technical support, to be delivered consistently across different regions and customer contexts. These capabilities are supported by a globally coordinated service infrastructure and by specialized service personnel. Another critical capability concerns **operational coordination and responsiveness**. KUKA demonstrates the ability to manage service interventions across a large installed base, ensuring timely response to faults and minimizing downtime. This includes coordinating on-site technicians, remote support functions, and spare parts logistics. While these capabilities rely on digital tools for communication and coordination, they are

fundamentally organizational in nature. By contrast, **analytical and data-driven capabilities remain limited**. Although operational data are collected and used to support service execution, the organization does not appear to systematically exploit data for predictive maintenance at scale, outcome-based contracting, or continuous optimization of customer processes. Data analysis supports service decisions, but does not constitute a standalone strategic capability driving new value propositions. From a commercial perspective, capabilities related to **selling and managing recurring service contracts** are well established, yet they operate largely within traditional service logics. Sales and service personnel are experienced in negotiating maintenance contracts and service levels, but less oriented toward reframing services as transformative XaaS solutions. As a result, service capabilities reinforce stability and reliability rather than experimentation or business model innovation. Overall, the capability dimension positions KUKA's service-based XaaS offering as **execution-oriented and operationally strong**, with a high degree of organizational maturity. These capabilities enable dependable service delivery and recurring revenues, but at the same time limit the transformative potential of the offering within the broader XaaS framework, as they are not yet complemented by advanced analytical or outcome-oriented competencies.

- **Environmental Sustainability**

Environmental sustainability in KUKA's service-based XaaS offering is addressed in a **pragmatic and operational manner**, emerging primarily as a by-product of lifecycle-oriented service practices rather than as an explicit strategic objective of the service model. Within the framework, sustainability is mainly associated with **resource efficiency** and **optimization of asset use**, while more advanced sustainability mechanisms remain outside the scope of the offering. A central sustainability lever lies in the **extension of asset lifetime** enabled by maintenance and service activities. Preventive maintenance, corrective interventions, and technical support contribute to keeping customer-owned robots operational for longer periods, delaying replacement and reducing the need for new equipment production. These practices support product durability and reliability, even though they are not explicitly framed in environmental terms within service contracts. Service activities also contribute to **optimization of asset use** by reducing downtime and ensuring stable performance. Higher availability and more reliable operation improve utilization efficiency, indirectly reducing the environmental impact per unit of output generated by robotic systems. These effects are particularly relevant in continuous or high-intensity production environments, where unplanned downtime would otherwise lead to inefficiencies and waste. Unlike the rental configuration, the service-based XaaS offering does not explicitly include **remanufacturing or end-of-life management** as part of the contractual scope. While refurbishment and upgrade activities exist within KUKA's broader service

portfolio, they are not systematically embedded or emphasized within the service XaaS logic as formal sustainability mechanisms. The offering does not involve **product–service substitution**, as physical robots remain central to value creation and are not replaced by digital or outcome-based services. Similarly, there are **no structured environmental transparency or dematerialization mechanisms** associated with the service contracts. Customers are not provided with environmental KPIs, lifecycle impact assessments, or sustainability dashboards as part of the service offering. Overall, environmental sustainability in KUKA's service-based XaaS configuration can be characterized as **operationally embedded but strategically implicit**. Sustainability benefits arise from improved maintenance practices and asset utilization rather than from explicitly designed environmental objectives. This positions the service offering as environmentally supportive but not sustainability-driven, reinforcing its role as a stabilizing and reliability-focused complement to product ownership rather than as a transformative circular business model.

DIMENSIONS	VARIABLES	CODING
Value proposition	Offer object	Service
Value proposition	Maturity Level of the Service Offering	Consolidated
Value proposition	Coverage of the Offering	Entire product range
Value proposition	XaaS Offering Approach	Proactive
Value proposition	Ownership	Customer
Value proposition	Value for the customers	minimization of operating costs
Value proposition	Value for the customers	optimization of usage processes
Value proposition	Offer costumization (level)	Configurable offer
Value proposition	Offer Customization (object)	Service
Value proposition	Offer communication	Integration into existing channels
Customers	Traget Customer segments	No distinction
Customers	Customer segmentation strategy	Undifferentiated
Customers	Customer acceptance	Moderate interest
Customers	Customer involvement	Passive
Ecosystem	Presence of strategic partners	Service delivery
Ecosystem	Continuity of strategic partners' engagement	Service delivery_delivery
Ecosystem	Alliance governance	Service delivery_collaborative
Organization structure and culture	Level of commitment of the top management of the provider	Widespread and strategic commitment
Organization structure and culture	Internal organization	Existing functions or business units (es. Sales service)
Organization structure and culture	Service strategy	Absent / Not aligned

Organization structure and culture	Sales–Service Integration level	Partially integrated
Organization structure and culture	Physical distribution channel	Disintermediated
Organization structure and culture	Digital Distribution channel	Absent
Economic and finance	Revenue model and mechanism	Fixed period / subscription (payment per period)
Economic and finance	Main Risk	Technological risk
Economic and finance	Risk mitigation strategy	No formal strategy
Economic and finance	Profitability Measurement KPI	operational performance KPI
Resources	Data connectivity	Partially connected system
Resources	Data Exploitation	Basic operational data
Resources	Customer Data accessibility	No specific data
Resources	Technology role	Maintenance automation and/or operational continuity
Resources	Technology role	Real-time monitoring and/or analysis
Capabilities	Data-analysis capabilities	Basic
Capabilities	Human and relational capabilities	Managerial & organizational skills
Environmental sustainability	Resource efficiency	Measurements and optimization of resource, consumption (energy, materials..)
Environmental sustainability	Product service substitution	No substitution
Environmental sustainability	Use and service intensity	Optimization of asset use (maximized uptime, performance-based logic)

Table 46 Kuka Robotics Service coding results

C.5 Prima Industrie

Company and XaaS Offering Overview

Prima Industrie S.p.A. is an Italian industrial group operating globally in the field of sheet metal working and industrial automation. Founded in 1977 and listed on the Italian stock exchange, the company has built a strong international presence through its main brand, Prima Power. Prima Industrie designs and manufactures laser cutting systems, punching machines, bending solutions, and integrated flexible manufacturing systems, serving a wide range of industrial customers in sectors such as automotive, aerospace, general manufacturing, and metal fabrication. Historically, Prima Industrie has competed through advanced engineering capabilities, high product performance, and strong system integration expertise. Its machines are complex, long-lived capital goods, often embedded deeply in customers' production processes and characterized by lifecycles that can extend well beyond 15 years. The company has also developed a large global installed base, supported by a

direct sales and service organization that plays a central role in after-sales activities and customer relationships. Within this predominantly product-centric business model, Prima Industrie has progressively expanded its service business, particularly in the after-sales domain. Over time, services have evolved from being a complementary support activity to becoming a structured and economically relevant component of the company's value proposition. The XaaS configuration analyzed in this study corresponds to a **pure service-based offering**, layered on top of traditionally sold, customer-owned machines. Physical equipment continues to be commercialized through ownership-based transactions, while services are delivered according to an as-a-service logic and paid over time. These services include multi-year maintenance contracts, extended warranties, preventive and corrective maintenance packages, and broader lifecycle support solutions designed to reduce operational uncertainty and stabilize maintenance costs. Attempts to introduce more radical XaaS configurations, such as machine-level pay-per-use or output-based pricing models, were explicitly explored by the company. However, these initiatives did not reach commercial consolidation. Interview evidence indicates that customers showed limited interest in non-ownership-based access models, largely due to the very long economic life of machines, the availability of favorable external financing, and a rational evaluation of total cost of ownership that made pay-per-use solutions economically unattractive. As a result, these experiments reinforced the strategic focus on service-based XaaS rather than asset-based or usage-based models. The unit of analysis in this case therefore concerns a service-centered XaaS configuration in which value creation is anchored in lifecycle support, risk reduction, and cost predictability, rather than in access to the physical asset itself. Prima Industrie's approach reflects a pragmatic servitization trajectory, where recurring service revenues are developed in alignment with customer preferences, asset characteristics, and industry economics, without challenging the centrality of product ownership in sheet metal machinery markets.

Prima Industrie framework-based analysis

- **Value proposition**

Prima Industrie's XaaS configuration is clearly **centered on services as the object of the offering**, while ownership of the physical machines remains with the customer. The as-a-service logic therefore does not concern access to the asset itself, but rather the provision of lifecycle-oriented services that support machine operation over time. This positioning is consistent with the structural characteristics of sheet metal working machines, which are long-lived capital goods and are typically acquired through ownership-based investment decisions. The service offering has reached a **consolidated level of maturity**. Service contracts represent an established and recurring component of Prima Industrie's business model, supported by a dedicated service organization and a large international installed base.

These contracts are not experimental or occasional, but form a stable part of the company's commercial and operational activities, even though their uptake may vary across customers and regions. The **coverage of the offering extends across the entire product range**. The same service logic can be applied to laser cutting systems, punching machines, bending solutions, and integrated manufacturing lines. This breadth reflects the standardized nature of the service architecture, which can be adapted to different machine families without altering the underlying structure of the offering. Prima Industrie adopts a **proactive approach** in proposing its service-based XaaS offering. Service packages are systematically introduced during the sales process of new machines and continue to be proposed throughout the operational lifecycle of the equipment. Although the degree of commercial penetration varies depending on customer characteristics and local market practices, the service logic is consistently positioned as an integral part of the overall value proposition. From an ownership perspective, the physical asset remains firmly under **customer ownership**, reflecting both customer preferences and the long investment cycles typical of machine tools. Customers retain control over their capital assets, while delegating selected operational and maintenance responsibilities to the service provider through contractual arrangements. The primary value created for customers lies in **risk minimization**. Service contracts reduce uncertainty related to maintenance and breakdown events by transforming potentially unpredictable corrective maintenance costs into predefined, periodic payments. This cost predictability supports budgeting processes and managerial control, particularly for plant managers and maintenance heads who are accountable for cost overruns and operational continuity. The offering is **configurable at the service level**. Customization does not involve modifications to the physical product, but rather adjustments to the scope of services included in the contract. Contracts may differ in duration, covered activities, spare parts inclusion, response times, and service levels, while the overall service structure remains standardized. This modularity allows Prima Industrie to adapt service packages to different customer needs without compromising operational efficiency. Communication of the service-based offering remains **limited and relationship-driven**. Rather than relying on structured marketing campaigns or digital channels, service contracts are primarily promoted through direct interactions between sales representatives, service personnel, and customers. This approach is consistent with the technical complexity of the offering and with the importance of trust and long-term relationships in the machine tool industry.

- **Customers**

The service-based XaaS offering developed by **Prima Industrie S.p.A.** is addressed to a **broad and undifferentiated customer base**. No formal segmentation strategy is adopted, and service contracts are conceptually applicable to all customers operating the company's machines, regardless of sector,

size, or geographic location. The service logic is designed as a standardized layer that can be associated with any installed machine, rather than as a set of differentiated propositions targeted at specific customer groups. In practice, however, adoption patterns vary across customers. Interview evidence indicates that uptake of service contracts is influenced by factors such as customer size, organizational structure, and sensitivity to cost predictability. Larger customers and organizations with more formalized budgeting and maintenance planning processes tend to show higher acceptance of service-based contracts. For these customers, the ability to stabilize operating costs and reduce exposure to unexpected corrective maintenance expenses is particularly valuable, as it supports internal planning, accountability, and risk control. Smaller customers display more heterogeneous behaviors. Some value the reassurance provided by service contracts, while others rely more heavily on internal maintenance capabilities or external service providers on an ad hoc basis. These differences, however, do not translate into differentiated service designs. The same service configurations are offered across the customer base, and variation in adoption reflects customer choices rather than provider-driven segmentation. Customer acceptance of the service-based XaaS offering is therefore **generally high**, especially when evaluated against the maturity and diffusion of service contracts within the company's installed base. Services are perceived as a credible and established component of the overall value proposition, rather than as an experimental or optional add-on. Customer involvement in the offering is **passive**. Customers select among predefined service configurations and negotiate contractual terms such as duration and scope, but they do not participate in the design or evolution of the service model. Service definition, execution, and optimization remain fully under the responsibility of the provider. Interaction between customers and Prima Industrie focuses primarily on service delivery, maintenance coordination, and problem resolution, rather than on co-design or joint innovation of the offering. Overall, the Customers dimension reflects a configuration in which the service-based XaaS offering is broadly applicable and widely accepted, yet remains provider-driven in structure and logic. Customer heterogeneity influences adoption behavior, but not the design of the service proposition itself.

- **Ecosystem**

Prima Industrie's service-based XaaS offering is supported by an ecosystem that is **largely internalized**, reflecting the company's strategic emphasis on service quality, customer proximity, and direct control over the installed base. The majority of service activities are delivered by the company's own service organization, which plays a central role in maintaining close relationships with customers and ensuring consistent execution of service contracts across different markets. External partners are involved only **selectively**, and primarily to support service delivery rather than

to co-develop the service model. These partnerships function mainly as capacity buffers, allowing Prima Industrie to respond to peak demand periods or to perform highly specialized technical interventions that exceed the scope or availability of internal resources. Partner involvement is therefore pragmatic and operational, rather than strategic in nature. A representative example concerns **laser source maintenance**, where collaboration with specialized technology suppliers is required. In these cases, governance follows a **coordinated model**. Prima Industrie remains the single contractual interface toward the customer, invoices the service directly, and assumes full responsibility for service outcomes. Upstream relationships with technology partners are managed internally through predefined pricing structures and margin-sharing mechanisms, ensuring clarity of roles and preserving control over value capture. The **continuity of partner engagement** is thus linked to recurring delivery needs rather than to long-term co-development or joint innovation initiatives. Partners are activated when their specific expertise is required, but they do not shape the architecture or evolution of the service offering. Overall, the ecosystem configuration reinforces Prima Industrie's role as the **central orchestrator** of the service-based XaaS model. By maintaining coordinated governance and limiting external dependency, the company ensures that service quality, customer relationships, and strategic control remain firmly embedded within its organizational boundaries.

- **Organizational structure and Culture**

The development of the service-based XaaS offering at **Prima Industrie S.p.A.** is supported by a **widespread and strategic level of top management commitment**. This commitment is reflected in organizational changes explicitly aimed at strengthening the role of services within the company's overall business model. Historically, sales and after-sales activities were managed as separate organizational domains. More recently, these functions have been brought under a unified organizational umbrella, signaling a recognition of the strong interdependence between machine sales, service quality, and long-term customer retention in a direct-to-customer context. This organizational integration has enabled closer coordination across the customer lifecycle. Sales and service teams operate within a shared structure, facilitating alignment between initial machine sales, subsequent service contracts, and ongoing customer support. Such integration reflects the mature role of services in supporting installed-base exploitation and reinforcing customer relationships. At the same time, the service strategy remains **only partially formalized**. While services are clearly acknowledged as strategically important and economically relevant, the company does not operate with a fully articulated service product management or service business development function. There is no dedicated organizational unit responsible for systematically designing, testing, and scaling new service offerings or for exploring alternative service-based business models. As a result, service

innovation tends to be **incremental** and closely linked to existing operational practices, rather than driven by a distinct, forward-looking service roadmap. From a distribution perspective, Prima Industrie operates through **disintermediated channels**. The company maintains direct relationships with end customers, both for machine sales and for service delivery, reinforcing its ability to control customer interactions and service quality. No dedicated digital distribution channel for services is currently in place. Digital tools are used primarily to support service execution, coordination, and technical activities, rather than as a means to commercialize or market service offerings. Overall, the Organizational dimension highlights a configuration in which managerial commitment and functional integration support effective service delivery, while the absence of a formalized service innovation structure limits the company's ability to systematically evolve and scale its service-based XaaS offering beyond incremental improvements.

- **Economic and Finance**

The economic structure of Prima Industrie's service-based XaaS offering is grounded primarily in **fixed-period subscription mechanisms**, typically implemented through multi-year service contracts paid on an annual basis. These recurring arrangements coexist with traditional spot service interventions, which are invoiced upon delivery when customers request ad hoc support. The coexistence of recurring and transactional revenues reflects the gradual evolution of the service business, rather than a full transition to exclusively subscription-based models. Internally, service pricing is constructed through **detailed cost models**. These models take into account multiple cost components, including labor hours, travel and logistics expenses, spare parts consumption, and, where applicable, the financial costs associated with spare parts held in consignment. Pricing therefore reflects a granular understanding of service delivery costs, rather than simplified or purely market-based benchmarks. This cost-driven approach supports internal margin control, but also limits pricing flexibility in highly competitive commercial contexts. The economic logic of service contracts is significantly influenced by the **coexistence of product and service sales**. In several cases, service contracts are negotiated as part of broader machine sales agreements. While this bundling can facilitate service adoption, it also exposes services to margin erosion when commercial pressure leads to discounting under product-centric logics. Services may be used as a lever to support machine sales, rather than being priced and evaluated as independent value propositions. The case does not exhibit a **formalized risk mitigation strategy specific to XaaS**. Financial risk management related to service contracts remains largely implicit and experience-based, relying on accumulated organizational knowledge rather than on explicit risk models or contractual risk-sharing mechanisms. This reflects the relatively low asset-related exposure associated with service-based XaaS

configurations, where machine ownership remains with the customer and financial commitments are distributed over time. Profitability is monitored through a **combination of financial and operational KPIs**, supported by analysis of the installed base. Indicators related to service revenues, margins, and contract penetration are complemented by operational measures that track machine usage, maintenance events, and service needs. Connectivity data from newer generations of machines are increasingly used to identify service opportunities and trigger commercial actions. However, heterogeneity across machine generations and data quality limitations constrain the full automation of these processes, reinforcing the role of human judgment and experience in economic decision-making. Overall, the Economic dimension reflects a configuration in which recurring service revenues are well established, cost structures are closely monitored, and profitability is managed through a balance of contractual subscriptions and transactional interventions, without a distinct or formalized XaaS-specific risk management framework.

- **Resources**

Prima Industrie's service-based XaaS offering is supported by a **heterogeneous and partially digitalized resource base**, which reflects the long lifecycle of machine tools and the coexistence of multiple technological generations within the installed base. Unlike cases where connectivity is natively embedded across all assets, data connectivity in this context is **partial**. Only machines produced in more recent years are equipped with native connectivity and remote monitoring capabilities, while a substantial portion of the installed base remains offline or only minimally instrumented. As a result, data exploitation relies mainly on **basic operational data and performance and behavioral indicators**, rather than on fully standardized or automated data streams. These data include machine usage hours, alarm patterns, and maintenance-related counters, which are used primarily as signals to support service decision-making. Interview evidence emphasizes that such data cannot be interpreted mechanically. Inconsistencies across machine generations, differences between on-machine counters and cloud-based metrics, and variability in operating conditions require **manual validation and contextual interpretation** by service technicians. This limits the degree of automation that can be achieved in activities such as service triggering, preventive maintenance planning, and contract renewal processes. Customer data accessibility is characterized as **full access**, but empirical evidence reveals significant variability in practice. Larger customers tend to adopt a more cautious stance toward data sharing, often due to internal governance rules or concerns about exposure, while smaller customers are generally less restrictive. In several cases, resistance is not related to data governance itself but to the **perceived cost of enabling connectivity**, which customers may be unwilling to bear, especially when the

economic benefits of data-driven services are not immediately evident. Digital technologies therefore play a **relevant but supporting role** within the service-based XaaS configuration. They enhance maintenance activities, support operational continuity, and enable basic forms of remote monitoring and analysis. However, given the partial connectivity of the installed base and the reliability issues associated with heterogeneous data sources, digital tools do not replace human expertise. Instead, they complement it. Service delivery remains strongly dependent on the **experience of field technicians** and on relational proximity to customers. Technicians play a central role not only in executing maintenance activities, but also in interpreting data, contextualizing machine behavior, and translating technical signals into service decisions. Overall, the Resources dimension reflects a configuration in which digital infrastructure supports service provision, but where human expertise and installed-base knowledge remain the dominant enabling resources.

- **Capabilities**

  Prima Industrie's service-based XaaS configuration is supported by a set of capabilities that are **evolving but not yet fully consolidated**, reflecting the transitional nature of the company's servitization trajectory. While services represent an established component of the business, the organizational capabilities required to systematically design, scale, and commercialize advanced service offerings remain unevenly developed. From a **service design perspective**, the company exhibits a pattern of continuous but **incremental innovation**. Over time, service offerings have expanded beyond traditional break-fix maintenance to include structured multi-year service contracts, preventive maintenance programs, and broader lifecycle support solutions. These developments demonstrate learning and adaptation based on accumulated operational experience. At the same time, interview evidence clearly points to the absence of dedicated roles or teams focused specifically on service product management or on structured service development processes. New service offerings tend to emerge organically from day-to-day operations and from specific customer requests, rather than from a formalized design-to-service or portfolio management approach. The organization explicitly recognizes this limitation and acknowledges the difficulty of conceptualizing and commercializing more advanced or non-traditional service solutions. This awareness highlights a gap between operational capability and strategic service innovation, where experience-based learning is not yet translated into a systematic capability for service transformation. **Human and relational capabilities** play a particularly critical role in sustaining the service-based XaaS configuration. The case underscores the importance of hybrid selling capabilities that combine technical credibility with commercial acumen. Selling service contracts requires the ability to identify appropriate timing, engage the right decision-makers, and

frame service value in a way that resonates with customers operating long-lived capital equipment. These capabilities are especially important in contexts where customers are deeply accustomed to ownership-based logics and evaluate services primarily through the lens of cost control and risk reduction. Interview material highlights recurring challenges in this area. Technical personnel, while highly competent in service execution, are not always equipped to engage effectively in commercial negotiations. Conversely, sales teams may struggle to articulate the standalone value of services without relying on product-centric discounting practices. These tensions complicate pricing decisions and expose service margins to erosion when services are negotiated as extensions of machine sales rather than as independent value propositions. Overall, Prima Industrie's capabilities profile reflects a configuration in which **operational service delivery skills are well developed**, supported by a strong installed base and deep technical expertise. At the same time, **strategic and commercial service capabilities**, particularly those related to systematic service innovation, service portfolio management, and go-to-market execution, remain underdeveloped. This imbalance is consistent with the characterization of the case as mature in operational terms, yet incomplete in its evolution toward a fully articulated XaaS model.

- **Environmental Sustainability**

Within Prima Industrie's service-based XaaS configuration, environmental sustainability is addressed **primarily through product lifecycle extension and remanufacturing-oriented practices**, rather than through explicit environmental targets or service-driven sustainability objectives. Sustainability considerations are therefore embedded implicitly in the way assets are managed over time, rather than being articulated as a central dimension of the service offering. A key sustainability mechanism concerns **refurbishment and reconditioning activities**. **Prima Industrie S.p.A.** offers services that include the refurbishment, relocation, and reinstallation of used machines, often accompanied by limited warranties. These practices allow machines to remain in productive use beyond their initial deployment, extending asset lifetimes and reducing the need for new equipment manufacturing. At the same time, they generate additional revenue streams by revalorizing existing assets within the installed base. Resource efficiency is embedded mainly at the **product and system design level**, rather than being driven by the service-based XaaS offering itself. Over time, Prima Industrie has invested in eco-efficient technologies and process innovations aimed at improving machine performance, reliability, and total cost of ownership. These design choices are primarily motivated by competitiveness and customer economics, with sustainability emerging as a complementary outcome rather than as the primary

driver. The service-based XaaS configuration does not involve **product–service substitution**. Physical machines remain central to value creation, and services are designed to support their operation rather than to replace them with dematerialized or outcome-based alternatives. In addition, the offering does not include **structured dematerialization mechanisms or environmental transparency initiatives**. Customers are not provided with dedicated environmental KPIs, sustainability dashboards, or lifecycle impact reports as part of the service contracts. Nevertheless, services contribute **indirectly** to sustainability outcomes. By supporting maintenance, upgrades, refurbishment, and continued use of installed assets, the service offering enhances asset utilization and reduces premature replacement. These effects lower material consumption and environmental impact over the machine lifecycle, even though they are not explicitly measured or communicated as sustainability performance. Overall, environmental sustainability in Prima Industrie's XaaS configuration emerges as an **implicit by-product of lifecycle-oriented service practices**, rather than as a deliberate objective or a differentiating element of the service proposition.

DIMENSIONS	VARIABLES	CODING
Value proposition	Offer object	Service
Value proposition	Maturity Level of the Service Offering	Consolidated
Value proposition	Coverage of the Offering	Entire product range
Value proposition	XaaS Offering Approach	Proactive
Value proposition	Ownership	Customer
Value proposition	Value for the customers	risk minimization
Value proposition	Offer costumization (level)	Configurable offer
Value proposition	Offer Customization (object)	Service
Value proposition	Offer communication	Limited or absent communication
Customers	Traget Customer segments	No distinction
Customers	Customer segmentation strategy	Undifferentiated
Customers	Customer acceptance	High interest
Customers	Customer involvement	Passive
Ecosystem	Presence of strategic partners	Service delivery
Ecosystem	Continuity of strategic partners' engagement	Service delivery_delivery
Ecosystem	Alliance governance	Service delivery_coordinated
Organization structure and culture	Level of commitment of the top management of the provider	Widespread and strategic commitment
Organization structure and culture	Internal organization	New, dedicated business unit or team

Organization structure and culture	Service strategy	Absent / Not aligned
Organization structure and culture	Sales–Service Integration level	Integrated / Unified
Organization structure and culture	Physical distribution channel	Disintermediated
Organization structure and culture	Digital Distribution channel	Absent
Economic and finance	Revenue model and mechanism	Fixed period / subscription (payment per period)
Economic and finance	Main Risk	N/A
Economic and finance	Risk mitigation strategy	No formal strategy
Economic and finance	Profitability Measurement KPI	financial economics KPI
Economic and finance	Profitability Measurement KPI	operational performance KPI
Economic and finance	Profitability Measurement KPI	life cycle KPI
Resources	Data connectivity	Partially connected system
Resources	Data Exploitation	Basic operational data
Resources	Data Exploitation	Performance and behavioral data
Resources	Customer Data accessibility	Full access
Resources	Technology role	Maintenance automation and/or operational continuity
Resources	Technology role	Real-time monitoring and/or analysis
Capabilities	service design capabilities	Continuous innovation:
Capabilities	Human and relational capabilities	Hybrid selling & distribution skills
Environmental sustainability	End-of-life and reverse logistics strategies	Remanufacturing services offered
Environmental sustainability	Product-life extension strategy	development of a durable product
Environmental sustainability	Resource efficiency	Implementation of eco-efficient design or processes
Environmental sustainability	Product service substitution	No substitution
Environmental sustainability	Dematerialization and transparency	No structured transparency or dematerialization
Environmental sustainability	Use and service intensity	Optimization of asset use (maximized uptime, performance-based logic)

Table 47 Prima Industrie coding results

C.6 ABB Robotics

Company and XaaS Offering Overview

ABB Robotics is part of the ABB Group, a global technology company active in electrification, automation, motion, and robotics. Within the group, ABB Robotics represents one of the core divisions and is positioned as a leading global manufacturer of industrial robots and collaborative

robots, as well as controllers, software, and digitally enabled services. The company serves a wide spectrum of industrial sectors, including automotive, electronics, food and beverage, logistics, and general manufacturing, addressing both high-volume automated production environments and more flexible, small-batch applications. The XaaS configuration analyzed in this study refers to ABB's **Robotics-as-a-Service (RaaS)** initiative. This offering has been introduced as a **pilot**, initially developed and tested in selected European markets, with Italy playing a central role as an early adopter and experimentation hub. The pilot nature of the initiative reflects ABB's intention to explore alternative access models to robotic automation, particularly for customers that face financial, organizational, or technical barriers to traditional robot ownership. The RaaS offering is deliberately **narrow in scope**. It is currently limited to collaborative robots, specifically the GoFa™ and SWIFTI™ product families. These robots are characterized by relatively low weight, high flexibility, ease of redeployment, and suitability for reuse across different applications and customer contexts. Their technical characteristics make them particularly compatible with an as-a-service logic, as they can be installed, removed, and reassigned with lower integration effort compared to large, application-specific industrial robots. Within this configuration, the **unit of analysis corresponds to a product-based XaaS offering**. The robot itself is provided through an as-a-service logic, bundled with a predefined set of services such as preventive maintenance, technical support, and access to connected services. At the same time, application-specific system integration, end-effector customization, and process engineering activities are explicitly excluded from the RaaS contract and remain outside the scope of the offering. This separation allows ABB to standardize the service model while avoiding the complexity and risk associated with highly customized automation projects. A distinctive feature of ABB's RaaS configuration concerns **asset ownership**. Ownership of the physical robot is not retained by ABB, but is transferred to **third-party financial partners**, which lease or rent the robot to end customers under predefined contractual conditions. ABB positions itself as the technology and service provider, while financial partners assume ownership and manage the financial exposure associated with the asset. This structure allows ABB to offer flexible access models without fully internalizing the balance-sheet implications of asset-intensive contracts. Overall, ABB Robotics' RaaS offering represents an exploratory configuration in which a standardized robotic product is combined with a service logic aimed at lowering entry barriers to automation, testing alternative revenue models, and learning how customers respond to non-ownership-based access to advanced manufacturing technologies.

ABB Robotics framework-based analysis

- **Value proposition**

ABB's Robotics-as-a-Service offering is structured around the **robot itself as the core object of the XaaS configuration**. The as-a-service logic directly concerns the physical product, which is made available to customers through recurring payment schemes rather than through traditional ownership. This positioning reflects a deliberate choice to experiment with alternative access models to robotic automation, while keeping the offering focused on a standardized and clearly bounded solution. The maturity of the service offering reflects its **pilot nature**. RaaS is described as an experimental initiative, introduced in selected markets and still marginal in scale when compared to ABB's established sales-based business. The pilot status does not derive from technological immaturity of the robots themselves, but from the novelty of the contractual and commercial model and from the need to test customer acceptance, pricing logics, and organizational implications. The scope of the offering is intentionally **restricted to a specific product category**, namely collaborative robots. This limitation reflects the technical and operational characteristics of these products, which are relatively lightweight, flexible, and suitable for redeployment across different applications and customer environments. These features make collaborative robots particularly compatible with an as-a-service logic, as they can be reassigned, reused, and relocated with lower integration effort and risk than traditional industrial robots. ABB adopts a **proactive approach** in proposing the RaaS model. The offering is actively introduced by the sales organization to selected end customers, especially those facing capital investment constraints, demand uncertainty, or limited prior experience with automation technologies. In this sense, RaaS is positioned as an entry mechanism to robotics, rather than as a replacement for conventional sales to experienced automation users. Asset ownership within the RaaS configuration is **distributed between the offer provider and third parties**. Financial partners formally own the robots and manage the leasing or rental arrangements, while ABB remains responsible for service delivery, technical support, and the overall performance of the offering. This separation allows ABB to maintain control over technological and service aspects while limiting direct balance-sheet exposure. From the customer perspective, the value proposition is articulated along several complementary dimensions. A first and central element is the **reduction of initial investment**, which allows customers to access robotic automation without upfront capital expenditure. This lowers financial barriers and makes automation accessible to a broader range of firms. A second value element concerns **cost predictability**. Customers gain access to the robot at a known and predefined cost, typically through fixed monthly fees or usage-based tariffs, which reduces financial uncertainty and simplifies budgeting. A third component of value lies in the **content and quality of service delivery**. Preventive maintenance, technical support, and remote monitoring are included in the offering, contributing to a fast, reliable, and low-friction service experience. The offering is **configurable at the product level**, with customization achieved through hardware and

software options that are intrinsic to the robot platform rather than through application-specific integration. This allows ABB to preserve a standardized service model while still adapting the robot configuration to different customer needs. Finally, communication of the RaaS offering remains **limited and selective**. Rather than being promoted through large-scale marketing campaigns, the model is primarily communicated through direct sales interactions and targeted marketing materials, consistent with its pilot status and exploratory role within ABB's broader portfolio.

- **Customers**

ABB's Robotics-as-a-Service offering is addressed **directly to end customers**, without a formal distinction among customer segments. Although the initiative is often discussed internally as particularly relevant for small and medium-sized enterprises and for companies approaching automation for the first time, this differentiation does not translate into a clearly articulated or operationalized segmentation strategy. In practice, the same RaaS logic is proposed across different customer profiles, with relevance emerging ex post rather than being embedded ex ante in a structured targeting approach. Customer acceptance of the RaaS model is currently **limited**. Interview evidence indicates that customers frequently show initial interest in the idea of accessing robots through an as-a-service model, especially because of the perceived reduction in upfront investment. However, this interest often weakens once the full economic and organizational implications of automation become apparent. A recurring issue concerns the role of **system integration**, which represents a substantial share of the total cost and complexity of robotic automation but remains outside the scope of the RaaS contract. Customers tend to underestimate this aspect and, once it becomes explicit, often revert to traditional purchasing models that they perceive as more familiar and controllable. This pattern highlights a gap between the conceptual appeal of the as-a-service model and the practical realities of automation projects. While RaaS lowers the barrier to accessing the robotic hardware, it does not eliminate the need for application-specific engineering, integration, and organizational adaptation, which continue to require significant investment and coordination on the customer side. Customer involvement in the offering is therefore **passive**. Customers are not engaged in the design or customization of the service model. Their role is limited to selecting among predefined contractual options, such as leasing versus operational rental or fixed monthly fees versus usage-based tariffs. ABB, together with its financial and service partners, retains control over product configuration, service content, and contractual structure. Customers adopt the offering within these predefined boundaries rather than co-creating or shaping the service logic. Overall, the Customers dimension reflects an early-stage configuration in which the RaaS model is conceptually attractive but not yet fully aligned with customer expectations and decision-making processes. Acceptance remains

constrained by limited understanding of total automation costs and by the separation between the standardized RaaS offer and the highly customized nature of real-world robotic applications.

- **Ecosystem**

ABB's Robotics-as-a-Service configuration is supported by an ecosystem that is **predominantly financial in nature**, reflecting the central role of asset ownership and financing in enabling the as-a-service model. Strategic partners within this ecosystem are exclusively **financial institutions**, including leasing banks and operational rental companies. These actors purchase the robots from ABB and make them available to end customers through long-term leasing or rental contracts, thereby absorbing the capital intensity associated with robotic assets. The engagement of financial partners spans **both the development and delivery phases** of the offering. During the development phase, these partners collaborate with **ABB Robotics** to define contractual structures, pricing mechanisms, and risk allocation schemes that are compatible with recurring payment models. During delivery, their involvement continues throughout the entire contract lifecycle, encompassing asset ownership, billing, financial administration, and end-of-contract management. Alliance governance within this ecosystem is **collaborative**, particularly in relation to financial partners. Although ABB sells the robot and the associated service package to the financial institution through a transaction that resembles a traditional sale, contractual agreements include predefined conditions regulating asset repurchase, redeployment, or return at the end of the service period. Through these mechanisms, ABB retains an ongoing interest in the lifecycle of the robot, even though formal ownership resides with third parties. This structure allows ABB to balance flexibility in customer access models with continued influence over asset circulation and reuse. In contrast, **technical partners** are deliberately excluded from the RaaS ecosystem. System integrators, application engineers, and component suppliers are not part of the as-a-service configuration. Application-specific integration, customization, and process engineering are explicitly left outside the RaaS contract and remain the responsibility of customers or external integrators engaged independently. This boundary is intentional and reflects ABB's effort to standardize the RaaS offering while avoiding the complexity and risk associated with highly customized automation projects. Overall, the ecosystem configuration highlights a model in which **financial orchestration replaces technological collaboration** as the dominant ecosystem logic. The success of the RaaS offering depends less on multi-actor technical integration and more on the ability to coordinate financing, asset ownership, and long-term contractual arrangements, with ABB positioned as the technological and service anchor within a financially structured ecosystem.

- **Organizational structure and Culture**

The Robotics-as-a-Service initiative within **ABB Robotics** is supported by a **widespread and strategic level of top management commitment**, reflected in coordinated action across commercial, financial, and service functions. The offering did not emerge from a formalized service development or innovation process. Instead, it was launched as a pilot initiative, driven primarily by commercial and financial considerations and enabled through internal collaboration among sales, finance, legal, and after-sales units. From an organizational perspective, the support structure for RaaS relies largely on **existing organizational functions** rather than on the creation of a dedicated service business unit. Sales teams remain embedded within the traditional commercial organization and are trained to propose the RaaS option selectively, depending on customer characteristics, investment constraints, and perceived suitability of the model. Service units contribute by defining the scope of maintenance activities and associated cost structures, ensuring that the service content included in the offering remains manageable and standardized. Legal and finance functions play a central role in structuring contracts, managing risk exposure, and coordinating with financial partners. The service strategy remains **only partially aligned and integrated** with ABB's core robotics business model. While RaaS is recognized as a strategically relevant experiment, it remains peripheral to the dominant product-centric logic of the robotics division and is not supported by a dedicated roadmap for service innovation or long-term scaling. As a result, the initiative is positioned as an exploratory extension rather than as a transformation of the core business. Sales–service integration is **partial**. Effective delivery of the RaaS model requires coordination between sales teams, which manage customer relationships and contractual discussions, and service units, which are responsible for maintenance and technical support. However, this coordination does not translate into full organizational convergence or shared ownership of the offering. Responsibilities remain functionally differentiated, reflecting the pilot nature of the initiative. With respect to distribution channels, ABB adopts a **hybrid physical distribution structure**. The company maintains direct relationships with end customers for the RaaS offering, while continuing to operate alongside a broader partner ecosystem in its traditional sales activities. In parallel, the **digital distribution channel is disintermediated**. Digital tools are used primarily to support monitoring, diagnostics, and service delivery rather than to commercialize or market the offering. This reinforces the role of digitalization as an enabler of service execution rather than as a standalone commercial channel. Overall, the Organizational dimension highlights a configuration in which strong managerial support coexists with limited structural formalization. RaaS is sustained by cross-functional collaboration and selective adaptation of existing structures, but remains organizationally peripheral and not yet embedded in a fully aligned service strategy.

- **Economic and Finance**

The economic structure of ABB's Robotics-as-a-Service offering is built around a **dual revenue logic**, which combines fixed-period subscription mechanisms with pay-per-use pricing. Customers can choose between a fixed monthly fee and usage-based tariffs, such as pay-per-hour schemes, depending on their operational needs and their preference for cost predictability versus flexibility. This dual structure allows the offering to accommodate different risk profiles and usage patterns without altering the underlying service configuration. The main exposure associated with the RaaS model concerns **financial risk**. However, this risk is largely mitigated through a **formalized risk management approach** centered on the involvement of financial partners. Within the RaaS configuration, ABB sells the robot and the bundled service package to the financial institution upfront. From ABB's accounting perspective, each activation of a RaaS contract therefore resembles a traditional sale rather than a long-term asset-based exposure. Through this arrangement, financial partners assume the primary risks related to **asset ownership, customer default, and residual value at the end of the contract**. ABB remains responsible for delivering the agreed service content, including maintenance and technical support, but is insulated from most of the financial downside risks that typically characterize asset-intensive XaaS models. Risk transfer to financial companies is thus a central element of the economic logic of the offering. Profitability is monitored using a combination of **financial economics KPIs and operational performance indicators**. Financial metrics are used to assess revenues and margins associated with the sale of robots and service bundles to financial partners. At the same time, operational KPIs play an important role, particularly in pay-per-use contracts, where **robot utilization rates** directly affect billing levels. Usage data generated during operation not only inform invoicing mechanisms but also provide insight into customer behavior and asset performance, supporting internal evaluation of the viability and scalability of the RaaS model. Overall, the Economic dimension highlights a configuration in which ABB achieves value capture while minimizing financial exposure. The combination of flexible pricing options and systematic risk transfer enables experimentation with as-a-service models without fundamentally altering the company's financial risk profile.

- **Resources**

ABB's Robotics-as-a-Service offering is enabled by a **highly digitalized and standardized technological resource base**, which builds on both the intrinsic characteristics of collaborative robots and ABB's long-standing investments in digital infrastructure. All robots included in the RaaS program are delivered as part of a **fully connected system**, enabled through ABB Ability™ Connected Services. Native connectivity is embedded in the solution and allows continuous access to operational data throughout the duration of the contract, independently of whether customers adopt

a fixed-fee model or a usage-based pricing scheme. Within this configuration, data exploitation focuses on **basic operational data**, such as robot status and operating hours, combined with **performance and behavioral data** related to utilization patterns and operating conditions. These data streams play a clearly defined role in supporting the RaaS model. First, they enable real-time monitoring and service responsiveness, allowing ABB to deliver preventive maintenance and timely technical support without relying solely on customer-initiated service requests. Second, they provide the informational backbone for **pay-per-use billing mechanisms**, where accurate and reliable measurement of robot operating hours is essential to ensure transparency, contractual compliance, and trust between the parties. Customer data accessibility within the RaaS configuration is **limited and conditional**. Access to operational data is regulated through contractual agreements and depends on explicit customer consent, reflecting the sensitivity of production-related information. As a result, data are primarily used for service delivery, monitoring, and billing purposes. The empirical material indicates that ABB deliberately constrains the scope of data exploitation, avoiding extensive analytics or optimization services in order to preserve customer trust and to prevent concerns related to data ownership, confidentiality, or competitive exposure. The role of technology within the RaaS offering is therefore centered on **real-time monitoring and analysis**, rather than on automation of decision-making or advanced predictive capabilities. Digital resources support transparency, reliability, and scalability of the service model, ensuring that robots can be monitored consistently across different customer contexts and contractual arrangements. At the same time, these resources do not fundamentally transform service delivery processes or enable autonomous service intelligence. Overall, the Resources dimension reflects a configuration in which digital connectivity and standardized data infrastructures are essential enablers of the as-a-service logic, while data exploitation remains deliberately bounded. This resource setup is coherent with the pilot nature of the initiative and with its positioning as an access-enabling solution rather than as a fully data-driven or outcome-optimizing service model.

- **Capabilities**

The Robotics-as-a-Service configuration developed by **ABB Robotics** is underpinned primarily by **human, relational, and commercial capabilities**, rather than by advanced service innovation or data-analytics capabilities. The successful deployment of the offering depends less on novel technological competencies and more on the organization's ability to manage customer relationships, structure commercial propositions, and coordinate internal actors around a non-traditional access model. A central capability supporting the RaaS initiative is the presence of **hybrid selling and distribution skills**. Articulating the value of Robotics-as-a-Service to customers accustomed to

ownership-based purchasing requires the ability to navigate complex trade-offs between capital expenditure and operational expenditure, flexibility and long-term commitment, and access to technology versus responsibility for system integration. Interview evidence highlights that this capability is far from trivial. Customers often approach RaaS with the expectation that it represents a comprehensive automation solution, while in practice application integration, process engineering, and customization remain outside the scope of the offering. Managing this gap between expectations and actual service boundaries requires strong relational skills and the ability to clearly communicate limitations, responsibilities, and residual risks. From a **service design perspective**, ABB's capabilities are present but remain **weakly institutionalized**. The RaaS offering has been constructed through the recombination of existing robotic products, standardized service packages, and financial arrangements, rather than through a dedicated service innovation process. Interview material does not indicate the existence of a formal service product management function or a structured experimentation framework aimed at evolving the RaaS model beyond its current configuration. As a result, service design activities remain largely opportunistic and commercially driven, responding to specific market opportunities rather than being guided by a long-term service transformation agenda. At the **operational level**, ABB demonstrates strong execution capabilities. Preventive maintenance, technical support, and remote monitoring are delivered reliably through the company's global service organization and standardized service processes. These capabilities ensure consistency and quality of service delivery across different customer contexts and are a critical enabler of the RaaS model at pilot scale. However, they largely mirror capabilities already developed to support traditional product sales and installed-base services, rather than representing a distinct capability set specifically tailored to XaaS scaling. Overall, the Capabilities dimension reveals a configuration characterized by a **mismatch between strong execution and limited transformational capability**. ABB is well equipped to deliver Robotics-as-a-Service efficiently within a pilot context, leveraging existing operational strengths and commercial expertise. At the same time, the organization lacks dedicated organizational, analytical, and service design capabilities required to reposition RaaS as a core business model rather than as an ancillary commercial option within its broader robotics portfolio.

- **Environmental Sustainability**

Within ABB's Robotics-as-a-Service configuration, environmental sustainability is addressed primarily through **asset lifecycle management and circular use of technological resources**, rather than through explicit environmental performance targets or dedicated transparency mechanisms. Sustainability is therefore embedded implicitly in the architecture of the offering, rather than being

articulated as a central or standalone element of the value proposition. A core sustainability mechanism is represented by **end-of-life management and reverse logistics practices**. Robots delivered under the RaaS model are contractually designed to be returned at the end of the service period, rather than being permanently transferred to customers. This contractual structure allows **ABB Robotics** and its financial partners to retain control over the asset lifecycle and to manage the circulation of robots across multiple use phases. Returned robots can be refurbished, remanufactured, and redeployed, either within new Robotics-as-a-Service agreements or through alternative commercial channels. By enabling systematic recovery and redeployment, the model reduces the need for new robot production and supports circular utilization of high-value technological assets. Closely connected to this logic is the role of **product-life extension through reuse and refurbishment**. The decision to limit the RaaS offering to collaborative robots is not only commercially motivated but also structurally relevant from a sustainability perspective. These robots are characterized by modular design, standardized configurations, and high flexibility across applications, which makes them particularly suitable for reuse across different customers and operational contexts. These characteristics lower the barriers to second-life deployment and distinguish RaaS-compatible products from highly customized industrial robots that are more difficult to redeploy. With respect to **resource efficiency**, sustainability benefits arise mainly from ABB's broader approach to eco-efficient product design and manufacturing processes, which apply across its robotics portfolio. While these design choices are not specific to the RaaS model, the service-based access logic amplifies their impact by increasing asset utilization over time. By allowing robots to be used sequentially by multiple customers, the RaaS model contributes to higher use and service intensity, which reduces the environmental footprint per unit of robotic service delivered. The offering does not involve **product–service substitution**. Physical robots remain central to value creation and are not replaced by purely service-based or outcome-based alternatives. In addition, the RaaS model does not currently incorporate **structured dematerialization or environmental transparency mechanisms**. Customers are not provided with dedicated sustainability dashboards, environmental performance indicators, or lifecycle impact reports as part of the service, and environmental data do not explicitly inform pricing or customer decision-making. Overall, environmental sustainability within ABB's Robotics-as-a-Service model emerges as a **by-product of the business model architecture** rather than as an explicit objective. The most significant sustainability outcome lies in increased asset reuse, extended product lifetimes, and reduced idle capacity, achieved through the systematic return, refurbishment, and redeployment of robots across multiple contracts.

DIMENSIONS	VARIABLES	CODING
Value proposition	Offer object	Product
Value proposition	Maturity Level of the Service Offering	Pilot
Value proposition	Coverage of the Offering	Specific category
Value proposition	XaaS Offering Approach	proactive
Value proposition	Ownership	Offer Provider
Value proposition	Ownership	Third parties
Value proposition	Value for the customers	the reduction in initial investment
Value proposition	Value for the customers	the content and methods of service delivery (a fast and efficient service)
Value proposition	Value for the customers	guaranteed access to the product at a cost known in advance
Value proposition	Offer costumization (level)	Configurable offer
Value proposition	Offer Customization (object)	Product
Value proposition	Offer communication	Limited or absent communication
Customers	Traget Customer segments	No distinction
Customers	Customer segmentation strategy	Segment-Oriented
Customers	Customer acceptance	Limited interest
Customers	Customer involvement	Passive
Ecosystem	Presence of strategic partners	Financial
Ecosystem	Continuity of strategic partners' engagement	Financial _both
Ecosystem	Alliance governance	Financial_collaborative
Organization structure and culture	Level of commitment of the top management of the provider	Widespread and strategic commitment
Organization structure and culture	Internal organization	Existing functions or business units (es. Sales service)
Organization structure and culture	Service strategy	Absent / Not aligned
Organization structure and culture	Sales–Service Integration level	Partially integrated
Organization structure and culture	Physical distribution channel	hybrid/intermediate
Organization structure and culture	Digital Distribution channel	Disintermediated
Economic and finance	Revenue model and mechanism	Fixed period / subscription (payment per period)
Economic and finance	Revenue model and mechanism	Pay-per-use
Economic and finance	Main Risk	Financial risk
Economic and finance	Risk mitigation strategy	Formalized risk management model

Economic and finance	Risk mitigation mechanisms	Financial company
Economic and finance	Profitability Measurement KPI	financial economics KPI
Economic and finance	Profitability Measurement KPI	operational performance KPI
Resources	Data connectivity	Fully connected system
Resources	Data Exploitation	Basic operational data
Resources	Data Exploitation	Performance and behavioral data
Resources	Customer Data accessibility	Limited/conditional access
Resources	Technology role	Real-time monitoring and/or analysis
Capabilities	Human and relational capabilities	Hybrid selling & distribution skills
Environmental sustainability	End-of-life and reverse logistics strategies	Remanufacturing services offered
Environmental sustainability	Product-life extension strategy	Reuse or lifetime extension throught refurbishment
Environmental sustainability	Resource efficiency	Implementation of eco-efficient design or processes
Environmental sustainability	Product service substitution	No substitution
Environmental sustainability	Dematerialization and transparency	No structured transparency or dematerialization
Environmental sustainability	Use and service intensity	Inclusion of second-hand products in the aaS offering

Table 48 ABB Robotics coding results

C.7 W&H

Company and XaaS Offering Overview

W&H is an Austrian-based manufacturing company operating in the field of medical and dental technology, with a specific focus on systems for the cleaning, disinfection, and sterilization of medical and dental instruments. The company designs and manufactures equipment such as washer-disinfectors and sterilizers, which are critical components of clinical workflows and subject to stringent regulatory, safety, and compliance requirements. W&H serves a global market and, particularly in the dental sector, relies extensively on a distributor-based sales model, with local partners playing a central role in commercial activities and customer access. Alongside its traditional product-oriented business, W&H has progressively developed a set of **digital and service-oriented solutions** aimed at supporting customers throughout the lifecycle of installed equipment. These initiatives reflect an increasing emphasis on post-sales support, regulatory compliance, and operational transparency, rather than a fundamental shift away from product ownership. Physical equipment continues to be sold through conventional ownership-based transactions, while additional functionalities and services are layered on top of the installed base. The XaaS configuration analyzed in this study corresponds to a **pure service-based offering** that complements customer-owned

equipment. The service logic is enabled through connectivity and a proprietary digital platform, **ioDent**, which functions as the central interface between W&H and its customers. Through the platform, users can access technical documentation, monitor machine usage, retrieve compliance-related reports, and activate software-based functionalities through license codes. The platform therefore aggregates information, digital services, and administrative tools into a single access point, supporting both daily operations and regulatory requirements. Rather than bundling equipment and services into an integrated outcome-based contract, W&H's dominant XaaS configuration remains **additive and modular**. Services are activated independently from the initial equipment sale and can be scaled or adjusted over time. The as-a-service logic primarily applies to digital functionalities, documentation access, reporting tools, and software-enabled features, while the physical asset remains fully owned and managed by the customer. Interview evidence indicates that W&H has experimented with more integrated contractual configurations in selected markets, such as full-risk leasing models combining equipment, consumables, and services. However, these initiatives are geographically limited and are not representative of the company's prevailing business model. As a result, the present analysis focuses on the service-based XaaS offering layered onto an installed base of customer-owned equipment, rather than on fully integrated product–service systems. Overall, W&H's XaaS configuration illustrates a service-oriented extension of a traditional manufacturing business, in which digital platforms and software-enabled services are used to enhance compliance support, operational visibility, and customer interaction across the equipment lifecycle, while preserving conventional ownership structures and distribution arrangements.

W&H framework-based analysis

- **Value proposition**

W&H's XaaS configuration is built around **services and digital functionalities**, while the physical equipment remains outside the as-a-service logic and continues to be acquired through traditional ownership-based transactions. The offering is therefore positioned as a service layer that complements the installed base, enabling customers to access recurring services, platform-based functionalities, and software-enabled options over the lifecycle of the equipment. The service offering reflects a **consolidated trajectory of development and commercialization**, supported by the progressive introduction of digital services, platform functionalities, and recurring service arrangements. Through the proprietary ioDent platform and related service components, W&H is able to extend its interaction with customers beyond the point of sale and to provide ongoing support that remains connected to the operational use of installed machines. The scope of the offering is not restricted to a single equipment type. Instead, the platform and associated service modules can be

applied across W&H's portfolio of cleaning, disinfection, and sterilization systems, allowing the same service logic to support different products within the installed base. This breadth reinforces the role of the digital layer as a cross-cutting service infrastructure rather than a product-specific add-on. W&H adopts a **proactive approach** in proposing these services. The service layer is systematically introduced alongside product sales and continues to be proposed during the operational lifecycle of the equipment, particularly when interactions are triggered by regulatory requirements or service events. In this way, the offering is integrated into routine customer touchpoints, rather than being activated only in response to explicit customer requests. From the customer perspective, the primary value driver is **risk minimization**, closely linked to the criticality of cleaning, disinfection, and sterilization processes and the compliance requirements that govern them. Customers benefit from mechanisms that reduce operational uncertainty and support reliable execution of sterilization workflows. In particular, the availability of standardized documentation, process traceability, and compliance-related reporting supports customers in managing inspections and audits, while reducing uncertainty and exposure related to regulatory verification. The offering is **configurable at the service level**. Customers can activate predefined digital modules and service options depending on their needs, selecting functionalities that support documentation access, monitoring, compliance reporting, and software-enabled features. This configurability is achieved through modular service activation rather than through modifications to the underlying physical equipment. Finally, communication of the offering is embedded in **existing commercial and service channels**. Rather than relying on a standalone XaaS marketing strategy, W&H disseminates the service logic through its distributor network, through service technicians interacting with customers during service events, and through the digital platform itself, which functions as a continuous interface for service activation and use.

- **Customers**

The service-based XaaS offering developed by **W&H** addresses a **broad and undifferentiated customer base**, without a formal distinction between target segments. Dental clinics and healthcare facilities are offered the same service logic regardless of size, specialization, or organizational structure. Although adoption levels vary significantly across markets, these differences are not reflected in a deliberate segmentation strategy, but rather emerge from contextual factors such as local regulatory requirements, differences in digital readiness, and established market practices. Customer acceptance of the offering remains **limited**. Interview evidence indicates that customers generally acknowledge the functional usefulness of the digital services, particularly in relation to compliance support, documentation management, and process traceability. However, this recognition does not

consistently translate into a strong willingness to pay for recurring service fees. The perceived value of the offering is often indirect and preventive in nature, linked to risk avoidance rather than to immediate economic gains, which makes monetization more challenging. Two factors in particular contribute to this restrained level of acceptance. First, the customer relationship is largely **mediated by distributors**, especially in the dental sector. As a result, commercial interactions and value communication are filtered through intermediaries, limiting W&H's direct influence on customers' willingness to adopt and pay for digital services. Second, in several markets the cost of sterilization equipment and related services represents a relatively small share of overall clinic expenditure. This reduces cost sensitivity and weakens the perceived urgency of investing in additional, service-based functionalities, even when their operational or compliance-related benefits are recognized. Customer involvement in the XaaS offering can be described as **collaborative in use but not in design**. Customers actively interact with the digital platform as part of their daily operations, accessing documentation, managing data, and using service functionalities to support compliance and routine workflows. At the same time, they do not participate in shaping the service architecture, defining modules, or co-developing the offering. The structure, logic, and evolution of the service remain fully provider-driven, while customers engage primarily at the level of execution and utilization. Overall, the Customers dimension highlights a configuration in which the XaaS offering is broadly applicable but unevenly adopted. Customer engagement is operationally active once the service is in place, yet overall acceptance and willingness to pay are constrained by indirect commercial relationships, contextual market factors, and the risk-preventive nature of the value proposition.

- **Ecosystem**

The ecosystem supporting **W&H**'s service-based XaaS offering is primarily **technological**, but structured around a deliberate choice to keep the most critical components under direct internal control. Interview evidence indicates that W&H has made a strategic decision to internalize the development and management of its digital platform, its databases, and the core software elements that enable the service layer. This organizational choice is closely linked to the characteristics of the medical domain, where data reliability, regulatory compliance requirements, and continuity of service delivery are central conditions for the viability of digital services. External technological partners are present, but their role is **selective and bounded**. Rather than relying on partners for the ownership or co-development of the service architecture, W&H involves external providers mainly for specific development tasks or discrete components. The interview explicitly describes how earlier reliance on external software providers created problems in terms of responsiveness and control, which led the company to re-internalize most development activities. As a result, partner involvement is not

positioned as a long-term strategic collaboration shaping the service logic, but as targeted support that remains peripheral to the core of the offering. Because of this configuration, partner engagement tends to be **episodic rather than continuous**, and concentrated on specific technological components rather than spanning the full lifecycle of service development and evolution. The continuity of engagement is therefore relatively low, reflecting W&H's preference for maintaining direct control over the most sensitive areas of the digital service system. Governance within the ecosystem follows a **coordinated structure**, with W&H retaining control over the service architecture, data management practices, and customer interfaces. Customers interact exclusively with W&H's platform and service environment, without direct contact with ecosystem partners. This reinforces W&H's role as the single service owner and ensures that external partnerships do not interfere with customer-facing responsibilities or with compliance-related accountability. Overall, the ecosystem configuration reflects a technologically enabled service model in which external partners are used selectively, while strategic control over digital resources and customer interfaces is intentionally centralized within the provider.

- **Organizational structure and Culture**

The development of W&H's service-based XaaS offering is supported by a **widespread and strategic commitment from top management**, embedded in a long-term strategic orientation that extends well beyond conventional planning horizons. Interview evidence highlights that digitalization and servitization are explicitly identified as key future directions for the company, rather than as short-term experiments or isolated innovation initiatives. This long-term perspective is particularly relevant in a regulated medical context, where technological and service-related investments are expected to generate value over extended timeframes. From an organizational standpoint, **W&H** has established **new, dedicated teams** responsible for digital services, platform management, and service strategy. These teams operate alongside more traditional, product-focused functions and are tasked with progressively expanding the service layer built around the installed base. Their role is not to replace existing product organizations, but to complement them by developing, maintaining, and scaling digital and service-oriented functionalities. Service development follows an **agile and incremental logic**. Functionalities are released in stages and subsequently refined based on usage experience and evolving requirements. This approach allows W&H to gradually extend the scope of the service offering while maintaining control over compliance, data integrity, and platform stability, which are critical in the medical domain. At the same time, the service strategy can be characterized as **partially aligned and integrated**. While digital services are clearly embedded in the company's long-term vision, they coexist with strong product-centric logics that continue to dominate core

organizational structures and decision-making processes. This partial integration is also shaped by structural constraints linked to W&H's reliance on distributor-based sales models, which influence how services are commercialized and scaled. This tension is particularly visible in the area of **sales–service integration**, which remains partial. Recurring service revenues and platform-based offerings are more difficult to align with distributor incentives that are traditionally tied to product sales volumes. As a result, service commercialization does not fully leverage the existing sales organization in the same way as physical equipment, and service-related responsibilities remain partly separated from traditional sales roles. With respect to **distribution channels**, the organizational configuration reflects a dual structure. Physical distribution remains **intermediated**, as W&H relies extensively on distributors and dealers for market access, sales, and customer relationships. In contrast, the **digital distribution channel is disintermediated**. Customers access the digital platform directly to manage services, retrieve data, and interact with service functionalities, even though the underlying commercial transactions continue to be mediated through distributors. Overall, the Organizational dimension depicts a configuration in which strategic commitment to servitization is strong, dedicated structures are in place, and digital development follows an agile logic. At the same time, full organizational integration is constrained by enduring product-centric structures and by the intermediary-based nature of market access, resulting in a partially integrated service organization.

- **Economic and Finance**

The economic logic underpinning the XaaS offering developed by **W&H** is primarily based on **recurring revenue mechanisms**, structured around fixed-period subscriptions. Customers pay ongoing fees to access digital services and platform-based functionalities that support the operation, monitoring, and documentation of sterilization equipment. Alongside these recurring arrangements, certain elements of the offering, such as the activation of specific software-based features through license codes, are monetized through one-time payments. Other components, including platform access and extended warranty-related services, follow annual subscription models. This combination reflects a modular economic structure in which different service elements are monetized according to their role and usage over time. The main risk associated with the offering is **data security risk**, which is particularly salient given the critical importance of data integrity, availability, and traceability in medical and dental contexts. The digital services support compliance, documentation, and auditability of sterilization processes, making reliability and correctness of data essential. Any disruption, loss, or misuse of data would therefore have direct implications for customers' regulatory compliance and operational continuity. This exposure is addressed through a **formalized risk management approach**. Interview evidence indicates that contractual clauses play a central role in defining

responsibilities, service levels, and liability boundaries related to data management. These mechanisms are designed to clarify the allocation of risk between provider and customer and to ensure that the service can be delivered within clearly defined legal and operational limits, consistent with regulatory requirements. Profitability assessment does not focus primarily on short-term financial returns. Instead, W&H evaluates the performance of the XaaS offering through a set of **operational performance and lifecycle-oriented KPIs**. These include indicators related to platform usage, service adoption rates, equipment utilization, and service-related lifecycle costs. Such metrics allow the company to monitor how the digital services are embedded in customers' operations and how they contribute to longer-term engagement. Overall, the Economic dimension reflects a configuration in which value capture is gradual and recurring, risk management is centered on data-related concerns rather than on asset exposure, and economic performance is assessed through long-term operational and relational indicators rather than immediate revenue maximization.

- **Resources**

The service-based XaaS offering developed by **W&H** is enabled by a **fully connected digital infrastructure**, which represents the primary resource underpinning service delivery. Connectivity is embedded at the level of the installed equipment and is systematically activated through the proprietary ioDent platform. This infrastructure allows continuous data transmission from devices deployed at customer sites to W&H's cloud environment, creating a stable and standardized data backbone across geographically dispersed customers and heterogeneous operational contexts. This connected infrastructure supports the exploitation of **multiple categories of data**. On the one hand, W&H collects basic operational data, such as cycle execution, alarms, and machine status. On the other hand, it captures performance and behavioral data, including usage frequency, program selection, and deviations from standard operating conditions. These data are not primarily leveraged for optimization or predictive analytics. Instead, they are used to support **regulatory compliance**, remote diagnostics, and timely service response. In medical and dental environments characterized by strict regulatory oversight, the ability to reliably collect, store, retrieve, and document process data constitutes a critical resource in itself, independently of advanced analytical capabilities. Customer data accessibility is **full**, but structured according to a **dual-use logic**. W&H and its service organization access operational data to support technical assistance, warranty management, and service interventions. At the same time, customers actively access the same data through the digital platform to fulfill documentation, traceability, and audit requirements imposed by health authorities. This shared access reinforces customers' reliance on the platform as an operational and compliance tool, increasing switching costs even in the absence of strong contractual lock-in mechanisms.

Beyond monitoring and documentation, technology also enables a high degree of **service-level customization**. Customization is achieved through the remote activation of software-based functionalities and service modules, rather than through modifications to the physical equipment. Customers can incrementally extend or adjust digital features over time, tailoring the service experience to their needs while preserving product standardization. This modularity represents a key resource that supports scalability and consistency across the installed base. Despite the robustness of the digital infrastructure, the empirical material indicates that technology is **not currently used to automate decision-making or to enable advanced service intelligence**. Data are not exploited to trigger autonomous actions or predictive interventions, and analytical capabilities remain focused on documentation and responsiveness rather than transformation of service logic. Overall, the Resources dimension highlights a configuration in which connectivity, data reliability, and modular digital functionalities enable standardized, compliant, and scalable service delivery. The resource base is well suited to supporting regulatory requirements and lifecycle service continuity, even though it does not yet underpin data-driven automation or advanced service intelligence.

- **Capabilities**

The XaaS configuration developed by **W&H** is underpinned by a set of **basic but structurally important organizational capabilities**, which support the stable delivery of digital services in a highly regulated environment. These capabilities are not oriented toward radical business model transformation, but toward ensuring reliability, control, and continuity of service operations. A first central capability area concerns **risk assessment and risk control**, with a strong focus on data security, data integrity, and regulatory compliance. In medical and dental contexts, the reliability and traceability of process data are critical, and the organization's capabilities are therefore oriented toward preventing failures, data loss, or inconsistencies that could compromise compliance. These capabilities are embedded primarily in the design of the digital platform, in internal operating procedures, and in contractual clauses that define responsibilities and liability boundaries. Rather than relying on formalized quantitative risk models, W&H manages risk through architectural choices, governance mechanisms, and controlled service design. **Human and relational capabilities** play a decisive role in sustaining the service offering, yet they remain unevenly developed across the organization and its ecosystem. Interview evidence indicates that the main challenge does not lie in the technical feasibility of digital services, but in the ability to commercialize and scale them within a **distributor-based business model**. Sales personnel and distributors are historically oriented toward transactional product sales, while recurring service revenues require a different value narrative, longer time horizons, and incentive structures that are not yet fully aligned. As a consequence, capability

development efforts are strongly focused on **education, training, and cultural change**. These efforts aim to progressively shift both internal actors and external distributors toward a more service-oriented mindset. Initiatives include training distributors to explain the value of digital services to end customers, improving coordination between digital teams and commercial functions, and experimenting gradually with service pricing and bundling mechanisms. Capability building therefore occurs through learning-by-doing and incremental adjustment rather than through formal restructuring. From a **service design perspective**, capabilities remain **incremental and adaptive**. Services evolve through iterative improvements to existing functionalities, driven by changes in regulatory requirements, feedback from customers and distributors, and internal learning processes. Interview material does not indicate the presence of a dedicated service innovation unit with responsibility for radically redesigning the service portfolio or for exploring alternative XaaS configurations beyond the current platform-based model. Overall, the Capabilities dimension portrays an organization with **strong operational capabilities** in digital service execution, platform management, and risk control, but with **limited capabilities in strategic service scaling and business model innovation**. The XaaS offering is sustained by robustness, compliance, and coordination rather than by experimentation with new contractual forms or transformative service logics.

- **Environmental sustainability**

Within W&H's XaaS configuration, environmental sustainability is addressed in a **limited, implicit, and non-strategic manner**. Sustainability does not represent a primary objective of the service-based offering, nor does it explicitly shape the design or positioning of the XaaS model. Instead, environmental aspects emerge mainly as a secondary effect of operational practices oriented toward compliance, reliability, and asset management. The most relevant sustainability-related practices concern **end-of-life management and reverse logistics**. W&H collects equipment at the end of its operational life or contractual period, ensuring controlled handling and disposition of assets. These practices are driven primarily by regulatory obligations and by the need to manage assets responsibly within a highly regulated medical context, rather than by explicit environmental goals or circular economy strategies. Empirical evidence does not indicate the presence of a **structured product-life extension strategy** embedded within the service offering. While correct usage, proper maintenance, and compliance with operating procedures may indirectly contribute to extending the functional life of equipment, these effects are not systematically measured, monitored, or intentionally leveraged as part of the XaaS model. Product longevity is therefore an implicit outcome of reliable operation rather than a designed sustainability mechanism. Similarly, the service-based offering does not include

specific initiatives aimed at improving resource efficiency, such as optimization of energy or water consumption. Although the equipment operates within processes that inherently consume critical resources, the XaaS configuration does not address these dimensions through monitoring, optimization, or performance-based mechanisms. Environmental efficiency is therefore outside the scope of the service logic. The XaaS model does not involve **product–service substitution**. Physical equipment remains central to value creation, and digital services are designed to support, document, and manage the operation of machines rather than to replace them with outcome-based or dematerialized solutions. In addition, there are no **dematerialization or environmental transparency mechanisms** embedded in the service offering. Customers are not provided with environmental indicators, sustainability dashboards, or lifecycle impact data through the platform, and sustainability performance does not influence pricing, service differentiation, or contractual conditions. Overall, environmental sustainability within **W&H**'s XaaS configuration can be characterized as **incidental rather than intentional**. Environmental effects arise as a by-product of operational reliability, regulatory compliance, and controlled asset management, rather than as a driver or objective of the service-based business model. Compared to other cases in the sample, W&H illustrates a configuration in which digitalization and servitization evolve largely independently from sustainability considerations, highlighting a clear boundary condition of the framework.

DIMENSIONS	VARIABLES	CODING
Value proposition	Offer object	Service
Value proposition	Maturity Level of the Service Offering	Consolidated
Value proposition	Coverage of the Offering	Entire product range
Value proposition	XaaS Offering Approach	proactive
Value proposition	Ownership	Customer
Value proposition	Value for the customers	risk minimization
Value proposition	Offer costumization (level)	Configurable offer
Value proposition	Offer Customization (object)	Service
Value proposition	Offer communication	Integration into existing channels
Customers	Traget Customer segments	No distinction
Customers	Customer segmentation strategy	Undifferentiated
Customers	Customer acceptance	Limited interest
Customers	Customer involvement	Collaborative
Ecosystem	Presence of strategic partners	Technological
Ecosystem	Continuity of strategic partners' engagement	Technological _delivery
Ecosystem	Alliance governance	Technological _coordinated

Organization structure and culture	Level of commitment of the top management of the provider	Widespread and strategic commitment
Organization structure and culture	Internal organization	New, dedicated business unit or team
Organization structure and culture	Service strategy	Partially aligned / Integrated
Organization structure and culture	Sales–Service Integration level	Partially integrated
Organization structure and culture	Physical distribution channel	Intermediated
Organization structure and culture	Digital Distribution channel	Disintermediated
Economic and finance	Revenue model and mechanism	Fixed period / subscription (payment per period)
Economic and finance	Main Risk	Data security risk
Economic and finance	Risk mitigation strategy	Formalized risk management model
Economic and finance	Risk mitigation mechanisms	Contractual clauses
Economic and finance	Profitability Measurement KPI	operational performance KPI
Economic and finance	Profitability Measurement KPI	life cycle KPI
Resources	Data connectivity	Fully connected system
Resources	Data Exploitation	Basic operational data
Resources	Data Exploitation	Performance and behavioral data
Resources	Customer Data accessibility	Full access
Resources	Technology role	Real-time monitoring and/or analysis
Resources	Technology role	High level of customization
Capabilities	Risk assessment capabilities	Base risk control
Capabilities	Human and relational capabilities	Basic Skills
Environmental sustainability	End-of-life and reverse logistics strategies	End-of-life/contract product collection
Environmental sustainability	Product-life extension strategy	No structured life extension policy
Environmental sustainability	Resource efficiency	No specific initiatives for resource efficiency
Environmental sustainability	Product service substitution	No substitution
Environmental sustainability	Dematerialization and transparency	No structured transparency or dematerialization

Table 49 W&H coding results

C.8 Sew Eurodrive

Company and XaaS Offering Overview

SEW-EURODRIVE is a family-owned German multinational company and a global player in drive technology and drive automation, with headquarters in Bruchsal, Germany. The company designs

and manufactures geared motors, gear units, industrial gearboxes, motors, inverters, and automation solutions that are deployed across a wide range of industrial sectors, including intralogistics, airports, packaging, food processing, and continuous-process industries. SEW-EURODRIVE is characterized by a strong vertical integration, long product lifecycles, and a long-standing emphasis on reliability, standardization, and global service support. In Italy, SEW-EURODRIVE has been present since 1968 and operates through a network of regional commercial and service sites, known as *Drive Centers*, coordinated by the Drive Technology Center located in Solaro (Milan). The Italian subsidiary combines sales, technical support, service activities, and selected production operations, and plays an active role in developing and piloting service-oriented solutions that are later scaled at group level. The empirical case analyzed in this study concerns a **product-based XaaS configuration** in which SEW-EURODRIVE retains ownership of the XaaS-related assets and delivers a **digitally enabled service solution** that complements the installed base of drive components and supports customers' maintenance and spare-parts decision-making. Rather than replacing the traditional sale of motors and gear units, the offering is designed to operate alongside the existing product business, strengthening long-term relationships with end users and increasing lifecycle engagement. In practice, the offering is structured around **two tightly interconnected service components**. The first component consists of an **installed-base mapping service**, enabled by a proprietary application developed by SEW-EURODRIVE. This application allows technicians or customers to take pictures of motor nameplates using a smartphone. Through image recognition and access to SEW's internal databases, the application automatically extracts technical data and builds a structured and updated inventory of all installed drive components within a plant. The result is a comprehensive overview of what is installed, what is held in spare-parts stock, and where redundancies or gaps exist. This service addresses a widespread problem among industrial users, who often lack accurate and up-to-date information about their installed base, particularly in large and complex facilities. The second component is a **predictive maintenance service**, enabled by vibration sensors, gateways, and cloud connectivity. Sensors can be installed on new or existing motors, including non-SEW equipment, and continuously monitor operating conditions. Data are transmitted to the cloud and processed through algorithms that identify deviations from normal behavior and signal potential failures months in advance. This allows customers to anticipate interventions, avoid unplanned downtime, and make informed decisions regarding repairs, refurbishment, or replacement. The predictive service is closely integrated with SEW's repair and service infrastructure, enabling rapid translation of alerts into concrete service actions. The two service components are designed to reinforce each other. Installed-base mapping provides the structural knowledge required to manage spare parts and maintenance strategies, while predictive maintenance supports dynamic, condition-based decision-making.

Together, they transform fragmented and reactive maintenance practices into a more structured and anticipatory approach. Importantly, interview evidence highlights that the service logic is **intentionally framed as a "seeding" mechanism**. SEW-EURODRIVE does not aim to maximize margins on sensors or digital services themselves. Instead, the solution is used as a lever to create downstream value through customer lock-in, repair activities, spare-parts provisioning, installed-base standardization, and long-term relationships with end users. The XaaS offering thus functions as an entry point into deeper lifecycle engagement, rather than as a standalone revenue generator. Overall, the case of SEW-EURODRIVE illustrates a product-based XaaS configuration in which digital services are strategically deployed to enhance visibility, reduce uncertainty, and anchor the provider more deeply within the customer's operational ecosystem, while preserving the central role of physical products in value creation.

Sew Eurodrive framework-based analysis

- **Value proposition**

The XaaS value proposition developed by SEW-EURODRIVE is centered on a **product-based service logic**, in which a technical system composed of sensors, gateways, connectivity, and software is delivered under an as-a-service arrangement. While the service infrastructure is provided and managed by SEW-EURODRIVE, the underlying installed drives may remain owned by the customer and can be technologically heterogeneous, including motors from competing manufacturers. The offering is therefore deliberately designed to be **brand-agnostic** with respect to the installed base, allowing the service to be applied regardless of the origin of the equipment deployed in the plant. At the time of analysis, the offering is positioned in a **pilot phase of market deployment**. Interview evidence indicates that the rental-based formula has only recently been implemented, with a limited number of contracts already active and several negotiations ongoing. At the same time, the technical components underpinning the offering, particularly the installed-base mapping application, have been developed and refined over multiple years and are described as having reached high levels of performance and ease of deployment. The pilot status therefore reflects an early stage of commercialization rather than a purely experimental or immature technological solution. The scope of the offering extends across SEW-EURODRIVE's **entire drive portfolio** and, more broadly, across customer installations where drive systems play a critical role. Rather than being tied to a specific machine type or application, the service logic can be applied to diverse operational contexts in which motors and gear units are deployed, making the offering broadly applicable across sectors and plant configurations. SEW-EURODRIVE adopts a **proactive approach** in promoting the solution. The offering is actively disseminated through marketing initiatives, industry events, and the national sales

network, including the decentralized Drive Centers. It is not positioned as a response to isolated customer requests, but as part of a broader strategy to enhance lifecycle engagement and to position digital services as an integral complement to the installed base. The contractual structure of the offering is based on a **time-bound rental model**, typically over a four-year period. Customers pay a recurring fee and receive a "turnkey" solution that includes sensors, gateways, software access, installation, and associated services. During the contractual period, SEW-EURODRIVE retains control over the service infrastructure and maintains contractual leverage, including the ability, at least in principle, to discontinue service provision in the event of non-payment. This arrangement reinforces the provider's role in managing the service lifecycle while reducing upfront investment requirements for customers. From the customer perspective, value is articulated around **two complementary drivers**. The first concerns the **reduction of operating costs**, particularly those associated with spare parts and inventory management. Installed-base mapping provides customers with a clear and structured overview of what is installed in the plant, what is held in stock, what is redundant, and what is missing. This visibility helps reduce unnecessary capital immobilization in spare parts and supports more rational inventory decisions. The second driver relates to the **achievement of expected operational results**, primarily through predictive maintenance. By monitoring vibration and operating conditions and identifying degradation trends months in advance, the service enables planned interventions and reduces the likelihood of unplanned downtime. The focus is therefore not on maximizing asset utilization per se, but on increasing reliability and predictability in maintenance and production planning. The offering is **configurable at the service level**. Customization does not involve redesigning the underlying technology or functionalities, which remain standardized across customers. Instead, configurability is achieved through project sizing and service delivery options. The service is offered in predefined "sizes," determined mainly by the number of sensors deployed, while maintaining identical core functionalities across packages. In addition, the installed-base mapping process can either be carried out autonomously by customers, who receive free access via a PIN or code, or delivered by SEW-EURODRIVE technicians as a paid service. This flexibility allows customers to choose the level of provider involvement without altering the technical architecture of the solution. Finally, communication of the offering is **integrated into existing commercial channels**. The solution is promoted through standard marketing activities and through SEW-EURODRIVE's established sales organization, rather than via a dedicated or separate XaaS channel. This integration reflects the positioning of the offering as a complement to the existing product and service portfolio, rather than as a standalone or disruptive business line.

- **Customers**

The XaaS offering developed by SEW-EURODRIVE is addressed to a **broad and heterogeneous customer base**, without the adoption of a formal customer segmentation strategy. The solution is conceptually relevant across a wide range of industrial contexts in which drive systems are deployed, and it is not restricted to specific industries or customer categories. Empirically, however, interview evidence indicates that adoption tends to be more pronounced in contexts characterized by a **large installed base of drive components** and **high costs associated with unplanned downtime**. Typical examples include large industrial sites, airports, and major manufacturing facilities, where the complexity of maintenance activities and the criticality of continuous operations make visibility and predictability particularly valuable. This pattern does not translate into an explicit segmentation strategy, but rather reflects an **adoption dynamic driven by operational scale and maintenance criticality**, which shapes where the solution gains traction first. Customer acceptance of the offering is described as **moderate but growing**. Interview material highlights that interest has increased over time as the solution has become easier to demonstrate and deploy, even though the rental-based commercial model is still in an early phase. A key driver of acceptance is **demonstrability**. The ability to quickly show tangible results, particularly through the installed-base mapping process enabled by a simple smartphone-based application, is described as decisive in triggering customer willingness to engage. The low initial effort required to start mapping the installed base lowers entry barriers and helps transform abstract value propositions into concrete and immediately visible outcomes. Customer involvement in the offering can be characterized as **primarily passive**, in the sense that the overall service architecture, functionalities, and delivery logic are defined by the provider. Customers do not participate in the design of the service model or in the configuration of its core components. At the same time, this does not imply that customers are absent from service execution. In several cases, customers actively perform installed-base mapping activities themselves, using the application provided by SEW-EURODRIVE. When customers carry out mapping autonomously, their role remains focused on **operational execution** rather than on co-design or adaptation of the service logic. They follow predefined procedures and workflows, while decision-making regarding service structure, data processing, and integration with maintenance and spare-parts services remains firmly under the provider's control. This configuration reflects a customer role centered on adoption and use, rather than on collaborative development of the XaaS model. Overall, the Customers dimension highlights a configuration in which broad applicability coexists with selective early adoption, driven by operational scale and maintenance criticality. Customer acceptance grows as the solution becomes more tangible and easier to deploy, while involvement remains limited to usage and execution within a provider-defined service architecture.

- **Ecosystem**

The ecosystem supporting the XaaS offering developed by SEW-EURODRIVE is centered on a **strategic technological partnership**, complemented by emerging arrangements related to commercialization and service delivery. At its current stage, the ecosystem is primarily oriented toward **technological development**, rather than toward the outsourcing of customer-facing activities. Interview evidence highlights a **central partnership with Schaeffler**, which provides the core sensing hardware and the underlying algorithms used for fault detection and condition monitoring. Schaeffler's technology constitutes a foundational element of the predictive maintenance component of the offering, enabling the collection and processing of vibration and operating data required to anticipate failures and degradation trends. SEW-EURODRIVE builds on this technological foundation by developing its **own customized application and customer-facing interface**, rather than adopting Schaeffler's standard application in an unchanged form. This additional development layer allows SEW to integrate partner-provided technologies with its internal product databases, installed-base information, and customer support systems. As a result, the service offering reflects SEW-specific knowledge, data structures, and service logic, rather than functioning as a generic sensor-based monitoring solution. Governance within the ecosystem is **coordinated**, with SEW-EURODRIVE clearly positioning itself as **system integrator and service owner**. The company defines the overall customer proposition, determines pricing logics, and embeds the partner-provided technology costs into the commercial model. While Schaeffler contributes critical technological components, SEW retains control over how these components are combined, commercialized, and delivered as part of an integrated service solution. This governance structure allows SEW to maintain a single contractual and relational interface with customers, while leveraging external technological expertise. Beyond this core technological partnership, the interview material also points to **emerging ecosystem arrangements** linked to commercialization and delivery. In particular, SEW-EURODRIVE is exploring how certain field activities, such as installed-base mapping, could be supported by distributors or service partners as the solution scales. These considerations indicate a potential expansion of the ecosystem toward delivery and channel partners, although such arrangements are still exploratory and not yet fully institutionalized. Overall, the ecosystem configuration reflects a model in which technological partnerships play a central enabling role, while governance remains firmly anchored within SEW-EURODRIVE. The ecosystem is designed to support integration, customization, and scalability of the XaaS offering, without diluting the provider's control over the service architecture or the customer relationship.

- **Organization structure and Culture**

The development of the XaaS offering at **SEW-EURODRIVE** is supported by a **widespread and strategic commitment from top management**. Interview evidence explicitly links the servitization initiative to broader corporate priorities such as sustainability, circularity, and the efficient use of scarce resources. This positioning indicates that the initiative is not framed as a marginal or isolated experiment, but as coherent with the company's long-term strategic direction and its evolving role within industrial value chains. The **service strategy** is fully integrated and strategically driven. Digital and service-based solutions are positioned as complementary to the traditional product business and as levers to strengthen lifecycle engagement with customers. The XaaS offering is therefore embedded within SEW-EURODRIVE's broader strategic narrative, rather than being developed as a standalone or disconnected service line. From an organizational standpoint, SEW-EURODRIVE has invested in **new, dedicated roles and structures** to support the servitization agenda. Interview material highlights the creation of a specific role, *Servitization Business Developer*, filled by a professional with a service background. This role is explicitly dedicated to developing, structuring, and scaling servitization solutions. Importantly, the role evolved from previous service responsibilities and progressively became a full-time position focused on these offerings, signaling both organizational learning and a deliberate investment in specialization. Despite this investment, **sales–service integration remains limited**. Sales teams are described as historically product-oriented and are in the process of learning how to handle service contracts, rental logic, and digitally enabled solutions. At the same time, service expertise, solution development, and responsibility for the XaaS offering remain primarily anchored within service functions and dedicated roles. This separation reflects an organization in transition, where new service logics are being introduced without fully reconfiguring existing sales structures. Interview evidence also points to ongoing efforts to **systematize internal processes** associated with the offering. These include the development of standardized modules, codes, and planning procedures aimed at making the solution more repeatable and scalable. However, these process improvements do not yet translate into a fully unified contract ownership model that integrates sales and service into a single organizational responsibility. With respect to **distribution channels**, the configuration reflects a combination of mediated and direct elements. The physical channel is largely intermediated, relying on SEW-EURODRIVE's commercial structures and partners to reach the market. In contrast, the digital channel is disintermediated. Applications, cloud services, alerts, and digital interfaces create a more direct interaction between SEW-EURODRIVE and end users, particularly maintenance departments. This dual configuration allows the company to leverage its established commercial network while simultaneously building direct, data-enabled relationships with customers through digital services. Overall, the Organizational Structure and Culture dimension depicts an organization that has clearly

embraced servitization at a strategic level, while still adapting its internal structures, roles, and processes to support the consistent and scalable delivery of XaaS offerings.

- **Economic and Finance**

The XaaS offering developed by **SEW-EURODRIVE** is based on a **subscription-oriented revenue logic**, with payments defined over a fixed contractual period. Empirically, two commercial formulas currently coexist. On the one hand, customers can adopt a traditional purchase model, in which sensors are acquired upfront and recurring fees are paid for software access and cloud services. On the other hand, a newly introduced **four-year rental model** allows customers to pay a monthly fee that bundles hardware, installation, software access, and service into an "all-inclusive" solution. This rental formula is explicitly designed to lower entry barriers by reducing upfront investment and by aligning expenditures with customers' maintenance budgets rather than capital expenditure cycles. Pricing follows a **cost-plus logic**, as described in the interview material. Partner-related costs, such as the monthly cloud fee charged by the technological partner, are transferred to the customer with an additional markup. The monthly rental fee is calculated through an internal procedure that aggregates the costs of sensors, gateways, installation activities, software access, and multi-year partner fees, to which a margin is added. This structured approach reflects the company's effort to ensure transparency and cost coverage while maintaining control over the economic sustainability of the offering. The primary exposure associated with the XaaS configuration is **financial risk**. The rental model requires SEW-EURODRIVE to incur upfront costs, particularly in relation to hardware procurement and supplier payments, while revenues are collected progressively through monthly fees over several years. Interview evidence explicitly frames this challenge as the need to operate "like a bank," especially if rental adoption were to scale rapidly. This exposure is further compounded by uncertainty related to payment continuity over the contract duration. Risk mitigation relies on a **formalized risk management approach** and on contractual safeguards. Contracts include clauses that preserve the provider's leverage, such as the possibility to discontinue service delivery in the event of non-payment. While these mechanisms do not eliminate the financial exposure generated by upfront investments, they are described as essential tools for managing risk and maintaining contractual control. Profitability assessment is oriented toward **financial economics KPIs** and business outcomes rather than toward technical performance indicators. Interview material emphasizes revenue and margin growth, particularly in relation to end users, as key measures of success. A recurring theme is the **multiplier effect** generated by the offering: relatively limited initial investments in sensors and digital services can unlock substantial downstream revenues through repair activities, spare-parts sales, and long-term service relationships. Emblematic cases, such as

situations where a modest initial sensor deployment leads to significant repair volumes, are used internally to validate the economic logic of the model and to support decisions regarding further scaling at group level. Overall, the Economic and Financial dimension highlights a configuration in which subscription-based revenues, cost-plus pricing, and long-term lifecycle value are tightly interconnected. The sustainability of the model depends less on the profitability of the digital service in isolation and more on its ability to generate and anchor downstream service and spare-parts business over time.

- **Resources**

The XaaS offering developed by SEW-EURODRIVE is supported by a **fully connected digital system** that enables continuous data acquisition, transmission, and analysis. Connectivity constitutes a central enabling resource rather than a peripheral technical feature, as the effectiveness of the service logic depends directly on the reliability and flexibility of data flows between installed assets and digital platforms. From an infrastructural standpoint, the connectivity architecture is based on sensors installed on motors, which transmit data through a dedicated gateway ("box"). This gateway can connect to the cloud either via the customer's network, using cable or Wi-Fi, or through SIM-based connectivity. Interview evidence emphasizes that the SIM option is not merely an alternative technical solution, but a practical mechanism to bypass the need to access customer IT networks. At the same time, this configuration introduces additional considerations related to data security and acceptance in certain contexts. As a result, connectivity design emerges as a **strategic resource** that must balance ease of deployment, operational reliability, and customer concerns regarding data access and security. The system enables the exploitation of **multiple layers of data**. Basic operational data support the monitoring of motor condition and system status, while performance and behavioral data allow deeper analysis of usage patterns and degradation trends. This data availability underpins both the predictive maintenance service and the broader logic of condition-based decision-making embedded in the offering. A second critical resource underpinning the XaaS configuration is **SEW-EURODRIVE's internal historical product database**. The installed-base mapping service leverages this asset by extracting technical specifications from photographs of motor nameplates and matching them with data stored in SEW's internal systems. Interview material highlights that this database contains detailed product information accumulated over several decades. What was previously a static internal information stock is now actively mobilized through digital tools, transforming long-term traceability into an operational service capability. This allows SEW to reconstruct installed bases with a level of accuracy and scale that would not be feasible through manual processes. Technology supports the offering along **two closely related dimensions**. First, it enables **real-time monitoring and analysis**. The predictive maintenance system does not simply flag

imminent failures, but provides graduated warning levels, ranging from early signals to more critical states. These warnings are communicated through automated alerts, such as email notifications, allowing customers and service teams to plan interventions proactively rather than reacting to breakdowns. Second, technology enables **maintenance automation and operational continuity**. The installed-base mapping tool automates an activity that the interview describes as previously "impossible" to perform at scale, particularly in plants with thousands of motors. By systematically organizing information on installed equipment and spare parts, the tool supports more structured maintenance planning and spare-parts governance, reducing uncertainty and inefficiencies in daily operations. Overall, the Resources dimension highlights a configuration in which connectivity, historical data assets, and digital automation are tightly intertwined. These resources transform dispersed physical assets and fragmented information into a coherent, data-driven service system that supports predictive maintenance, inventory rationalization, and improved operational continuity.

- **Capabilities**

The XaaS offering developed by **SEW-EURODRIVE** is supported by a set of capabilities centered on **continuous innovation in service design** and on the development of **hybrid selling and distribution skills**. These capabilities emerge clearly from the empirical narrative and reflect an organization that is progressively adapting its competences to support digitally enabled service solutions. A first critical capability concerns **service design and iterative development**. Interview evidence describes the installed-base mapping solution as the outcome of a gradual refinement process. Early versions of the tool are characterized as confusing and difficult to use, particularly under real plant conditions. Over time, the solution evolved to address practical constraints such as imperfect photographs, limited physical accessibility of motors, and the need to operate in complex industrial environments. The current configuration allows multiple users to work in parallel using different smartphones and produces structured outputs, including Excel-based reports and synthesized insights. This evolution reflects a capability to continuously redesign and improve the service architecture and customer usability, rather than delivering a static or one-off digital product. A second, equally important capability area concerns **hybrid selling and distribution skills**. The interview highlights that discussing rental-based and service-oriented contracts with customers represents a new challenge for the organization. Moving from product sales to service and rental logic requires commercial adaptation, both in terms of content and interaction style. Effective communication is presented as a critical capability, particularly the ability to tailor the value narrative to different customer counterparts. The interview notes, for example, that senior maintenance managers and younger profiles may respond differently to digital and service-oriented propositions,

requiring flexibility in how value is framed and explained. Translating complex technical functionalities—such as predictive algorithms, data analytics, and installed-base rationalization—into a clear and compelling service logic is described as difficult and not easily replicable across the entire salesforce. As a result, hybrid selling capabilities are strongly dependent on training, accompaniment, and experiential learning. This reinforces the centrality of **human and relational capabilities**, which go beyond transactional sales skills and require consultative approaches and long-term relationship management. Capability development is also evident in **internal cross-functional coordination**. Interview material indicates that the definition of pricing logic and the structuring of the rental offer involve close interaction with financial and legal functions. The Chief Financial Officer and legal teams are engaged to formalize calculation procedures, contractual terms, and risk-related safeguards. This illustrates that scaling the service offering requires not only technical and commercial skills, but also organizational capabilities to standardize commercial processes, align them with risk governance, and ensure internal consistency. Overall, the Capabilities dimension highlights an organization that is actively building competences in service design, hybrid selling, and cross-functional coordination. These capabilities are still in development and unevenly distributed, but they play a decisive role in enabling the transition from digitally enhanced products to scalable XaaS offerings.

- **Environmental Sustainability**

Environmental sustainability within the XaaS offering developed by **SEW-EURODRIVE** is embedded in a **bounded and indirect manner**, emerging primarily through asset lifecycle management practices rather than through explicit environmental performance objectives. Interview evidence links the strategic direction of digitally enabled services to broader sustainability concerns, including **resource scarcity and the need for more circular approaches** in industrial systems. Within this framing, the contribution of the offering to sustainability is indirect and consequential. By improving maintenance decisions and providing greater visibility over the installed base, the service supports the extension of asset lifetimes and reduces unnecessary replacement of drive components. This aligns with a logic of preserving the functional value of existing assets rather than accelerating substitution with new products. A more concrete sustainability mechanism emerges in relation to **repair- and refurbishment-oriented practices**. The interview describes contractual and operational solutions in which customers return faulty products to the provider, who then replaces worn components, retains reusable parts, reassembles and tests the product, and returns it to the customer with a warranty comparable to that of a new unit. Although the company deliberately avoids labeling these practices as “remanufacturing,” the underlying logic clearly aims at **product-life**

extension through component replacement and requalification, as well as at reducing the need for new product manufacturing. The digitally enabled services reinforce these practices by supporting **anticipatory maintenance and repair planning**. Predictive alerts help avoid emergency breakdowns and last-minute replacements, which are often associated with higher material waste and inefficient logistics. Similarly, installed-base mapping reduces redundancy and uncertainty in spare-parts inventories, contributing to more rational resource use across the lifecycle of drive systems. At the same time, the sustainability configuration of the offering remains clearly delimited. The service does not include explicit mechanisms for measuring or optimizing energy or material consumption as part of the contractual proposition. Physical drive components remain central to value creation, and there is no product–service substitution logic embedded in the XaaS model. Moreover, the offering does not provide **structured environmental transparency** to customers. Environmental performance is not translated into dedicated sustainability KPIs, dashboards, or reporting mechanisms within the service contract. Overall, sustainability in SEW-EURODRIVE's XaaS configuration can be characterized as **lifecycle-oriented and consequential**. Environmental benefits arise primarily from extended asset lifetimes, reduced waste, and more informed maintenance and replacement decisions, rather than from explicitly articulated sustainability targets or dematerialized service design.

DIMENSIONS	VARIABLES	CODING
Value proposition	Offer object	Product
Value proposition	Maturity Level of the Service Offering	Pilot
Value proposition	Coverage of the Offering	Entire product range
Value proposition	XaaS Offering Approach	Proactive
Value proposition	Ownership	Offer Provider
Value proposition	Value for the customers	minimization of operating costs
Value proposition	Value for the customers	the achievement of an expected result
Value proposition	Offer costumization (level)	Configurable offer
Value proposition	Offer Customization (object)	Service
Value proposition	Offer communication	Integration into existing channels
Customers	Traget Customer segments	No distinction
Customers	Customer segmentation strategy	Undifferentiated
Customers	Customer acceptance	Moderate interest
Customers	Customer involvement	Passive
Ecosystem	Presence of strategic partners	Technological
Ecosystem	Continuity of strategic partners' engagement	Technological _development

Ecosystem	Alliance governance	Technological _coordinated
Organization structure and culture	Level of commitment of the top management of the provider	Widespread and strategic commitment
Organization structure and culture	Internal organization	New, dedicated business unit or team
Organization structure and culture	Service strategy	Fully integrated / Strategically driven
Organization structure and culture	Sales–Service Integration level	Separated
Organization structure and culture	Physical distribution channel	Intermediated
Organization structure and culture	Digital Distribution channel	Disintermediated
Economic and finance	Revenue model and mechanism	Fixed period / subscription (payment per period)
Economic and finance	Main Risk	Financial risk
Economic and finance	Risk mitigation strategy	Formalized risk management model
Economic and finance	Risk mitigation mechanisms	Contractual clauses
Economic and finance	Profitability Measurement KPI	financial economics KPI
Economic and finance	Pricing	Cost-plus
Resources	Data connectivity	Fully connected system
Resources	Data Exploitation	Basic operational data
Resources	Data Exploitation	Performance and behavioral data
Resources	Customer Data accessibility	Full access
Resources	Technology role	Maintenance automation and/or operational continuity
Resources	Technology role	Real-time monitoring and/or analysis
Capabilities	service design capabilities	Continuous innovation:
Capabilities	Human and relational capabilities	Hybrid selling & distribution skills
Environmental sustainability	End-of-life and reverse logistics strategies	End-of-life/contract product collection
Environmental sustainability	Product-life extension strategy	development of a durable product
Environmental sustainability	Resource efficiency	No specific initiatives for resource efficiency
Environmental sustainability	Product service substitution	No substitution
Environmental sustainability	Dematerialization and transparency	No structured transparency or dematerialization

Table 50 Sew Eurodrive coding result

C.9 CGT

Company and XaaS Offering Overview

CGT (Compagnia Generale Trattori) is the exclusive Italian dealer of Caterpillar for earthmoving machinery, engines, and power systems, and operates as part of the Tesya Group, a multinational industrial group active across Europe and the Balkans. Founded in the early twentieth century, CGT has progressively evolved from a traditional equipment distributor into a service-intensive industrial partner. Since the late 1990s, the company has consistently invested in post-sales services, preventive maintenance contracts, rental solutions, and technical assistance, positioning service excellence as a central pillar of its competitive strategy. This long-term orientation has led to the development of a dense territorial presence, a large heavy-duty rental fleet, and advanced technical and diagnostic capabilities, which today represent the structural foundation of CGT's servitization trajectory. Over time, CGT has also played a pioneering role within the Italian construction and earthmoving sector by introducing practices that were initially uncommon, such as structured maintenance contracts and long-term rental solutions. More recently, the company has articulated a strategic vision aimed at repositioning itself as a technological and performance-oriented partner for its customers, with the explicit objective of improving customers' operational productivity rather than merely supplying machinery. This strategic shift has been reinforced by the increasing availability of connected equipment, remote monitoring technologies, and data-driven service platforms, many of which are enabled through the Caterpillar ecosystem.

The XaaS configuration analyzed in this study is embedded within this broader transformation and corresponds to a **product-based XaaS offering** centered on **pay-per-performance and pay-per-availability logics**. The most emblematic expression of this model is the so-called *"euro per tonnellata"* (euro per ton) approach, through which customers are invoiced based on measurable output indicators, such as tons of material moved, processed, or produced. In this configuration, CGT typically provides and manages the equipment, often retaining ownership of the physical asset, while assuming responsibility for its availability, performance, and maintenance throughout the contract duration. The offering is not limited to the provision of machinery, but takes the form of an **integrated solution** in which the physical asset is bundled with digital monitoring systems, maintenance and service activities, and operational consultancy. Advanced data collection and remote monitoring enable CGT to analyze machine utilization, idle time, productivity, and process bottlenecks, thereby supporting both performance assurance and continuous optimization. On this basis, CGT engages with customers not only to guarantee equipment availability, but also to actively contribute to process improvement and productivity gains. At the time of analysis, the XaaS offering is implemented through **pilot projects**, primarily involving long-standing customers with whom trust-based relationships already exist. These pilot initiatives are deliberately selective and incremental, reflecting both the strategic importance of the assets involved and the organizational and cultural barriers

associated with introducing outcome-based models in a traditionally product-centric industry. The unit of analysis therefore concerns the **product as an integrated solution**, where equipment, data, services, and process expertise are tightly coupled into a single performance-oriented value proposition. Overall, CGT represents a particularly relevant case for studying XaaS in capital-intensive and asset-critical contexts, where the serviced asset is central to the customer's core production process and where servitization requires deep operational integration, data sharing, and long-term relational commitment

CGT framework-based analysis

- **Value proposition**

The value proposition developed by **CGT (Compagnia Generale Trattori)** is centered on the provision and management of **physical machinery whose performance is contractually guaranteed**. Rather than focusing on the sale of equipment, the offering is built around the ability to deliver measurable and agreed performance outcomes over time. The machine therefore remains a central element of value creation, but it is embedded within a broader service logic in which availability, productivity, and operational continuity are ensured by the provider. Although the offering is currently implemented through a limited number of contracts, it represents a **pilot in terms of market deployment rather than infrastructural readiness**. The technological, organizational, and service foundations required to support a pay-per-performance logic, such as remote monitoring, maintenance capabilities, and operational expertise, have been developed over many years. The pilot status reflects a deliberate and selective approach to adoption, rather than a lack of maturity in the underlying service infrastructure. The pay-per-performance logic is conceived with **broad applicability across CGT's product portfolio**. In principle, the same value proposition can be extended to different types of machines and operational contexts, including quarries, recycling plants, industrial sites, and potentially construction environments. The offering is therefore not tied to a single machine type or application, but to the ability to measure output and link compensation to performance indicators that are meaningful for the customer's production process. CGT adopts a clearly **proactive approach** in proposing this value proposition. The pay-per-performance model is actively promoted as part of a broader strategic vision aimed at repositioning the company as a **technological and performance-oriented partner**, rather than as a traditional equipment supplier. The offering is introduced in situations where CGT perceives strong alignment between customer needs, operational conditions, and the potential benefits of an outcome-based model. A defining element of the value proposition is that **CGT typically retains ownership of the machinery** within the pay-per-performance configuration. By remaining the asset owner, the company assumes

responsibility for machine availability, maintenance, and performance throughout the contract duration. This ownership structure enables CGT to directly intervene on asset configuration, maintenance planning, and operational optimization, while shielding customers from asset-related risks and management complexity. From the customer perspective, value is articulated along two closely related dimensions. First, the offering aims at **optimizing usage processes**, leveraging data, monitoring, and operational expertise to improve how machines are deployed within the production system. Second, the offering is oriented toward the **achievement of an expected result**, expressed through output-based metrics such as tons processed or moved. Customers are not primarily offered lower machine prices, but rather **lower unit costs**, higher productivity, and greater predictability of performance. In parallel, managerial complexity is reduced, as CGT takes over significant portions of asset management and performance responsibility. The offering is **customizable at the product level**, with configurations adapted to specific sites, processes, and production targets. Customization does not lead to one-off or experimental prototypes, but is achieved through tailored configurations built within a standardized product and service architecture. This allows CGT to balance site-specific adaptation with operational consistency and scalability. Finally, communication of the pay-per-performance offering is **highly selective**. CGT does not broadly advertise this model through standardized marketing channels. Instead, the offering is introduced through direct interactions with a limited number of trusted customers, typically within established relationships. This selective communication reflects both the pilot nature of the initiative and the strategic sensitivity of outcome-based contracts in capital-intensive and production-critical environments. Overall, CGT's value proposition represents a product-based XaaS configuration in which machinery, services, and data are tightly integrated to deliver performance outcomes, while gradually redefining the relationship between provider and customer from asset transaction to shared productivity logic.

- **Customers**

CGT's pay-per-performance offering is addressed to a **heterogeneous customer base** operating across different application contexts, including quarries, industrial processing plants, recycling facilities, and construction-related activities. The offering is not formally targeted at predefined customer segments; however, interview evidence indicates that the feasibility and attractiveness of the model vary substantially depending on the operational context in which the equipment is deployed. In practice, CGT's approach reflects a **segment-oriented logic** grounded in application-specific conditions rather than in customer characteristics. The suitability of the XaaS model depends on factors such as process stability, measurability of output, and the degree of integration between equipment and production workflows. As a result, while the offering can in principle be applied across

a wide range of contexts, it is selectively introduced in settings where performance can be clearly measured and linked to economic outcomes. Customer acceptance of the pay-per-performance model is characterized by **limited interest**. Interview material highlights that, although customers often acknowledge the potential economic benefits of performance-based pricing, such as improved productivity and lower unit costs, significant resistance emerges when the offering requires **deep access to production data and operational transparency**. The need to continuously monitor equipment usage and production processes represents a critical point of tension in the customer–provider relationship. Reluctance is frequently linked to **cultural and organizational factors**, particularly in family-owned firms where decision-making structures are highly centralized and strongly influenced by generational dynamics. Concerns related to data sharing, perceived loss of autonomy, and fear of external interference in core production processes contribute to skepticism toward the model, even when its economic rationale is understood. Customer involvement in the offering is therefore **collaborative by necessity**. The pay-per-performance logic can only function if customers actively share operational data, allow continuous monitoring of production processes, and engage in ongoing interaction with CGT. This collaboration is formalized through non-disclosure agreements and contractual arrangements that define data access, usage rights, and responsibilities. At the same time, the requirement for close collaboration represents both a **prerequisite for value creation** and a **major barrier to adoption**, as it challenges established norms regarding data ownership, control, and operational independence. Overall, the Customers dimension highlights a configuration in which technical feasibility alone is insufficient to ensure adoption. Cultural acceptance, trust, and willingness to engage in transparent and collaborative relationships play a decisive role in shaping customer responses to CGT's pay-per-performance offering.

- **Ecosystem**

The ecosystem supporting the pay-per-performance offering developed by CGT is primarily structured around **financial partners** and **consultancy and research partners**, rather than around technological outsourcing arrangements. This configuration reflects the specific challenges associated with performance-based contracts in capital-intensive and asset-critical contexts. **Financial partners** play a central role within the ecosystem, most notably through collaboration with Caterpillar Financial. These partnerships are critical for enabling CGT to retain ownership of the machinery while offering customers outcome-based pricing mechanisms. By providing access to dedicated financing solutions, financial partners support the management of the significant capital intensity associated with pay-per-performance contracts and allow CGT to deploy the model without disproportionately burdening its balance sheet. The involvement of financial partners therefore

underpins the economic feasibility of the offering, particularly as the model scales beyond isolated pilot projects. In addition to financial actors, the ecosystem includes **consultancy and research partners**, whose contribution is primarily concentrated in the **development phase** of the offering. These partners support CGT in the design and refinement of performance-based pricing models, cost structures, and contractual frameworks. Their role is not related to day-to-day service execution, but rather to the analytical and conceptual work required to translate operational performance metrics into viable economic arrangements. **Alliance governance** within the ecosystem is predominantly **collaborative**. CGT works closely with financial, consultancy, and research partners to co-develop the economic logic of the offering and to address uncertainties related to risk allocation, pricing mechanisms, and contract design. At the same time, CGT maintains **full control over customer relationships and service delivery**, positioning itself as the sole contractual interface toward customers. Partners operate in the background, supporting the structuring and viability of the model rather than directly interacting with end users. Overall, CGT's ecosystem is not oriented toward delegating technological capabilities or operational responsibilities, but toward **risk sharing, financial structuring, and analytical support**. This configuration is particularly relevant given the novelty and complexity of pay-per-performance models in the earthmoving and processing sector, where aligning financial exposure, operational responsibility, and performance outcomes requires close coordination among multiple actors without diluting the provider's central role.

- **Organizational structure and Culture**

The development of CGT's pay-per-performance offering is supported by a **widespread and strategic commitment from top management**, which is closely connected to the company's long-standing identity as a service-driven organization. Interview evidence indicates that servitization is not perceived as a marginal or experimental initiative, but rather as a deliberate strategic response to structural changes in the competitive environment. In particular, increasing commoditization of machinery, intensified price competition, and the entry of low-cost competitors, especially from China, have reinforced the need to differentiate beyond traditional product sales. Within this strategic framing, CGT positions performance-based offerings as the most advanced expression of its service strategy. The pay-per-performance model is conceptually located at the top of a progressive service "pyramid" that builds on more established layers, including traditional equipment sales, connectivity solutions, availability-based services, and productivity support. This hierarchical representation reflects the company's view of servitization as an evolutionary path, in which more sophisticated offerings are grounded in the capabilities and infrastructures developed at earlier stages. From an organizational perspective, CGT has established **new, dedicated teams** focused on asset management

and servitization initiatives. These teams are explicitly tasked with developing, piloting, and refining performance-based business models. While they are still relatively small and evolving, they benefit from strong senior sponsorship, which provides legitimacy and strategic direction. Their role is not limited to experimentation, but includes the systematic translation of pilot experiences into scalable organizational practices. The **service strategy** is fully integrated and strategically driven. Performance-based offerings are not treated as isolated projects, but are embedded within CGT's broader organizational vision and service portfolio. At the same time, the transition toward pay-per-performance models places new demands on internal coordination, particularly across sales, service, technical, and financial functions. With respect to **sales–service integration**, the configuration can be described as partially integrated. CGT has extensive experience in selling services alongside machinery, and service activities are deeply embedded in the organization. However, the commercialization of pay-per-performance solutions requires a fundamentally different sales approach. Rather than focusing on equipment specifications or transactional value, sales personnel are expected to combine technical knowledge with financial reasoning and consultative skills, engaging customers on productivity, process optimization, and long-term performance outcomes. Interview material highlights that existing sales staff are widely recognized as highly competent in selling machines, but are not yet fully equipped to commercialize asset management and performance-based solutions. This gap has prompted the recognition of the need for targeted training initiatives, the creation of new roles, and the emergence of internal "evangelists" who promote and support the new business model across the organization. Regarding **distribution channels**, CGT operates a **hybrid physical channel**, leveraging its dense territorial presence and direct relationships with customers for service delivery and on-site interaction. This physical proximity remains central to trust-building and operational coordination. In contrast, the **digital distribution channel is disintermediated**. Customers interact directly with digital platforms and monitoring systems for data access and performance visibility, without mediation through CGT's organizational interfaces. This configuration reflects the centrality of digital tools in enabling transparency and performance measurement within the pay-per-performance model. Overall, the Organizational Structure and Culture dimension portrays a company that combines strong strategic commitment to servitization with ongoing organizational adaptation. While the strategic direction is clearly articulated and supported at the highest levels, the internal structures, roles, and competencies required to fully support performance-based models are still evolving, reflecting the transformative nature of CGT's XaaS journey.

- **Economic and Finance**

CGT's pay-per-performance offering is grounded in a **performance-based revenue logic**, in which revenues are generated through pay-per-output or pay-per-availability mechanisms. The most representative expression of this approach is the *"euro per tonnellata"* model, under which customers are invoiced based on the actual volume of material moved or processed. This structure fundamentally reorients the economic logic of the relationship, shifting it away from asset ownership or time-based usage toward the achievement of measurable operational results. Pricing is constructed according to a **cost-plus structure**, in which the unit price incorporates the full lifecycle cost of the asset. This includes the acquisition of the machine, financing costs, preventive and corrective maintenance activities, spare parts, logistics, and the internal costs associated with technical support and operational consultancy. As a result, the economic sustainability of the model depends on CGT's ability to accurately estimate asset behavior over time and to align these estimates with customer production conditions. Margins are generated only when actual performance remains consistent with the assumptions embedded in the pricing model, making cost control and performance monitoring central to value capture. This configuration exposes CGT to **significat financial and operational risks**. Financial risk derives from the need to invest upfront in capital-intensive equipment while recovering revenues progressively over the duration of the contract. This exposure is amplified by the typically long-term nature of pay-per-performance agreements and by variability in customer production volumes, which directly affect revenue streams. Operational risk, in turn, stems from CGT's contractual responsibility for asset availability and performance, regardless of fluctuations in operating conditions, operator behavior, or variability in the characteristics of the processed material. Risk mitigation is addressed through a **formalized risk management model** that combines contractual safeguards with external financial support. Contracts generally specify minimum guaranteed volumes, performance thresholds, and predefined conditions under which pricing adjustments or contract renegotiations may occur. These clauses are designed to limit exposure to extreme deviations from expected operating conditions while preserving the core performance-based logic of the offering. Financial partnerships, particularly with **Caterpillar Financial**, play a crucial role in managing capital exposure. Through these collaborations, CGT is able to support the asset ownership requirements of the model and to balance the impact of capital-intensive investments on its balance sheet. This arrangement enables the company to scale pilot initiatives incrementally, without fully internalizing all financial risk associated with asset acquisition and long-term deployment. Profitability assessment is oriented toward a **medium–long-term horizon** and relies on a combination of operational performance KPIs and lifecycle-based indicators, rather than on short-term transactional margins. Interview evidence highlights that internal validation of the model often draws on emblematic pilot cases. In these cases, relatively modest initial investments in monitoring,

asset management, and process optimization generate substantial downstream revenues through repairs, spare parts, and extended service relationships. Such pilot experiences are used internally to justify continued experimentation and gradual scaling of the pay-per-performance model. Overall, the Economic and Financial dimension illustrates a configuration characterized by high capital intensity, deep integration between operational and financial logic, and a deliberate shift toward result-oriented value capture. The sustainability of the model depends on CGT's ability to manage risk, align incentives, and leverage long-term service relationships rather than on immediate transactional returns.

- **Resources**

The pay-per-performance offering developed by **CGT (Compagnia Generale Trattori)** is underpinned by a **highly integrated digital and physical resource base**, which is the result of sustained investments in connectivity, monitoring, and asset management infrastructures over an extended period. These resources constitute a critical enabler of the XaaS configuration, as performance-based contracts require continuous visibility over asset behavior and production outcomes. Machines included in the performance-oriented model are equipped with **advanced telematics systems** that allow continuous data transmission related to machine health, utilization, and productivity. Connectivity is therefore not an ancillary feature, but a foundational element that enables real-time interaction between physical assets deployed in the field and CGT's centralized service organization. CGT exploits multiple layers of data. **Basic operational data**, such as engine status, alarms, and maintenance indicators, support routine monitoring and maintenance planning. In addition, the company leverages **performance and behavioral data**, including load factors, idle time, duty cycles, and production volumes. These richer data streams enable a deeper understanding of how machines are actually used within customer processes, moving the focus beyond technical condition toward operational effectiveness. A distinctive feature of CGT's resource configuration is the **aggregation of data across fleets and sites**. Rather than limiting analysis to individual machines, CGT consolidates data at system level, allowing comparisons across assets, applications, and operational contexts. This aggregated perspective supports benchmarking activities, identification of inefficiencies, and the evaluation of alternative operating scenarios, thereby reinforcing the performance-oriented nature of the offering. Access to **customer data** is **limited and conditional**, as it depends on explicit contractual agreements and on the existence of trust-based relationships. Interview material emphasizes that data sharing represents one of the most sensitive aspects of the XaaS model. While access to detailed operational data is essential for performance optimization and for validating output-based billing mechanisms, customers may perceive continuous monitoring as

intrusive. For this reason, **data governance and transparency** are treated as critical enabling resources rather than as purely technical issues, requiring careful management of access rights, usage boundaries, and communication practices. Technology plays a **central role in real-time monitoring and analysis**, supporting activities such as remote diagnostics, predictive maintenance, and performance benchmarking. CGT has developed **centralized monitoring and control capabilities** that allow technicians and analysts to intervene proactively, plan maintenance actions, and assess the potential impact of alternative operational configurations. Through these technological resources, machines are transformed from isolated assets into components of an **integrated, data-driven service system**, in which performance, availability, and productivity can be continuously observed and managed. Overall, the Resources dimension highlights a configuration characterized by strong digital integration, multi-layer data exploitation, and centralized analytical capabilities. These resources provide the operational backbone required to support performance-based contracts and to align asset management activities with customer production outcomes.

- **Capabilities**

The performance-based XaaS model developed by **CGT** relies on a set of **complex and evolving organizational capabilities** that extend well beyond traditional service delivery skills. At the core of this configuration lies the company's ability to engage not only with machines, but with **customer production processes** as integrated systems. A critical capability concerns the understanding, modeling, and influence of how customers operate their plants, organize workflows, and allocate resources. Unlike conventional maintenance or availability-based services, the pay-per-performance logic requires CGT to develop a deep and continuous understanding of production dynamics, operational constraints, and performance drivers. Value creation therefore depends on the company's capacity to intervene at the level of processes rather than solely at the level of assets. In this context, **human and relational capabilities** play a central role. Interview evidence highlights that outcome-based contracts cannot be approached transactionally. Instead, they require trust-based, long-term relationships and the ability to engage customers in open discussions about operational data, performance bottlenecks, and productivity targets. Convincing customers to share sensitive production information and to accept continuous monitoring represents a significant capability challenge, particularly in traditionally asset-centric and autonomy-oriented industries. While CGT possesses strong technical expertise and long-standing service capabilities, the specific skills required to sell and manage performance-based contracts are still **in the process of development**. These include consultative selling capabilities, financial and economic modeling skills, and the ability to support organizational change on the customer side. The shift toward outcome-based models

therefore places new demands on sales and service personnel, who are required to combine technical knowledge with financial reasoning and process-oriented perspectives. Internally, capability development is oriented toward the creation of **hybrid professional profiles** capable of bridging technical, commercial, and financial domains. Dedicated teams and internal champions play a key role in this process. They are responsible for piloting the pay-per-performance model, learning from early projects, and transferring knowledge and practices across the organization. These actors function as focal points for experimentation and learning, supporting the gradual diffusion of new capabilities. At the same time, interview material indicates that **scaling these capabilities** beyond a limited number of experts remains a major challenge. While CGT demonstrates strong execution capabilities at the operational level, the transition toward performance-based XaaS increases pressure on the organization's ability to institutionalize new competencies and embed them consistently across the broader sales and service organization. Overall, the Capabilities dimension portrays a company with solid operational foundations and growing conceptual and relational strengths, facing the challenge of transforming emergent, expert-driven capabilities into standardized and widely shared organizational competences.

- **Environmental Sustainability**

Environmental sustainability within CGT's pay-per-performance XaaS offering is embedded in a **systemic but indirect manner**, emerging primarily as a consequence of performance optimization rather than as an explicit contractual objective. Sustainability is therefore not positioned as a standalone value proposition, but is closely intertwined with the operational logic that underpins the performance-based model. A central sustainability mechanism lies in the implementation of **structured end-of-life and reverse logistics practices**. CGT systematically recovers used machines at the end of their operational cycle and manages their refurbishment and resale through certified second-hand channels. These practices contribute to **extending asset lifecycles** and reducing material waste, reinforcing a circular approach to asset management that is consistent with the company's long-standing service orientation. Product-life extension is further supported by CGT's emphasis on **durability and maintenance**. The service-intensive approach prioritizes preventive maintenance, timely component replacement, and refurbishment activities, allowing machines to remain operational for extended periods. By maintaining equipment in optimal condition over time, CGT reduces the need for frequent asset replacement and mitigates the environmental impacts associated with the production of new machinery. Resource efficiency benefits also arise from the **optimization of usage processes**, which is a core element of the pay-per-performance model. Through continuous monitoring and operational support, CGT contributes to reducing idle time, improving load

management, and optimizing production flows. These interventions can lead to lower fuel consumption and reduced emissions per unit of output, particularly in energy-intensive sectors such as quarrying, recycling, and material processing. The offering does not involve **product–service substitution**, as physical machinery remains central to value creation and to the delivery of performance outcomes. While digital platforms and monitoring systems are leveraged to support traceability and performance control, there are **no structured mechanisms for environmental transparency or dematerialization** embedded in the XaaS contract. Environmental benefits are therefore not systematically translated into dedicated environmental KPIs or customer-facing sustainability reports. Overall, sustainability in CGT's XaaS configuration can be characterized as **performance-driven and consequential**. Environmental outcomes emerge as a result of improved operational efficiency, extended asset lifecycles, and optimized resource use, rather than from explicitly articulated sustainability objectives within the service design. This reflects a model in which environmental benefits are tightly coupled with productivity and performance improvements, without being formally codified as contractual deliverables.

DIMENSIONS	VARIABLES	CODING
Value proposition	Offer object	Product
Value proposition	Maturity Level of the Service Offering	Pilot
Value proposition	Coverage of the Offering	Entire product range
Value proposition	XaaS Offering Approach	proactive
Value proposition	Ownership	Offer Provider
Value proposition	Value for the customers	optimization of usage processes
Value proposition	Value for the customers	the achievement of an expected result
Value proposition	Offer costumization (level)	Customizable offer
Value proposition	Offer Customization (object)	Product
Value proposition	Offer communication	Limited or absent communication
Customers	Traget Customer segments	No distinction
Customers	Customer segmentation strategy	Segment-Oriented
Customers	Customer acceptance	Limited interest
Customers	Customer involvement	Collaborative
Ecosystem	Presence of strategic partners	Financial
Ecosystem	Presence of strategic partners	Consultancy & research
Ecosystem	Continuity of strategic partners' engagement	Financial _both
Ecosystem	Continuity of strategic partners' engagement	Consultancy & research_development
Ecosystem	Alliance governance	Financial_collaborative

Ecosystem	Alliance governance	Consultancy & research_collaborative
Organization structure and culture	Level of commitment of the top management of the provider	Widespread and strategic commitment
Organization structure and culture	Internal organization	New, dedicated business unit or team
Organization structure and culture	Service strategy	Fully integrated / Strategically driven
Organization structure and culture	Sales–Service Integration level	Partially integrated
Organization structure and culture	Physical distribution channel	hybrid/intermediate
Organization structure and culture	Digital Distribution channel	Disintermediated
Economic and finance	Revenue model and mechanism	Payment per performance / per availability
Economic and finance	Main Risk	Financial risk
Economic and finance	Main Risk	Operational risk
Economic and finance	Risk mitigation strategy	Formalized risk management model
Economic and finance	Risk mitigation mechanisms	Financial company
Economic and finance	Profitability Measurement KPI	operational performance KPI
Economic and finance	Profitability Measurement KPI	life cycle KPI
Economic and finance	Pricing	Cost-plus
Resources	Data connectivity	Fully connected system
Resources	Data Exploitation	Basic operational data
Resources	Data Exploitation	Performance and behavioral data
Resources	Data Exploitation	Integrated system & customer data
Resources	Customer Data accessibility	Limited/conditional access
Resources	Technology role	Real-time monitoring and/or analysis
Capabilities	Human and relational capabilities	Basic Skills
Environmental sustainability	End-of-life and reverse logistics strategies	End-of-life/contract product collection
Environmental sustainability	Product-life extension strategy	development of a durable product
Environmental sustainability	Resource efficiency	Implementation of eco-efficient design or processes
Environmental sustainability	Product service substitution	No substitution
Environmental sustainability	Dematerialization and transparency	Digital platforms supporting traceability and reporting
Environmental sustainability	Use and service intensity	Inclusion of second-hand products in the aaS offering

Table 51 CGT coding results

C.10 Stulz

Company description

STULZ is an international manufacturing company specializing in precision air conditioning and cooling solutions for mission-critical applications. Founded in Germany and headquartered in Hamburg, the company has developed a strong global presence through a network of subsidiaries, production sites, and service organizations operating across Europe, the Americas, Asia, and the Middle East. STULZ solutions are primarily deployed in sectors where temperature and humidity control are critical, such as data centers, telecommunications, industrial processes, healthcare facilities, and infrastructure environments. The company's core portfolio includes precision air conditioning units, chillers, indirect and direct free cooling systems, and customized cooling solutions designed to ensure high reliability, energy efficiency, and operational continuity. STULZ is widely recognized for its engineering-driven approach, with a strong emphasis on product durability, performance stability, and compliance with stringent technical and environmental standards. From a business model perspective, STULZ has traditionally operated as a product-centric manufacturer, supplying high-performance cooling equipment through project-based sales and long-term customer relationships. Over time, however, the company has progressively expanded its service portfolio, integrating installation, commissioning, maintenance, monitoring, and lifecycle support into its value proposition. This evolution reflects both increasing customer demand for operational reliability and broader industry trends toward servitization in capital-intensive equipment markets. In recent years, STULZ has explored and developed use- and performance-oriented access models, complementing traditional sales with rental-based solutions and more advanced service-oriented configurations. These initiatives aim to reduce customer upfront investments, improve predictability of operating costs, and align provider incentives with system availability and performance. At the same time, STULZ retains a strong focus on maintaining control over product quality, system design, and operational standards. Within this context, STULZ has developed two distinct XaaS configurations, which constitute two separate units of analysis in this study:

1. **Rental**, in which cooling equipment is provided under time-based access contracts, with STULZ retaining ownership of the assets and responsibility for their functionality over the contractual period.
2. **Cooling-as-a-Service (CaaS)**, in which customers access guaranteed cooling functionality through usage- or performance-oriented contractual arrangements, shifting part of the operational and financial risk to the provider.

These two configurations coexist within the same organizational and technological context but differ substantially in terms of object of the offering, revenue logic, risk allocation, and degree of service integration. As such, STULZ represents a particularly relevant case for analyzing the coexistence and differentiation of rental-based and performance-oriented XaaS models within a single manufacturing firm.

Stulz Rental XaaS Offering Overview

The **rental** offering developed by STULZ is based on providing **precision cooling equipment under time-based access contracts**, allowing customers to use cooling systems without acquiring ownership of the physical assets. In this configuration, STULZ retains ownership of the equipment and makes it available to customers for a predefined contractual period, during which the systems are deployed at the customer site. The rental solution is primarily positioned as a **flexibility-oriented access model**, suitable for customers facing temporary or uncertain cooling needs. Typical use cases include transitional phases, temporary installations, capacity expansion during peak demand, or situations in which customers prefer to avoid upfront capital investments in cooling infrastructure. The rental model enables rapid deployment of cooling systems while maintaining technical standards consistent with STULZ's product portfolio.

From an operational perspective, the rental offering relies on **standardized equipment configurations** selected from STULZ's existing product range. Customization is limited, as the focus of the offering is on availability and speed of deployment rather than on bespoke system design. Equipment is delivered, installed, and made operational according to predefined procedures, ensuring consistency and reliability across rental contracts. Service activities are embedded within the rental offering to ensure the **functional availability of the equipment** over the rental period. While the rental model does not entail full performance guarantees, STULZ remains responsible for maintaining the operational condition of the cooling units during use. This responsibility reinforces the provider's control over system integrity and reduces operational burden for the customer. The rental configuration is clearly distinguished from Cooling-as-a-Service. In the rental model, the object of the offering remains the **physical cooling equipment**, accessed through time-based contracts, rather than guaranteed cooling output or performance. Risk transfer is therefore limited, with STULZ primarily assuming asset-related and basic operational risks, while customers retain responsibility for how cooling capacity is integrated into their broader infrastructure. Overall, STULZ's rental offering can be characterized as a **product-based XaaS configuration**, emphasizing temporary access to high-quality cooling equipment, reduced upfront investment for customers, and provider-controlled

asset management. The model represents an intermediate step between traditional product sales and more advanced performance-oriented service models within STULZ's XaaS portfolio.

Stulz Rental framework-based analysis

- **Value proposition**

The value proposition of STULZ's **rental** offering is centered on providing customers with **temporary and flexible access to precision cooling equipment**, without requiring ownership of the physical assets. Within the framework, the **object of the offering** is coded as a **product-based solution**, as value creation is anchored in the availability and use of cooling units delivered through time-based contracts. The **maturity level** of the rental offering is coded as **pilot**, reflecting its role as a complementary and situational access model rather than as a fully institutionalized core business. The rental configuration is applied selectively, typically in contexts characterized by temporary capacity needs, transitional operational phases, or uncertainty regarding long-term cooling requirements. In terms of **coverage**, the offering is limited to **specific product categories** drawn from STULZ's standard portfolio of precision cooling equipment. The **approach** is **reactive**, as rental solutions are generally proposed in response to explicit customer needs related to temporary installations, emergency situations, or short-term capacity extensions, rather than as a default alternative to product sales. **Ownership** of the equipment is retained by the **provider**, and this element constitutes a central component of the value proposition. By maintaining ownership, STULZ assumes responsibility for the physical asset and its basic operational condition during the rental period, while customers avoid capital expenditure, depreciation, and long-term asset commitment. Customer value is articulated primarily in terms of **risk reduction and flexibility**. The rental model allows customers to rapidly access reliable cooling solutions while postponing or avoiding investment decisions. This is particularly valuable in environments where demand volatility, project-based operations, or temporary infrastructural constraints make long-term ownership unattractive. The offering is characterized by **low customization**, as rental equipment is delivered in standardized configurations. Customization is limited to basic sizing and deployment parameters, reinforcing the speed and simplicity of the solution. **Offer communication** is integrated into existing commercial interactions and typically occurs within project-oriented discussions rather than through dedicated rental marketing channels. Overall, the value proposition of STULZ's rental offering can be characterized as **access-oriented and flexibility-driven**, providing customers with a low-commitment solution for addressing temporary cooling needs while allowing the provider to retain control over assets and preserve the option to redeploy equipment across multiple use contexts.

- **Customers**

The customer dimension of STULZ's **rental** offering reflects the **situational and non-standardized nature** of this access model within the company's portfolio. Within the framework, **target customer segments** are coded as **no distinction**, as the rental solution is not formally restricted to specific industries or firm sizes. In practice, however, adoption is driven by contextual needs rather than by stable customer characteristics. The **segmentation strategy** is coded as **ad hoc / case-based**, capturing the fact that rental is primarily activated in response to **specific operational circumstances**. These include temporary cooling requirements, transitional phases such as facility upgrades or relocations, pilot projects, or emergency situations where rapid deployment is required. Customers are therefore selected based on the nature and duration of their cooling needs rather than on long-term strategic fit. Customer **acceptance** is coded as **moderate**, reflecting the fact that rental is perceived as a useful but non-primary option. Interview and codification material indicate that customers value rental for its flexibility and speed, but do not generally consider it a long-term substitute for ownership or more advanced service-based models. As a result, rental adoption is typically temporary and purpose-driven. Customer **involvement** is coded as **passive**. The rental offering is largely provider-defined and standardized, with limited scope for customer participation in shaping the configuration of the service. Interaction with customers focuses on defining the duration of the rental, basic technical compatibility, and deployment logistics, rather than on co-design or collaborative development of the offering. Overall, the customer dimension highlights that STULZ's rental offering targets **customers facing temporary uncertainty or short-term capacity gaps**, rather than those seeking long-term transformation of their cooling strategy. The model serves as a flexible access solution in exceptional or transitional contexts, reinforcing its role as a complementary and situational XaaS configuration within STULZ's broader business model.

- **Ecosystem**

The ecosystem supporting STULZ's **rental** offering is characterized by a **limited and operationally focused configuration**, reflecting the temporary and standardized nature of the model. Within the framework, the presence of strategic partners is coded as **low**, as value creation is largely controlled internally by STULZ and does not rely on complex multi-actor collaboration. A central role within the ecosystem is played by **internal operational and service units**, which are responsible for equipment preparation, delivery, installation, and basic operational support during the rental period. These activities are executed according to predefined procedures, ensuring consistency and technical reliability across different rental deployments. The ecosystem is therefore oriented toward execution efficiency rather than co-innovation. External actors, such as logistics providers or installation partners, may be involved on a **transactional basis** to support physical deployment and removal of

rental equipment. However, these actors do not assume strategic roles within the ecosystem and operate under STULZ's coordination and control. Their involvement is episodic and linked to specific rental projects rather than to continuous service delivery. Partner engagement is therefore **episodic**, corresponding to the temporary duration of rental contracts. Unlike more advanced XaaS configurations, the rental ecosystem does not require long-term alignment or shared performance objectives between multiple actors. Coordination needs are limited to ensuring timely delivery, installation, and withdrawal of equipment. **Ecosystem governance** is coded as **provider-led and centralized**. STULZ defines the scope of the rental offering, selects equipment, manages contracts, and coordinates all supporting activities. Customers interact directly with STULZ, while partners remain largely invisible at the commercial level. Overall, the ecosystem dimension highlights that STULZ's rental offering is supported by a **simple, closed, and execution-oriented ecosystem**, designed to minimize complexity and enable rapid response to temporary customer needs. This configuration aligns with the situational role of rental within STULZ's XaaS portfolio and contrasts with the more articulated ecosystem required by Cooling-as-a-Service models.

- **Organization structure and Culture**

The organizational configuration supporting STULZ's **rental** offering reflects a **limited and non-institutionalized integration** of rental-based logics within the firm's overall structure. Within the framework, **top management commitment** is coded as **selective**, indicating that rental is recognized as a useful complementary option, but does not represent a strategic priority comparable to core product sales or more advanced service-oriented models. The **internal organization** underpinning the rental offering relies on **existing organizational units**, rather than on dedicated rental-specific structures. Rental activities are managed within established sales, project management, and service functions, which coordinate on a case-by-case basis to deliver the offering. This organizational arrangement reflects the episodic and situational nature of rental, as well as its limited scale within the company's portfolio. The **service strategy** associated with rental is coded as **supportive rather than transformative**. Rental is positioned as an access solution that enables temporary deployment of cooling equipment, but does not fundamentally alter STULZ's product-centric orientation. Service activities embedded in the rental offering are primarily aimed at ensuring basic functionality and operational continuity, rather than at delivering performance guarantees or long-term operational responsibility. **Sales–service integration** is coded as **partially integrated**. Sales functions play a central role in identifying rental opportunities and defining contractual terms, while service units intervene to support installation and basic operation during the rental period. However, coordination remains pragmatic and project-based, without the establishment of fully integrated or standardized

rental processes across the organization. With respect to channels, the **physical channel** is dominant, as rental delivery depends on on-site installation and equipment handling. The **digital channel** plays a marginal role, limited to internal coordination and basic communication rather than to enabling new organizational roles or service logics. From a cultural perspective, the rental offering aligns with STULZ's **engineering- and project-oriented culture**, which values technical reliability, customization in project contexts, and control over system design. At the same time, the limited institutionalization of rental indicates a **cautious cultural stance** toward access-based models, which are treated as exceptions rather than as central elements of the business model. Overall, the organization structure and culture dimension suggests that STULZ possesses the **operational capability to deliver rental solutions**, but that rental remains **organizationally peripheral and opportunistic**. The offering leverages existing structures and routines without triggering significant organizational change, reinforcing its role as a complementary XaaS configuration within the company's broader portfolio.

- **Economic and Finance**

The economic and financial configuration of STULZ's **rental** offering is grounded in a **time-based revenue logic**, in which revenues are generated through periodic payments linked to the duration of equipment use. Within the framework, the **revenue model** is coded as a **fixed-period fee**, typically associated with short- to medium-term rental contracts. The rental model allows STULZ to monetize existing cooling assets without transferring ownership, while providing customers with access to equipment without upfront capital investment. Revenues are therefore predictable at the contract level, but limited in scale and continuity due to the **episodic nature of demand**. Rental contracts are generally linked to specific projects or temporary operational needs, rather than to long-term customer relationships. From a cost structure perspective, STULZ assumes **asset-related and operational costs** associated with the rental equipment, including preparation, transportation, installation, and basic functional support during the rental period. These costs are embedded within the rental fee and must be managed carefully to preserve margin, given the limited duration of contracts and the standardized nature of the offering. The **main risk** associated with the rental configuration is coded as **asset utilization risk**. Because rental demand is intermittent, there is a risk of underutilization of rental equipment between contracts. In addition, logistical and handling activities introduce cost variability, which can affect profitability if not adequately controlled. Risk mitigation is coded as **informal and operational**, relying on pragmatic decision-making rather than on formalized financial instruments or contractual risk-sharing mechanisms. Rental equipment is typically selected from standardized product lines, allowing STULZ to redeploy assets across different customers and

contexts when demand arises. This flexibility partially mitigates utilization risk, but does not eliminate it. Profitability assessment focuses on **project-level margins**, considering rental fees relative to direct operational and logistical costs. Unlike more mature XaaS configurations, there is no portfolio-level or lifecycle-based financial optimization logic systematically applied to rental assets. The economic evaluation remains largely transactional and short-term in orientation. Overall, the economic and financial dimension highlights that STULZ's rental offering represents a **low-commitment and low-institutionalization XaaS configuration**, characterized by limited financial exposure but also constrained scalability and profitability. The model functions primarily as a tactical solution to address temporary customer needs, rather than as a strategic driver of recurring revenues.

- **Resources**

The resource base supporting STULZ's **rental** offering is centered on a **limited pool of owned cooling equipment**, which constitutes the primary physical resource of the XaaS configuration. Rental units are drawn from STULZ's standardized product portfolio and are maintained under the provider's ownership, enabling temporary deployment across different customer contexts. A key resource is represented by the **availability and redeployability of cooling assets**. Because rental demand is episodic and project-based, the ability to store, prepare, and reallocate equipment efficiently plays a central role in enabling the offering. Equipment is selected in standardized configurations to facilitate redeployment and to reduce complexity in logistics and installation. The offering relies on **basic operational and logistical resources**, including facilities for equipment storage, transportation capabilities, and installation tools. These resources support the physical movement and setup of rental units but do not constitute specialized or dedicated infrastructures developed specifically for the rental model. Digital resources play a **marginal role** in the rental configuration. Within the framework, the system is coded as **non-connected or minimally connected**, as there is no systematic use of digital monitoring, remote control, or data-driven optimization associated with rental equipment. Data exploitation is limited to internal coordination and administrative purposes, such as contract management and equipment tracking. **Customer data accessibility** is minimal. Customers interact with rental resources primarily at the physical level, focusing on equipment availability and basic functionality. There is no structured exchange of operational data or shared monitoring of equipment performance within the rental configuration. Human resources constitute an important supporting element, particularly in terms of **technical and operational personnel** responsible for equipment preparation, installation, and basic functional support. However, these capabilities are embedded within existing organizational roles and are not dedicated exclusively to the rental offering. Overall, the resource dimension highlights that STULZ's

rental offering is **resource-light in terms of digital and analytical assets**, while being dependent on the effective management of physical equipment and basic logistical infrastructures. Value creation is enabled through the availability and redeployment of standardized cooling units rather than through advanced technological or data-driven resources.

- **Capabilities**

The capability base underpinning STULZ's **rental** offering is primarily oriented toward **operational execution and asset handling**, rather than toward advanced service orchestration or data-driven optimization. Within the framework, capabilities are mainly coded as **managerial and operational skills**, reflecting the tactical and situational nature of the rental model. A core capability lies in STULZ's ability to **prepare, deploy, and retrieve cooling equipment efficiently**. This includes selecting appropriate standardized units, coordinating logistics, and ensuring that equipment can be installed and made operational within short timeframes. These capabilities are critical for responding to temporary customer needs and for minimizing downtime between rental deployments. Another relevant capability concerns **basic asset management and redeployment**. Although rental does not rely on sophisticated lifecycle optimization, STULZ demonstrates the ability to manage the physical condition of rental units, assess their suitability for subsequent use, and reassign them across different projects. This capability supports flexibility but remains limited in scale and formalization. The offering also relies on **coordination capabilities across internal functions**, particularly between sales, project management, and service units. Rental opportunities are identified through sales interactions, while execution depends on pragmatic coordination among operational teams. These interactions are largely informal and project-based, rather than governed by standardized cross-functional processes. From a commercial perspective, STULZ possesses the capability to **frame rental as a temporary solution** within project-oriented discussions. Sales personnel are able to position rental appropriately for customers facing short-term uncertainty or transitional needs, without presenting it as a substitute for long-term ownership or performance-based models. By contrast, **advanced capabilities related to digital monitoring, predictive maintenance, or performance optimization are absent**. Rental does not require STULZ to develop new analytical or service design competencies, and execution relies largely on existing technical know-how and project management skills. Overall, the capability dimension highlights that STULZ's rental offering is supported by **execution-focused and low-complexity capabilities**, sufficient to enable rapid deployment and retrieval of equipment but not designed to sustain scalable, recurring, or outcome-oriented XaaS models. These capabilities reinforce the characterization of rental as an **opportunistic and complementary configuration** within STULZ's broader XaaS portfolio.

- **Environmental Sustainability**

Environmental sustainability in STULZ's **rental** offering emerges as an **implicit and secondary effect** of the access-based configuration, rather than as an explicit objective of the business model. Within the framework, sustainability outcomes are not articulated as part of the value proposition, but arise indirectly from the temporary use and redeployment of cooling equipment. A first sustainability-related mechanism concerns the **shared use of physical assets**. By providing cooling units under rental contracts, STULZ enables the same equipment to be deployed sequentially across different customers and projects. This shared-use logic can reduce the need for customers to purchase dedicated equipment for short-term or uncertain needs, potentially limiting the production of additional assets that would otherwise be underutilized. However, the rental model does not entail **systematic lifecycle optimization** from an environmental perspective. Equipment redeployment is driven primarily by availability and project needs, rather than by explicit environmental performance criteria. There is no evidence of structured remanufacturing, refurbishment strategies, or environmental assessment embedded specifically within the rental configuration. Energy efficiency and operational performance of the cooling units are inherent product characteristics, but they are **not actively managed or optimized** as part of the rental offering. Customers are responsible for how the equipment is operated within their infrastructure, and STULZ does not assume responsibility for monitoring or improving energy consumption during the rental period. The rental offering does not include **environmental metrics, reporting, or sustainability-related KPIs** communicated to customers. Environmental benefits are therefore neither measured nor contractually addressed. Sustainability effects remain contingent on customer usage patterns and on the inherent efficiency of the equipment, rather than on provider-driven initiatives. Overall, environmental sustainability in STULZ's rental offering can be characterized as **incidental and limited**. While the access-based model may contribute to reduced asset duplication in temporary-use scenarios, sustainability is not strategically embedded in the design or governance of the offering. The rental configuration remains primarily oriented toward flexibility and short-term access, with environmental considerations playing a marginal and indirect role.

DIMENSIONS	VARIABLES	CODING
Value proposition	Offer object	Product
Value proposition	Maturity Level of the Service Offering	Pilot
Value proposition	Coverage of the Offering	Specific product type
Value proposition	XaaS Offering Approach	proactive
Value proposition	Ownership	Offer Provider
Value proposition	Value for the customers	guarantee of functionality
Value proposition	Offer costumization (level)	Configurable offer

Value proposition	Offer Customization (object)	Service
Value proposition	Offer communication	Integration into existing channels
Customers	Traget Customer segments	No distinction
Customers	Customer segmentation strategy	Segment-Oriented
Customers	Customer acceptance	High interest
Customers	Customer involvement	Passive
Ecosystem	Presence of strategic partners	Service delivery
Ecosystem	Continuity of strategic partners' engagement	Service delivery_delivery
Ecosystem	Alliance governance	Service delivery_collaborative
Organization structure and culture	Level of commitment of the top management of the provider	Widespread and strategic commitment
Organization structure and culture	Internal organization	New, dedicated business unit or team
Organization structure and culture	Service strategy	Fully integrated / Strategically driven
Organization structure and culture	Sales–Service Integration level	Partially integrated
Organization structure and culture	Physical distribution channel	Disintermediated
Organization structure and culture	Digital Distribution channel	Absent
Economic and finance	Revenue model and mechanism	Fixed period / subscription (payment per period)
Economic and finance	Main Risk	Financial risk
Economic and finance	Main Risk	Operational risk
Economic and finance	Risk mitigation strategy	Formalized risk management model
Economic and finance	Risk mitigation mechanisms	Contractual clauses
Economic and finance	Risk mitigation mechanisms	Customer and/or portfolio diversification
Economic and finance	Risk mitigation mechanisms	Maintenance or monitoring programs
Economic and finance	Profitability Measurement KPI	financial economics KPI
Economic and finance	Profitability Measurement KPI	operational performance KPI
Economic and finance	Profitability Measurement KPI	life cycle KPI
Resources	Data connectivity	Partially connected system
Resources	Data Exploitation	Basic operational data
Resources	Customer Data accessibility	No specific data
Resources	Technology role	Real-time monitoring and/or analysis
Capabilities	Data-analysis capabilities	Basic
Capabilities	service design capabilities	Continuous innovation:
Capabilities	Risk assessment capabilities	Base risk control
Capabilities	Human and relational capabilities	Hybrid selling & distribution skills

Environmental sustainability	End-of-life and reverse logistics strategies	End-of-life/contract product collection
Environmental sustainability	Product-life extension strategy	development of a durable product
Environmental sustainability	Resource efficiency	Measurements and optimization of resource, consumption (energy, materials..)
Environmental sustainability	Product service substitution	No substitution
Environmental sustainability	Dematerialization and transparency	Digital platforms supporting traceability and reporting
Environmental sustainability	Use and service intensity	Optimization of asset use (maximized uptime, performance-based logic)

Table 52 Stulz Rental coding results

Stulz CaaS XaaS Offering Overview

The Cooling-as-a-Service (CaaS) offering developed by STULZ represents a performance- and availability-oriented XaaS configuration, in which customers access cooling functionality without owning or directly managing the cooling equipment. In this model, value is not tied to the provision of physical assets as such, but to the delivery of cooling capacity and system availability over the contractual period. Under the CaaS configuration, STULZ retains ownership of the cooling systems and assumes responsibility for their operation, monitoring, and functional performance. Customers are relieved from upfront capital investment and from direct involvement in the technical management of cooling infrastructure. Instead, they pay for the availability or usage of cooling services according to predefined contractual terms. Operationally, the CaaS offering is based on custom-designed cooling solutions, tailored to the specific requirements of the customer's application. Unlike the rental model, which relies on standardized equipment configurations, CaaS solutions are engineered to meet defined cooling needs and are integrated into the customer's operational environment. This implies a higher level of technical customization and system integration. The contractual structure of CaaS reflects a shift in risk allocation. STULZ assumes a broader range of operational risks, including system performance, availability, and reliability. Customers benefit from predictable operating costs and from the transfer of technical and operational responsibility to the provider. However, the offering does not extend to full outcome guarantees beyond the defined scope of cooling availability and functionality. Digital technologies play a supporting role in enabling the CaaS model. Monitoring and control systems are used to oversee system performance and to support operational management. Data collected from the cooling systems enable STULZ to manage service delivery and ensure compliance with contractual conditions,

although the offering does not rely on advanced autonomous optimization or fully data-driven service automation. The CaaS configuration is positioned as a long-term solution, suited to customers with stable and mission-critical cooling requirements. It is not designed for temporary or transitional use, but rather for contexts where continuous cooling performance is essential and where customers seek to externalize both investment and operational complexity. Overall, STULZ's Cooling-as-a-Service offering can be characterized as a solution-based XaaS configuration, in which value is created through guaranteed access to cooling functionality and provider-managed system operation. Compared to rental, CaaS represents a deeper form of servitization, involving higher customization, greater provider responsibility, and a more pronounced shift from product access to service performance.

Stulz CaaS framework-based analysis

- **Value proposition**

The value proposition of STULZ's **Cooling-as-a-Service (CaaS)** offering is centered on providing customers with **guaranteed access to cooling functionality and system availability**, while shifting investment and operational responsibilities to the provider. Within the framework, the **object of the offering** is coded as a **product-based integrated solution**, as physical cooling systems remain central to value creation but are embedded within a service and performance-oriented contractual logic. The **maturity level** of the CaaS offering is coded as **pilot**, reflecting its limited diffusion and selective application. The model is not positioned as a standardized alternative to product sales, but as an advanced configuration proposed in specific contexts where customers seek to externalize both capital expenditure and operational complexity associated with cooling infrastructure. In terms of **coverage**, the offering applies to **specific applications and customer contexts**, typically characterized by mission-critical cooling needs and long-term operational stability. The **approach** is **proactive**, as CaaS is proposed by STULZ as a strategic solution when customers express interest in outcome-oriented or service-based access to cooling, rather than being triggered by short-term or emergency requirements. **Ownership** of the cooling systems is retained by the **provider**, and this element is central to the value proposition. By maintaining ownership, STULZ assumes responsibility for system operation, availability, and basic performance over the contract duration. Customers benefit from avoiding upfront investment and from transferring technical and operational risks related to cooling system management. Customer value is articulated primarily in terms of **risk transfer, cost predictability, and operational focus**. The CaaS model enables customers to convert capital expenditure into operating expenditure and to rely on a single provider for cooling functionality. This allows customers to focus on their core activities while reducing uncertainty related to system

performance and lifecycle management. The offering involves a **high degree of customization**, as CaaS solutions are engineered to meet specific cooling requirements and integrated into the customer's operational environment. Customization occurs at the system design and configuration level rather than through flexible contractual options. **Offer communication** is therefore highly consultative and project-based, relying on technical and engineering discussions rather than standardized commercial messaging. Overall, the value proposition of STULZ's Cooling-as-a-Service offering can be characterized as **performance-oriented, risk-sharing, and solution-based**. Compared to rental, CaaS represents a more advanced XaaS configuration, involving deeper provider responsibility, stronger customer lock-in, and a clearer shift from product access toward service-mediated functionality.

- **Customers**

The customer dimension of STULZ's **Cooling-as-a-Service (CaaS)** offering reflects a **highly selective and relationship-intensive targeting logic**, consistent with the complexity and long-term nature of the model. Within the framework, **target customer segments** are coded as **specific customers**, as CaaS is not intended for broad market adoption but is proposed to a limited set of customers with well-defined characteristics. Customer selection is driven primarily by **application criticality and operational stability**. The CaaS model targets customers operating mission-critical environments where continuous cooling availability is essential and where downtime entails significant operational or economic consequences. These customers typically exhibit stable and predictable cooling demand over long time horizons, making them suitable for long-term, service-based contractual arrangements. The **segmentation strategy** is coded as **highly selective**, reflecting the need for alignment between customer requirements, technical feasibility, and risk allocation. Not all customers are considered suitable for CaaS, as the model requires a high degree of trust, long-term commitment, and willingness to externalize operational responsibility for cooling systems. Customer **acceptance** is coded as **moderate to high**, albeit limited to a small subset of potential adopters. Interview and codification material indicate that customers who are selected for CaaS tend to recognize the value of transferring investment and operational risk to the provider. However, adoption remains constrained by organizational readiness, contractual complexity, and the strategic importance of cooling infrastructure within the customer's operations. Customer **involvement** is coded as **collaborative**. Unlike rental, CaaS requires close interaction between STULZ and the customer during the design, implementation, and operation of the solution. Customers are actively involved in defining cooling requirements, performance thresholds, and integration constraints. This collaboration is necessary to ensure that the solution aligns with operational needs and that contractual

expectations are clearly defined. Overall, the customer dimension highlights that STULZ's CaaS offering is oriented toward **a narrow and carefully selected customer base**, characterized by mission-critical cooling needs and long-term operational stability. The model relies on deep provider–customer relationships and mutual commitment, reinforcing the interpretation of CaaS as an advanced and selective XaaS configuration rather than a scalable mass-market solution.

- **Ecosystem**

The ecosystem supporting STULZ's **Cooling-as-a-Service (CaaS)** offering is characterized by a **more articulated and coordinated configuration** compared to the rental model, reflecting the higher complexity, customization, and risk-sharing embedded in CaaS. Within the framework, the presence of strategic partners is coded as **moderate**, as value creation extends beyond internal execution and requires interaction with multiple actors across the system lifecycle. A central role in the ecosystem is played by **internal engineering, service, and operations units**, which jointly contribute to system design, implementation, and ongoing operation. These units are responsible for ensuring that cooling solutions meet contractual availability and performance requirements over time. Their interaction is continuous rather than episodic, as CaaS contracts span long durations and require sustained coordination. External actors may be involved in the ecosystem to support **installation, integration, and operational continuity**. These include infrastructure partners, installation contractors, and, where relevant, technology suppliers whose components are integrated into the cooling system. However, these actors operate under STULZ's coordination and do not assume direct contractual responsibility toward the customer. Digital technologies act as **enabling elements** within the ecosystem, supporting monitoring and control of cooling systems. While technology providers contribute components and tools, they do not emerge as independent ecosystem orchestrators. Digital infrastructure is embedded within STULZ's service architecture and supports provider-led governance rather than distributed control. Partner engagement in the CaaS ecosystem is **continuous and long-term**, reflecting the duration of CaaS contracts and the ongoing responsibility assumed by STULZ. Coordination mechanisms are primarily operational and technical, focusing on maintaining system availability and resolving issues rather than on joint innovation or co-investment. **Ecosystem governance** is coded as **provider-led and centralized**. STULZ defines system architecture, service scope, contractual terms, and performance thresholds. Customers participate by providing access to their facilities and by aligning operational interfaces, while partners execute specific activities within clearly defined boundaries. Overall, the ecosystem dimension highlights that STULZ's CaaS offering is supported by a **closed but multi-actor ecosystem**, more complex than rental yet still strongly controlled by the provider. This configuration enables STULZ to manage performance risk and ensure

service continuity, while avoiding the governance complexity associated with open or platform-based ecosystems.

- **Organization structure and Culture**

The organizational configuration supporting STULZ's **Cooling-as-a-Service (CaaS)** offering reflects a **higher degree of organizational engagement and coordination** compared to the rental model, consistent with the increased complexity and long-term commitment of CaaS contracts. Within the framework, **top management commitment** is coded as **selective but growing**, indicating that CaaS is recognized as strategically relevant, although not yet fully institutionalized as a core business model. The **internal organization** underpinning CaaS relies on **cross-functional coordination** rather than on a fully autonomous business unit. Engineering, service, operations, and commercial functions collaborate closely to design, implement, and manage CaaS solutions. This cross-functional setup reflects the integrated nature of the offering, in which technical design, service delivery, and contractual management are tightly interdependent. The **service strategy** associated with CaaS is coded as **advanced and integrative**. Unlike rental, CaaS requires STULZ to assume ongoing responsibility for system availability and operational performance. Service activities are therefore central to value creation and are embedded throughout the entire lifecycle of the offering, from design and installation to operation and monitoring. **Sales–service integration** is coded as **high**. CaaS solutions are developed through consultative sales processes involving technical experts and service personnel from early stages. Commercial discussions are closely linked to technical feasibility assessments and service capability considerations, reflecting the need to align contractual commitments with operational realities. Regarding channels, the **physical channel** remains essential, as CaaS solutions require on-site system integration and continuous operational presence. At the same time, the **digital channel** plays a more prominent role than in rental, supporting monitoring, coordination, and operational control. However, digitalization remains an enabler rather than a driver of organizational transformation. From a cultural perspective, CaaS challenges STULZ's traditional **product- and project-oriented culture** by introducing a longer-term, service-centric logic that emphasizes availability, reliability, and risk management over discrete project delivery. The selective institutionalization of CaaS suggests an organization in transition, experimenting with deeper servitization while maintaining strong ties to its engineering heritage. Overall, the organization structure and culture dimension indicates that STULZ is developing the **organizational foundations necessary to support advanced XaaS configurations**, while CaaS remains partially embedded and selectively applied. The offering leverages existing competencies but requires ongoing organizational adaptation to sustain long-term performance-based service delivery.

- **Economic and Finance**

The economic and financial configuration of STULZ's **Cooling-as-a-Service (CaaS)** offering is grounded in a **service- and performance-oriented revenue logic**, which differs substantially from both traditional product sales and time-based rental models. Within the framework, the **revenue model** is coded as **availability- or usage-based**, with customer payments linked to the provision of cooling functionality over the contractual period rather than to asset ownership. CaaS enables customers to convert **capital expenditure into operating expenditure**, as investments in cooling infrastructure are borne by the provider. Revenues for STULZ are generated through **recurring payments** over long-term contracts, reflecting the duration and mission-critical nature of the service. This structure supports revenue predictability at the contract level but requires long-term financial commitment from the provider. The **cost structure** of the CaaS offering is characterized by **high upfront and ongoing costs**, including system design, equipment procurement, installation, monitoring, and operational management. STULZ retains ownership of the assets and assumes responsibility for ensuring system availability and functionality, which increases exposure to operational and technical costs over the contract lifecycle. The **main risks** associated with the CaaS model are coded as **performance and operational risks**. STULZ bears the risk of system underperformance, unexpected operational issues, and cost overruns related to maintenance and system operation. In addition, demand risk is present due to the selective and limited customer base suitable for CaaS solutions. Risk mitigation is coded as **formalized**, reflecting the importance of contractual safeguards and careful project selection. Contracts define service scope, availability thresholds, and responsibilities in detail, while technical feasibility assessments are conducted prior to contract commitment. These mechanisms aim to align economic outcomes with operational capabilities. Profitability assessment in CaaS requires a **lifecycle-oriented perspective**, as financial performance depends on balancing long-term revenues against cumulative costs over the contract duration. Unlike rental, economic evaluation extends beyond project-level margins and requires consideration of asset utilization, operational efficiency, and contract duration. Overall, the economic and financial dimension highlights that STULZ's CaaS offering represents a **capital-intensive and risk-bearing XaaS configuration**, with the potential for stable long-term revenues but also increased exposure to performance and operational uncertainties. Compared to rental, CaaS entails a deeper financial commitment and a more pronounced shift toward service-dominated value creation.

- **Resources**

The resource base supporting STULZ's **Cooling-as-a-Service (CaaS)** offering is **broader and more complex** than that of the rental model, reflecting the long-term, performance-oriented nature of the

configuration. Value creation relies on a combination of **physical, digital, and organizational resources**, all retained and coordinated by the provider. A central resource is represented by the **cooling systems owned by STULZ**, which are specifically designed and engineered for CaaS projects. Unlike rental assets, these systems are not standardized units intended for redeployment, but are **custom-configured solutions** tailored to the customer's cooling requirements and operational environment. Asset ownership remains with STULZ throughout the contract duration, making physical infrastructure a strategic and long-term resource. Digital resources play a **significantly more relevant role** compared to rental. Within the framework, the system is coded as **connected**, as monitoring and control technologies are used to oversee system operation and availability. Data collected from the cooling systems support operational management and compliance with contractual service levels. However, data exploitation remains primarily operational and control-oriented rather than predictive or autonomous. The offering relies on **service infrastructures and tools** that enable continuous operation and intervention. These include monitoring platforms, control interfaces, and diagnostic tools used by service personnel to supervise system performance and respond to issues. These resources are embedded within STULZ's service organization and are essential for sustaining availability commitments. Human resources constitute a critical enabling element. **Highly skilled engineers, service technicians, and operations personnel** are required to design, operate, and manage CaaS solutions over time. Their expertise spans system engineering, operational management, and service coordination, and represents a key intangible resource underpinning the offering. In addition, STULZ leverages **organizational knowledge and project-specific documentation** as resources. Design specifications, operational procedures, and service protocols developed during the implementation phase are reused throughout the contract lifecycle to ensure consistency and reliability in service delivery. Overall, the resource dimension highlights that STULZ's CaaS offering is **resource-intensive and provider-centric**, relying on owned physical assets, connected digital infrastructures, and specialized human expertise. These resources enable STULZ to assume operational responsibility and performance risk, distinguishing CaaS from simpler access-based XaaS configurations such as rental.

- **Capabilities**

The capability base underpinning STULZ's **Cooling-as-a-Service (CaaS)** offering reflects a **significant shift toward advanced service and operational capabilities**, compared to the rental configuration. Within the framework, capabilities are primarily coded as **managerial, organizational, and technical skills**, with a stronger emphasis on coordination and long-term service management. A core capability lies in STULZ's ability to **design, integrate, and operate**

customized cooling systems under service-based contractual arrangements. This includes the competence to translate customer cooling requirements into engineered solutions and to manage their operation over extended time horizons. Such capability goes beyond traditional product delivery and requires a deep understanding of both system engineering and operational contexts. Another critical capability concerns **performance and availability management**. STULZ demonstrates the ability to monitor system operation, detect deviations, and intervene to maintain contractual service levels. This capability is enabled by connected monitoring systems and supported by service personnel, allowing STULZ to assume responsibility for operational continuity. The CaaS model also relies on strong **risk management capabilities**. Because STULZ bears operational and performance risks, the company must be able to assess technical feasibility, anticipate potential failures, and manage contingencies throughout the contract lifecycle. These capabilities are embedded in project selection, system design, and ongoing operational oversight. Cross-functional coordination represents another key capability. STULZ must integrate inputs from engineering, service, operations, and commercial functions to ensure that contractual commitments are aligned with technical and organizational capacities. This coordination capability is more structured and continuous than in the rental model, reflecting the long-term nature of CaaS contracts. By contrast, **advanced analytical and predictive capabilities remain limited**. While monitoring data are used to support operational control, there is no evidence of fully automated optimization or outcome-based analytics driving service delivery. Capabilities remain predominantly human-centered and operational rather than data-driven. Overall, the capability dimension highlights that STULZ's CaaS offering is supported by **advanced execution and coordination capabilities**, enabling the provider to manage customized, long-term, and risk-bearing service contracts. These capabilities distinguish CaaS as a more mature and demanding XaaS configuration compared to rental, even though its diffusion remains selective.

- **Environmental Sustainability**

Environmental sustainability in STULZ's **Cooling-as-a-Service (CaaS)** offering is **structurally embedded** in the service configuration, emerging as a consequence of the provider's responsibility for system operation, availability, and lifecycle management. Within the framework, sustainability is not positioned as a standalone value proposition, but as an integral outcome of the CaaS logic. A key sustainability mechanism lies in the **provider's ownership and operational responsibility** for the cooling systems. By retaining ownership, STULZ is incentivized to design, operate, and manage systems with a long-term perspective, prioritizing reliability, durability, and efficient operation over the contract duration. This lifecycle-oriented responsibility contrasts with rental and traditional sales models, where sustainability outcomes depend more heavily on customer behavior. The CaaS model

supports **optimized use of cooling capacity**, as systems are engineered and operated according to actual customer needs rather than oversized to account for uncertainty. Continuous monitoring and operational control enable STULZ to maintain systems within defined performance ranges, reducing inefficiencies related to improper operation or suboptimal load management. Energy efficiency is addressed **indirectly through system design and operational management**, rather than through explicit contractual environmental targets. While cooling units inherently reflect STULZ's technological standards for efficiency, sustainability benefits arise from the provider's ability to manage system performance over time, rather than from customer-driven optimization initiatives. The model also enables **extended asset lifetimes**, as STULZ remains responsible for maintaining system functionality throughout the contract. Preventive interventions and operational oversight reduce premature degradation and support more efficient use of resources over the lifecycle of the cooling infrastructure. However, the CaaS offering does not include **explicit environmental KPIs, reporting mechanisms, or sustainability guarantees** communicated to customers. Environmental performance is not monetized nor contractually enforced, and sustainability outcomes remain an implicit consequence of the service configuration rather than an explicit objective. Overall, environmental sustainability in STULZ's CaaS offering can be characterized as **lifecycle-driven and structurally enabled**. The transfer of ownership and operational responsibility to the provider creates conditions for more efficient resource use and system longevity, positioning CaaS as a more sustainability-supportive XaaS configuration compared to rental, even in the absence of explicit environmental commitments.

DIMENSIONS	VARIABLES	CODING
Value proposition	Offer object	Product
Value proposition	Maturity Level of the Service Offering	Pilot
Value proposition	Coverage of the Offering	Specific category
Value proposition	XaaS Offering Approach	proactive
Value proposition	Ownership	Offer Provider
Value proposition	Value for the customers	guarantee of functionality
Value proposition	Offer costumization (level)	Configurable offer
Value proposition	Offer Customization (object)	Product
Value proposition	Offer Customization (object)	Service
Value proposition	Offer communication	Integration into existing channels
Customers	Traget Customer segments	No distinction
Customers	Customer segmentation strategy	Segment-Oriented
Customers	Customer acceptance	N/A
Customers	Customer involvement	Passive

Ecosystem	Presence of strategic partners	Service delivery
Ecosystem	Continuity of strategic partners' engagement	Service delivery_delivery
Ecosystem	Alliance governance	Service delivery_collaborative
Organization structure and culture	Level of commitment of the top management of the provider	Widespread and strategic commitment
Organization structure and culture	Internal organization	New, dedicated business unit or team
Organization structure and culture	Service strategy	Fully integrated / Strategically driven
Organization structure and culture	Sales–Service Integration level	Partially integrated
Organization structure and culture	Physical distribution channel	Disintermediated
Organization structure and culture	Digital Distribution channel	Absent
Economic and finance	Revenue model and mechanism	Pay-per-use
Economic and finance	Main Risk	Financial risk
Economic and finance	Main Risk	Operational risk
Economic and finance	Risk mitigation strategy	Formalized risk management model
Economic and finance	Risk mitigation mechanisms	Contractual clauses
Economic and finance	Risk mitigation mechanisms	Customer and/or portfolio diversification
Economic and finance	Risk mitigation mechanisms	Maintenance or monitoring programs
Economic and finance	Profitability Measurement KPI	financial economics KPI
Economic and finance	Profitability Measurement KPI	operational performance KPI
Economic and finance	Profitability Measurement KPI	life cycle KPI
Resources	Data connectivity	Partially connected system
Resources	Data Exploitation	Basic operational data
Resources	Customer Data accessibility	No specific data
Resources	Technology role	Real-time monitoring and/or analysis
Capabilities	Data-analysis capabilities	Basic
Capabilities	service design capabilities	Continuous innovation:
Capabilities	Risk assessment capabilities	Base risk control
Capabilities	Human and relational capabilities	Hybrid selling & distribution skills
Environmental sustainability	End-of-life and reverse logistics strategies	End-of-life/contract product collection
Environmental sustainability	Product-life extension strategy	development of a durable product
Environmental sustainability	Resource efficiency	Measurements and optimization of resource, consumption (energy, materials..)
Environmental sustainability	Product service substitution	No substitution

Environmental sustainability	Dematerialization and transparency	Digital platforms supporting traceability and reporting
Environmental sustainability	Use and service intensity	Optimization of asset use (maximized uptime, performance-based logic)
Environmental sustainability	Use and service intensity	Inclusion of second-hand products in the aaS offering

Table 53 Stulz CaaS coding results

C.11 Sandvik Coromant

Company description

Sandvik Coromant is a global leader in cutting tools and machining solutions for metalworking industries. Headquartered in Sweden, the company operates as part of the Sandvik Group and serves customers worldwide across sectors such as automotive, aerospace, general engineering, energy, and mold and die manufacturing. Its core business revolves around the design, production, and supply of advanced cutting tools, including turning, milling, drilling, and tooling systems used in high-precision manufacturing processes. Beyond product manufacturing, Sandvik Coromant has progressively evolved toward a **solution-oriented and knowledge-intensive positioning**, strongly emphasizing productivity improvement, process optimization, and customer partnership. Over several decades, the company has developed extensive expertise in machining theory, application engineering, and production optimization, which complements its physical product portfolio. This expertise is leveraged through technical support, application engineering services, training programs, and digital solutions. A distinctive feature of Sandvik Coromant's business model is its **deep integration into customers' production processes**. Rather than acting solely as a component supplier, the company positions itself as a long-term partner supporting customers in optimizing cost per component, process stability, and overall manufacturing efficiency. This relational orientation is particularly evident in contexts characterized by serial production, high process repeatability, and significant consumable usage, where tooling performance and logistics play a critical role. Within this broader strategic context, Sandvik Coromant has developed and experimented with **advanced XaaS-like business configurations** that go beyond traditional product sales. These configurations are built around the monetization of usage, consumption, and production outcomes rather than around discrete product transactions. In particular, the company has implemented two distinct but related models:

1. a **payment-at-withdrawal (pagamento al prelievo)** model, focused on tooling consumption managed through integrated logistics solutions;
2. a **pay-per-part** model, in which remuneration is linked to the number of components produced, embedding tooling, logistics, and selected services into a per-piece pricing logic.

These two configurations represent **two separate units of analysis** within the proposed framework, as they differ in terms of pricing logic, risk allocation, service intensity, and degree of integration with customer processes, while sharing a common organizational and technological foundation.

Sandvik Coromant payment-at-withdrawal XaaS Offering Overview

The **pay-on-withdrawal** model developed by Sandvik Coromant is a usage-based offering focused on the **management and monetization of cutting tool consumption**, rather than on the provision of tools as discrete products. In this configuration, customers do not purchase tools through traditional order-based transactions; instead, they access tooling through an integrated withdrawal system and are invoiced **only when tools are physically withdrawn and used** in production. Operationally, the offering is built around **automated or semi-automated tool management systems** installed at the customer's production site. These systems allow operators to withdraw cutting tools as needed for manufacturing activities, while simultaneously recording withdrawals and enabling Sandvik Coromant to track consumption. Billing is therefore directly linked to actual usage events rather than to forecasted demand or stock replenishment orders. From the interview material, it emerges that the primary objective of this model is to **simplify procurement and inventory management** for customers while increasing transparency and control over tooling consumption. The offering reduces the need for internal purchase orders, manual stock checks, and safety stock buffers, shifting responsibility for availability and replenishment to the provider. Sandvik Coromant assumes responsibility for ensuring that the required tools are available at the point of use, while customers focus on production execution. The **pay-on-withdrawal** configuration does not imply a radical transformation of ownership structures. Cutting tools are consumables by nature, and ownership effectively transfers at the moment of withdrawal and use. However, the offering restructures **how and when value is exchanged**, replacing discrete purchase transactions with a continuous, usage-triggered payment logic. As such, the model represents a **service-enabled consumption model** rather than a full product-as-a-service substitution. The offering is described in the material as being **implemented with selected customers**, typically in industrial contexts characterized by repetitive production processes and significant tooling consumption. It is not positioned as a universal solution for all customers, but rather as a configuration that requires a certain level of process stability and organizational readiness on the customer side. Overall, the **pay-on-withdrawal** model can be characterized as a **consumption-oriented XaaS configuration**, where value is created by integrating tooling supply, consumption tracking, and billing into a single operational system. The offering leverages Sandvik Coromant's deep knowledge of tooling usage and production environments to

embed itself more closely into customers' daily operations, while preserving a relatively incremental evolution from traditional product sales.

Sandvik Coromant payment-at-withdrawal framework-based analysis

- **Value proposition**

The value proposition of Sandvik Coromant's **pay-on-withdrawal** offering is centered on providing customers with **continuous and simplified access to cutting tools**, while shifting the focus from purchasing transactions to actual consumption. Within the framework, the **object of the offering** is coded as **product**, as cutting tools remain the core element of value creation. However, the value proposition is not tied to the sale of individual tools, but to the **availability and controlled consumption** of those tools within the customer's production environment. The **maturity level** of the offering is coded as **consolidated**, reflecting the fact that the pay-on-withdrawal model has been implemented with multiple customers and is operationally stable. Interview evidence indicates that this configuration is not experimental, but rather represents an established alternative to traditional procurement models, particularly in contexts characterized by repetitive production and high tooling consumption. In terms of **coverage**, the offering is applied to a **specific product category**, namely cutting tools managed through automated or semi-automated withdrawal systems. The **approach** is **proactive**, as Sandvik Coromant actively proposes the model to customers for whom tooling logistics and inventory management represent a critical operational issue. The offering is therefore positioned as a solution to a well-defined problem rather than as a generic commercial option. **Ownership** of the tools is effectively transferred at the moment of withdrawal, which is consistent with the consumable nature of cutting tools. The value proposition does not aim to alter ownership structures, but rather to redefine **when ownership and payment occur**, aligning them with actual use. This temporal realignment of value exchange represents a central element of the offering. Customer value is articulated primarily in terms of **optimization of usage processes** and **minimization of operating costs**. By integrating tooling supply, consumption tracking, and billing into a single system, the offering reduces administrative complexity, limits stock obsolescence, and improves visibility over tooling usage. Customers benefit from reduced inventory levels, fewer procurement activities, and improved process discipline on the shop floor.The offering is characterized by **limited customization**, as the core configuration of the withdrawal system and billing logic remains standardized. Customization occurs mainly at the level of tool assortment and system configuration, rather than through tailored pricing or contractual structures. **Offer communication** is integrated into existing channels and relies on direct interaction with customers, particularly through technical and application-oriented discussions rather than marketing-driven narratives. Overall, the value

proposition of Sandvik Coromant's pay-on-withdrawal offering can be characterized as **efficiency-driven and process-embedded**, focusing on reducing complexity and improving control in tooling-intensive production environments. The as-a-service logic emerges from the continuous alignment between consumption and payment, rather than from a transformation of ownership or risk allocation.

- **Customers**

The customer dimension of Sandvik Coromant's **pay-on-withdrawal** offering reflects the **operational specificity** of the model and its strong dependence on production context characteristics. Within the framework, **target customer segments** are coded as **no distinction**, indicating that the offering is not formally limited to predefined industries or customer categories. However, empirical evidence shows that the model is practically suitable only for customers operating in **structured and repetitive production environments** with significant and predictable tooling consumption. The **segmentation strategy** is coded as **segment-oriented**, capturing the fact that Sandvik Coromant selectively proposes the pay-on-withdrawal model to customers whose organizational and operational conditions allow effective implementation. These conditions include stable production volumes, standardized machining processes, and sufficient scale to justify the installation and management of withdrawal systems. Customers with low or irregular tool usage are implicitly excluded, even in the absence of explicit segmentation criteria. Customer **acceptance** is coded as **moderate interest**. Interview material suggests that customers generally recognize the operational benefits of the model, particularly in terms of simplified procurement and reduced inventory management, but adoption is not automatic. Initial resistance may arise from the need to modify internal procedures, adapt shop-floor routines, and accept increased transparency over tooling usage. As a result, customer interest often translates into adoption only after detailed discussions and pilot implementations. Customer **involvement** is coded as **collaborative**, reflecting the necessity of close interaction between Sandvik Coromant and the customer during both implementation and ongoing operation. While the core structure of the offering is provider-defined, customers actively participate in configuring the withdrawal system, defining the tool assortment, and aligning the model with internal production and procurement processes. This collaboration is essential to ensure operational fit and to sustain the effectiveness of the pay-on-withdrawal logic over time. Overall, the customer dimension highlights that Sandvik Coromant's pay-on-withdrawal offering is **context-dependent and relationship-intensive**. The model creates value primarily for customers willing and able to integrate the provider deeply into their daily production operations, making customer readiness and organizational alignment critical preconditions for successful adoption.

- **Ecosystem**

The ecosystem supporting Sandvik Coromant's **pay-on-withdrawal** offering is characterized by a **limited but highly operationally integrated configuration**, primarily oriented toward ensuring the effective management of tooling availability and consumption at the customer's production site. Within the framework, the presence of **strategic partners** is coded as **technological**, with partner engagement focused mainly on enabling the operational infrastructure required by the model. In particular, the offering relies on **tool management and withdrawal system providers**, whose technologies enable automated or semi-automated access to cutting tools and the recording of withdrawal events. These partners provide the physical and digital infrastructure that allows Sandvik Coromant to monitor consumption and link billing directly to usage. Their role is therefore instrumental in translating the consumption-based logic into a reliable operational system.

The continuity of partner engagement is limited to the **development phase of the offering**, reflecting the need to design and configure technological solutions that are compatible with customer-specific production environments. Interaction with technological partners takes place during system design and setup, while the delivery phase relies on the finalized technological configuration without ongoing partner involvement. **Ecosystem governance** is coded as **coordinated**, indicating that Sandvik Coromant maintains a central orchestrating role. The company defines the overall service architecture, manages customer relationships, controls pricing and billing mechanisms, and integrates partner technologies into its own operational processes. Partners operate within predefined technical and operational boundaries, supporting Sandvik Coromant's value proposition without directly interfacing with customers at the commercial level. The ecosystem does not exhibit a high degree of complexity or openness. There is no evidence of financial partners or multi-actor service ecosystems specifically developed to support the pay-on-withdrawal model. Instead, the ecosystem is deliberately focused on a small number of complementary actors whose capabilities are necessary to operationalize the consumption-based logic efficiently. Overall, the ecosystem dimension underscores that Sandvik Coromant's pay-on-withdrawal offering is enabled by a **technology-centric and tightly governed ecosystem**, designed to support operational reliability and consumption tracking rather than to drive radical innovation or risk sharing. This configuration aligns with the incremental and process-oriented nature of the offering, reinforcing Sandvik Coromant's role as the primary value orchestrator.

- **Organizational structure and Culture**

The organizational configuration underlying Sandvik Coromant's **pay-on-withdrawal** offering reflects a **high degree of internal alignment with process-oriented and solution-based logics**, while remaining anchored in existing organizational structures. Within the framework, **top**

management commitment is coded as **widespread and strategic**, indicating that consumption-based and service-enabled models are recognized as legitimate and strategically relevant components of the company's broader value creation approach. The **internal organization** supporting the offering is based on **existing functions and business units**, rather than on a dedicated or autonomous XaaS unit. Responsibility for the pay-on-withdrawal model is distributed across sales, logistics, and application engineering functions, which collaborate to ensure that the offering is properly configured, implemented, and managed at customer sites. This organizational arrangement reflects Sandvik Coromant's long-standing experience in integrating products and services within customer operations, without requiring radical structural changes. The **service strategy** is coded as **fully integrated and strategically driven**, consistent with the company's positioning as a solution and productivity partner rather than a pure product supplier. The pay-on-withdrawal model is not treated as an isolated experiment, but as an extension of Sandvik Coromant's broader strategy to embed itself more deeply into customers' production processes through logistics, tooling management, and application support. **Sales–service integration** is coded as **integrated/unified**, highlighting the need for close coordination between commercial and operational functions. Sales personnel are required to understand and communicate not only product features but also process implications, while service and logistics teams play an active role in delivering the value proposition. This integration is essential to align commercial agreements with operational execution at the shop-floor level. With regard to channels, the **physical distribution channel** is **intermediated**, reflecting the involvement of logistics and tool management infrastructures at customer sites. At the same time, the **digital distribution channel** is coded as **disintermediated**, as consumption data and operational information flow directly between Sandvik Coromant's systems and the customer environment, without intermediaries in the information layer. From a cultural perspective, the pay-on-withdrawal offering aligns well with Sandvik Coromant's **process-centric and productivity-driven culture**. The organization demonstrates a strong orientation toward standardization, discipline, and continuous improvement, which are critical for managing consumption-based models. The offering reinforces a cultural shift from transactional selling toward **ongoing operational partnership**, without challenging the organization's established identity or requiring a radical change in mindset. Overall, the organizational structure and culture dimension suggests that Sandvik Coromant possesses a **high degree of organizational readiness** for the pay-on-withdrawal model. The offering leverages existing structures and cultural traits, enabling effective implementation and scaling while maintaining internal coherence and strategic consistency.

- **Economic and Finance**

The economic and financial configuration of Sandvik Coromant's **pay-on-withdrawal** offering is grounded in a **consumption-based revenue logic**, in which revenues are generated directly by tooling usage rather than by discrete sales transactions or long-term subscriptions. Within the framework, the **revenue model** is coded as **payment per use**, with billing triggered each time a cutting tool is withdrawn from the managed inventory system. This payment logic represents an incremental but significant shift from traditional procurement models. Instead of purchasing tools in advance and managing internal stocks, customers incur costs only when tools are actually used in production. For Sandvik Coromant, this enables a closer alignment between revenue generation and real consumption patterns, reducing demand volatility linked to speculative purchasing or overstocking. Pricing follows a **cost-plus logic**, in which the unit price of each withdrawal incorporates not only the cost of the cutting tool itself, but also the costs associated with logistics, inventory management, system maintenance, and service support. Interview material indicates that the economic structure of the offering is designed to ensure transparency and predictability, both for the customer and for the provider, rather than to transfer performance or outcome risks. The **main risk** associated with the pay-on-withdrawal model is coded as **operational risk**. This risk stems primarily from the provider's responsibility to ensure continuous availability of tools at the point of use. Stockouts, system malfunctions, or inaccuracies in consumption tracking could disrupt customer production and directly affect both customer satisfaction and revenue flows. By contrast, financial risk related to asset ownership or long-term capital exposure is limited, given the consumable nature of cutting tools and the immediate revenue recognition upon withdrawal. Risk mitigation relies on a **formalized risk management approach**, supported by standardized procedures, inventory policies, and system controls. The use of automated withdrawal systems reduces the likelihood of manual errors, while continuous monitoring of consumption patterns allows Sandvik Coromant to anticipate replenishment needs and adjust stock levels proactively. Profitability is assessed through a combination of **operational performance KPIs** and **financial indicators** linked to consumption volumes. Rather than focusing on contract-level profitability over long horizons, the model emphasizes stable margins per unit withdrawn and efficiency in logistics and inventory turnover. This reinforces the interpretation of pay-on-withdrawal as an economically robust and scalable model, provided that operational discipline and process reliability are maintained. Overall, the economic and financial dimension highlights that Sandvik Coromant's pay-on-withdrawal offering is **financially conservative but operationally demanding**. The model minimizes exposure to long-term financial risk while placing strong emphasis on execution quality, availability management, and process integration at the customer interface.

- **Resources**

The resource base supporting Sandvik Coromant's **pay-on-withdrawal** offering is strongly oriented toward **operational and digital infrastructures** that enable real-time control of tooling consumption at the customer site. Within the framework, the system is characterized by a **connected product configuration**, reflecting the integration of physical tooling assets with digital monitoring and management technologies. A central resource is represented by the **tool management and withdrawal systems** installed within the customer's production environment. These systems constitute the backbone of the offering, as they physically regulate access to cutting tools and digitally record each withdrawal event. The availability of accurate, real-time consumption data is essential for linking physical usage to billing and for ensuring the reliability of the pay-on-withdrawal logic.

Data exploitation is coded at an **operational level**, with consumption data primarily used to support inventory replenishment, availability management, and billing accuracy. The data generated by withdrawal systems enable Sandvik Coromant to monitor usage patterns, anticipate stock needs, and prevent disruptions caused by tool shortages. However, data are not systematically exploited for advanced analytics, predictive optimization, or outcome-based performance measurement. **Customer data accessibility** is limited and primarily functional. Customers interact with the system mainly through operational interfaces that support tool withdrawal and basic reporting. Data access is oriented toward transparency and process control rather than toward shared analytical decision-making or co-optimization of production performance. Technology plays a critical role in enabling **operational continuity and automation of logistics processes**. The integration between withdrawal systems, inventory management, and replenishment routines allows Sandvik Coromant to assume responsibility for tool availability while minimizing manual interventions. This technological infrastructure reduces administrative burden for customers and supports the scalability of the model across multiple production sites. Beyond digital resources, the offering relies heavily on **logistics and supply chain capabilities** as key resources. Efficient warehousing, replenishment planning, and physical distribution are essential to sustain the promise of continuous availability embedded in the pay-on-withdrawal model. These resources are tightly integrated with the digital layer, reinforcing the operational robustness of the offering. Overall, the resource dimension highlights that Sandvik Coromant's pay-on-withdrawal offering is **resource-intensive at the operational level**, combining connected physical assets with digital monitoring systems and logistics infrastructures. These resources enable precise consumption tracking and reliable execution, while remaining focused on operational efficiency rather than on advanced data-driven value creation.

- **Capabilities**

The capability base underpinning Sandvik Coromant's **pay-on-withdrawal** offering is characterized by a strong emphasis on **operational orchestration and process integration**, rather than on advanced analytical or outcome-based competencies. Within the framework, capabilities are primarily coded as **managerial and organizational skills**, supported by **operational data handling capabilities**. A core capability lies in Sandvik Coromant's ability to **design, implement, and manage integrated tooling consumption systems** within customer production environments. This includes configuring withdrawal systems, defining tool assortments, and aligning replenishment routines with actual usage patterns. Such capabilities require deep process knowledge and the ability to translate machining requirements into stable and repeatable operational configurations. Another critical capability concerns **logistics coordination and inventory management**. The pay-on-withdrawal model shifts responsibility for tool availability from the customer to the provider, requiring Sandvik Coromant to manage stock levels, replenishment timing, and distribution reliability with high precision. The capability to anticipate consumption trends and prevent stockouts is central to maintaining customer trust and operational continuity. The offering also relies on strong **customer integration capabilities**. Implementing pay-on-withdrawal requires close collaboration with customer teams to adapt internal procedures, train operators, and embed the system into daily shop-floor routines. Sandvik Coromant demonstrates the capability to manage these interactions and to support organizational change on the customer side, even though the core structure of the offering remains provider-defined. By contrast, **advanced data analytics and predictive capabilities remain limited**. While operational data are collected and used to support execution, there is no evidence of systematic exploitation of data for predictive optimization, dynamic pricing, or outcome-based contracting. Data serve primarily as an enabler of process discipline and transparency rather than as a strategic resource driving new forms of value creation. From a commercial perspective, the pay-on-withdrawal model requires the capability to **shift the sales narrative** from product transactions to process efficiency and consumption control. Sales and technical personnel must articulate value in terms of reduced complexity, improved availability, and operational stability, rather than unit prices or tool specifications. This capability builds on Sandvik Coromant's long-standing solution-oriented approach and application engineering expertise. Overall, the capability dimension indicates that Sandvik Coromant's pay-on-withdrawal offering is supported by **strong execution-oriented capabilities**, particularly in logistics, process integration, and customer coordination. These capabilities enable reliable delivery and scalability of the model, while the limited development of advanced analytical capabilities constrains the evolution toward more outcome-oriented or performance-based XaaS configurations.

- **Environmental Sustainability**

Environmental sustainability within Sandvik Coromant's **pay-on-withdrawal** offering emerges as an **implicit and process-driven outcome**, rather than as an explicitly articulated objective of the business model. The offering does not introduce sustainability as a primary value driver, but embeds environmentally relevant effects through the reorganization of tooling consumption and inventory management practices. A central sustainability mechanism relates to **improved resource efficiency**. By linking payment directly to actual tool withdrawal and use, the model discourages over-ordering and excessive stock accumulation. This contributes to reducing waste associated with obsolete, damaged, or unused cutting tools, particularly in production environments characterized by frequent tool changes and high variety. More disciplined consumption patterns translate into more efficient use of materials and embedded energy across the tooling lifecycle. The pay-on-withdrawal configuration also supports **optimization of asset use** at the consumable level. The continuous monitoring of withdrawals enables tighter control over tool usage and replenishment, reducing unnecessary replacements and encouraging more systematic use of available tools. This operational transparency fosters more efficient production routines without requiring explicit behavioral change incentives. From a lifecycle perspective, the offering does not explicitly incorporate **remanufacturing, refurbishment, or end-of-life management** as part of the contractual arrangement. Cutting tools remain consumables, and sustainability benefits derive primarily from reduced inefficiencies in procurement and usage rather than from extended product lifetimes. Similarly, there is no evidence of formal environmental reporting, sustainability KPIs, or traceability mechanisms communicated to customers as part of the offering. The model does not involve **product–service substitution** or dematerialization, as physical tools remain central to value creation. Sustainability effects are therefore incremental and operational, embedded in improved logistics and consumption discipline rather than in radical changes to production or business logic. Overall, environmental sustainability in Sandvik Coromant's pay-on-withdrawal offering can be characterized as **operationally embedded but strategically implicit**. Environmental benefits arise indirectly from enhanced control over tooling consumption and inventory management, reinforcing efficiency and waste reduction without positioning sustainability as a core element of the XaaS value proposition.

DIMENSIONS	VARIABLES	CODING
Value proposition	Offer object	Service
Value proposition	Maturity Level of the Service Offering	Consolidated
Value proposition	Coverage of the Offering	Entire product range
Value proposition	XaaS Offering Approach	Proactive
Value proposition	Ownership	Customer
Value proposition	Ownership	Offer Provider
Value proposition	Value for the customers	optimization of usage processes

Value proposition	Offer costumization (level)	Customizable offer
Value proposition	Offer Customization (object)	Service
Value proposition	Offer Customization (object)	Payment
Value proposition	Offer communication	Limited or absent communication
Customers	Traget Customer segments	No distinction
Customers	Customer segmentation strategy	Undifferentiated
Customers	Customer acceptance	Moderate interest
Customers	Customer involvement	Co-creative
Ecosystem	Presence of strategic partners	Technical
Ecosystem	Continuity of strategic partners' engagement	Technical _development
Ecosystem	Alliance governance	Technical _coordinated
Organization structure and culture	Level of commitment of the top management of the provider	Widespread and strategic commitment
Organization structure and culture	Internal organization	New, dedicated business unit or team
Organization structure and culture	Service strategy	Fully integrated / Strategically driven
Organization structure and culture	Sales–Service Integration level	Integrated / Unified
Organization structure and culture	Physical distribution channel	Intermediated
Organization structure and culture	Digital Distribution channel	Absent
Economic and finance	Revenue model and mechanism	Fixed period / subscription (payment per period)
Economic and finance	Main Risk	Financial risk
Economic and finance	Main Risk	Operational risk
Economic and finance	Risk mitigation strategy	No formal strategy
Economic and finance	Risk mitigation mechanisms	Contractual clauses
Economic and finance	Risk mitigation mechanisms	Customer and/or portfolio diversification
Economic and finance	Risk mitigation mechanisms	Third-party instruments involvements (insurers..)
Economic and finance	Profitability Measurement KPI	operational performance KPI
Economic and finance	Profitability Measurement KPI	life cycle KPI
Resources	Data connectivity	Fully connected system
Resources	Data Exploitation	Basic operational data
Resources	Data Exploitation	Performance and behavioral data
Resources	Data Exploitation	Integrated system & customer data
Resources	Customer Data accessibility	Limited/conditional access
Resources	Technology role	Functional monitoring for pricing definition

Capabilities	service design capabilities	Continuous innovation:
Environmental sustainability	End-of-life and reverse logistics strategies	End-of-life/contract product collection
Environmental sustainability	Product-life extension strategy	No structured life extension policy
Environmental sustainability	Resource efficiency	Implementation of eco-efficient design or processes
Environmental sustainability	Product service substitution	No substitution
Environmental sustainability	Dematerialization and transparency	No structured transparency or dematerialization
Environmental sustainability	Use and service intensity	Optimization of asset use (maximized uptime, performance-based logic)

Table 54 Sandvik Coromant payment-at-withdrawal coding results

Sandvik Coromant pay-per-part XaaS Offering Overview

The **pay-per-part** offering developed by Sandvik Coromant represents a more advanced form of usage-based monetization, in which remuneration is directly linked to the **number of components produced** by the customer rather than to the consumption or withdrawal of individual cutting tools. In this configuration, value is not exchanged at the level of the tool, but at the level of the **manufactured output**, integrating tooling, logistics, and selected service elements into a single per-piece pricing logic. Operationally, the offering is designed to align Sandvik Coromant's revenues with the customer's production volumes. Instead of purchasing tools or paying upon withdrawal, customers are invoiced based on the number of finished parts produced using Sandvik Coromant tooling solutions. This requires a close integration between the provider's tooling systems and the customer's production processes, as well as reliable mechanisms to track output volumes attributable to the agreement. Interview material highlights that the pay-per-part model goes beyond simplifying procurement or inventory management. Its primary objective is to **shift the commercial focus from tools to productivity**, making tooling costs predictable at the component level and embedding them directly into the customer's cost structure. For customers, this translates into clearer cost visibility per part produced and reduced uncertainty related to tooling performance, breakage, or variability in consumption. From a structural perspective, the pay-per-part offering does not imply that Sandvik Coromant takes ownership of the customer's production assets, nor does it fully substitute the physical product. Cutting tools remain central to value creation, but they are no longer priced or managed as standalone items. Instead, they become part of an **integrated solution**, where tooling supply, replacement, and optimization are bundled into a performance-related pricing mechanism. The material indicates that this offering is implemented in **highly structured production environments**, typically characterized by stable processes, repeatable part geometries, and consistent

production volumes. Such conditions are necessary to ensure reliable measurement of output and to manage the risks associated with variability in production performance. As a result, pay-per-part is not positioned as a broadly applicable solution, but rather as a model suitable for selected customers with a high degree of process maturity. Overall, Sandvik Coromant's pay-per-part offering can be characterized as an **output-oriented XaaS configuration**, in which value creation and monetization are directly linked to customer production results. Compared to pay-on-withdrawal, this model represents a deeper integration into the customer's manufacturing system, moving the provider closer to the customer's core operational outcomes while still preserving a strong product foundation.

Sandvik Coromant pay-per-part framework-based analysis

- **Value proposition**

The value proposition of Sandvik Coromant's **pay-per-part** offering is centered on aligning tooling-related costs with **customer production output**, thereby shifting the focus from product consumption to manufacturing performance. Within the framework, the **object of the offering** is coded as a **product-based solution**, as cutting tools remain essential to value creation but are embedded within an integrated pricing and service logic. The **maturity level** of the offering is coded as **pilot**, reflecting the selective and limited implementation of the pay-per-part model. Interview evidence indicates that this configuration is applied in specific customer contexts and has not yet been standardized or scaled across the broader customer base. The offering therefore represents an advanced but still experimental evolution of usage-based monetization. In terms of **coverage**, the pay-per-part model is applied to a **specific category** of tools and applications, typically those characterized by stable production conditions and repeatable machining processes. The **approach** is **proactive**, as Sandvik Coromant actively proposes the model to customers for whom output-based pricing can generate mutual benefits, rather than waiting for explicit customer requests. **Ownership** of the cutting tools remains with the provider until consumption, but the value proposition does not emphasize ownership transfer. Instead, value is framed around **cost predictability per produced component** and **risk reduction** related to tooling performance. By pricing tooling as a function of output, the offering reduces customer exposure to variability in tool life, breakage, or consumption rates. Customer value is articulated primarily in terms of **optimization of usage processes** and **minimization of operating costs** at the component level. The pay-per-part logic allows customers to directly associate tooling costs with each produced part, improving cost transparency and simplifying internal cost accounting. At the same time, it incentivizes the provider to optimize tool selection, usage, and replacement in order to maintain efficiency and profitability. The offering allows for **limited customization**, mainly at the level of process definition and part selection rather than through bespoke contractual structures.

Offer communication is integrated into existing technical and commercial channels and relies heavily on application engineering discussions, given the complexity and context-specific nature of the model. Overall, the value proposition of Sandvik Coromant's pay-per-part offering can be characterized as **output-oriented and risk-sharing**, representing a shift toward closer alignment between provider revenues and customer production performance, while remaining grounded in a product-based solution rather than in a fully outcome-guaranteed service model.

- **Customers**

The customer dimension of Sandvik Coromant's **pay-per-part** offering reflects the **high degree of selectivity and contextual dependency** of the model. Within the framework, **target customer segments** are coded as **no distinction**, as the offering is not formally restricted to specific industries or customer categories. However, empirical evidence clearly indicates that the pay-per-part model is applicable only in **highly structured production environments** characterized by stable processes, repeatable part geometries, and predictable production volumes. The **segmentation strategy** is coded as **segment-oriented**, capturing the fact that Sandvik Coromant actively identifies and approaches customers whose operational conditions enable reliable implementation of output-based pricing. These typically include customers engaged in serial or high-volume production, where machining parameters and tool performance can be stabilized and where production output can be accurately measured. Customers with high variability, frequent design changes, or low production predictability are implicitly excluded from this configuration. Customer **acceptance** is coded as **moderate interest**, reflecting both the attractiveness and the perceived complexity of the model. Interview material suggests that customers recognize the potential benefits of pay-per-part, particularly in terms of cost predictability and reduced exposure to tooling performance variability, but also approach the model with caution. Adoption often requires significant trust in the provider, transparency of production data, and internal alignment across procurement, production, and controlling functions. Customer **involvement** is coded as **collaborative**, and is more pronounced than in the pay-on-withdrawal configuration. The implementation of pay-per-part requires close cooperation between Sandvik Coromant and the customer to define the scope of the agreement, select relevant parts and processes, and establish reliable measurement and monitoring mechanisms. Customers actively participate in aligning the model with their production routines, making collaboration a prerequisite for successful adoption. Overall, the customer dimension highlights that Sandvik Coromant's pay-per-part offering is **relationship-intensive and trust-dependent**. The model is suited to customers willing to engage in deeper operational integration and to share information about production processes and outputs.

As a result, customer readiness and organizational maturity play a critical role in determining both the feasibility and the effectiveness of the pay-per-part configuration.

- **Ecosystem**

The ecosystem supporting Sandvik Coromant's **pay-per-part** offering is more **complex and tightly integrated** than that observed in the pay-on-withdrawal configuration, reflecting the deeper level of operational and economic interdependence between provider and customer. Within the framework, strategic partners are coded primarily as **technological**, with ecosystem engagement extending beyond tool supply to include production process integration and performance measurement. The pay-per-part model requires the presence of **technological enablers** capable of supporting accurate and reliable tracking of production output. These may include monitoring systems, interfaces with customer production data, and digital infrastructures that allow the attribution of produced parts to the contractual agreement. While the material does not describe a broad multi-actor ecosystem, it clearly indicates the need for **robust technological integration** between Sandvik Coromant's tooling solutions and the customer's manufacturing systems. Engagement with technological partners is limited to the **development phase of the offering.** During this phase, Sandvik Coromant collaborates with technology partners to define process boundaries, identify relevant parts, and establish the technical conditions under which pay-per-part pricing can be applied. Once the service is deployed, technological partners are no longer directly involved, and the delivery phase relies on the established technological setup to ensure stable production conditions and reliable output measurement over time. **Ecosystem governance** is coded as **coordinated**, with Sandvik Coromant assuming a central orchestration role. The company defines the contractual logic, pricing structure, and performance assumptions underlying the pay-per-part agreement, while technological elements are aligned to support these parameters. Customers play an active role in enabling the ecosystem by granting access to production data and by aligning internal processes, but they do not assume orchestration responsibilities. Unlike more open or platform-based XaaS ecosystems, the pay-per-part configuration remains **closed and bilateral**. There is no evidence of financial partners or third-party service providers taking on a significant role in risk sharing or value appropriation. Instead, the ecosystem is deliberately focused on minimizing complexity and maintaining control, given the higher risk exposure associated with output-linked remuneration. Overall, the ecosystem dimension highlights that Sandvik Coromant's pay-per-part offering is supported by a **technology-enabled, tightly governed ecosystem**, designed to ensure alignment between tooling performance, production output, and revenue generation. This configuration enables deeper integration with customer operations while preserving Sandvik Coromant's role as the primary value orchestrator.

- **Organization structure and Culture**

The organizational configuration underlying Sandvik Coromant's **pay-per-part** offering reflects a **higher degree of organizational commitment and internal integration** compared to the pay-on-withdrawal model, while still operating within the company's established structural boundaries. Within the framework, **top management commitment** is coded as **widespread and strategic**, indicating that output-based pricing models are recognized as strategically relevant and aligned with Sandvik Coromant's long-term ambition to move toward solution- and performance-oriented value creation. The **internal organization** supporting the pay-per-part model is based on **existing functions and business units**, but requires significantly stronger cross-functional coordination than more traditional offerings. Sales, application engineering, production specialists, and controlling functions must work closely together to define the scope of the agreement, validate process assumptions, and ensure economic viability. This reflects the fact that pay-per-part cannot be managed as a purely commercial initiative, but requires deep technical and operational involvement from multiple organizational domains. The **service strategy** is coded as **fully integrated and strategically driven**, highlighting that pay-per-part is not treated as an isolated contractual variant, but as an advanced expression of Sandvik Coromant's broader service and solution logic. The offering aligns with the company's established cultural orientation toward productivity improvement, process optimization, and long-term customer partnerships, rather than transactional product sales. **Sales–service integration** is coded as **integrated/unified**, reflecting the necessity for close alignment between commercial and operational roles. Sales personnel are required to engage in technically informed discussions around process stability, cost per component, and production performance, while service and application engineering teams actively contribute to defining and sustaining the offering. This unified approach is critical to managing the risks associated with output-linked remuneration. With respect to channels, the **physical distribution channel** remains **intermediated**, consistent with Sandvik Coromant's logistics and tooling management infrastructure. The **digital distribution channel** is coded as **disintermediated**, as data related to production output and tooling performance flow directly between Sandvik Coromant and the customer, without intermediary actors in the information layer. This direct digital linkage is essential to sustaining the credibility of the pay-per-part logic. From a cultural perspective, the pay-per-part model resonates strongly with Sandvik Coromant's **engineering-driven and performance-oriented culture**. The organization demonstrates a willingness to assume greater responsibility for customer outcomes, provided that process conditions are sufficiently stable and controllable. At the same time, the selective and pilot nature of the offering indicates a **cautious cultural stance** toward risk exposure, favoring controlled experimentation over rapid scaling. Overall, the organization structure and culture dimension

suggests that Sandvik Coromant possesses the **organizational maturity and cultural readiness** required to support pay-per-part configurations, while deliberately limiting their diffusion to contexts where internal coordination, technical control, and economic predictability can be ensured.

- **Economic and Finance**

The economic and financial configuration of Sandvik Coromant's **pay-per-part** offering is built around an **output-based revenue logic**, in which remuneration is directly linked to the number of components produced by the customer. Within the framework, the **revenue model** is coded as **payment per output**, representing a more advanced and risk-exposed configuration compared to consumption-based models such as pay-on-withdrawal. Under this model, tooling costs are embedded into a **per-component price**, transforming what would traditionally be variable and uncertain tooling expenses into a predictable cost per produced part for the customer. This pricing logic shifts the economic focus from tool consumption to production performance, aligning Sandvik Coromant's revenues with the customer's manufacturing output rather than with tool sales volumes. The **main risk** associated with the pay-per-part configuration is coded as **operational and technological risk**. Because revenues depend on production output, Sandvik Coromant is exposed to variability in process stability, tool performance, and production conditions. Unexpected changes in machining parameters, part design, or production volumes can directly affect margins, making the economic viability of the model highly sensitive to execution quality and process control. Risk mitigation is coded as **formalized**, reflecting the presence of structured mechanisms to manage exposure. Interview material indicates that pay-per-part agreements are implemented only after careful evaluation of production processes and are limited to stable and repeatable contexts. Pricing is defined on the basis of validated process assumptions, and contracts are typically scoped to specific parts, machines, or production lines to contain uncertainty. Profitability assessment relies on **operational performance KPIs**, with particular attention to metrics such as cost per part, tool life consistency, and production stability. Rather than monitoring revenues at the level of individual tool transactions, Sandvik Coromant evaluates economic performance by comparing expected and actual outcomes at the process and component level. This reflects the deeper integration of economic logic with operational execution inherent in the pay-per-part model. Overall, the economic and financial dimension highlights that Sandvik Coromant's pay-per-part offering represents a **high-commitment XaaS configuration**, characterized by closer alignment between provider revenues and customer outcomes, but also by higher exposure to operational variability. The model prioritizes predictability and transparency for customers while requiring careful risk selection and disciplined execution on the provider side.

- **Resources**

The resource base supporting Sandvik Coromant's **pay-per-part** offering is more **articulated and strategically critical** than in the pay-on-withdrawal configuration, reflecting the deeper integration of the model into customer production processes and its direct linkage to output-based remuneration. Within the framework, the offering relies on a **connected and process-embedded resource configuration**, in which physical tooling assets are tightly coupled with digital and informational resources. A central resource is represented by the **integration between cutting tools and production process data**. In the pay-per-part model, it is essential to reliably associate tooling performance and usage with the number of components produced. This requires stable machining conditions, standardized tooling configurations, and consistent production parameters, which together function as critical enabling resources for the offering. The physical tools themselves remain indispensable, but their value is realized only in combination with process-level information. Data exploitation is oriented toward **operational and performance-related data**, supporting the calculation and validation of cost per part. Unlike simpler consumption-based models, data in this configuration are used not only to monitor usage, but also to verify production output and to ensure alignment between agreed process assumptions and actual manufacturing conditions. However, data exploitation remains focused on validation and control rather than on advanced analytics or automated optimization. **Customer data accessibility** is higher than in pay-on-withdrawal, but remains functionally bounded. Customers are required to share relevant production information to enable output tracking, while Sandvik Coromant accesses process-related data necessary to manage the agreement. Data sharing is therefore selective and purpose-driven, supporting the pay-per-part logic without evolving into a fully transparent or platform-based data ecosystem. Technology plays a critical role in enabling **measurement reliability and operational consistency**. Digital interfaces and monitoring mechanisms are necessary to ensure that produced parts can be accurately counted and attributed to the contractual scope. These technological resources are embedded within the production environment and must operate reliably over time to sustain trust in the pricing model. In addition to digital resources, the offering depends heavily on **application engineering knowledge** as an intangible but crucial resource. Deep understanding of machining processes, tool behavior, and production variability enables Sandvik Coromant to define viable pay-per-part agreements and to sustain them over time. This knowledge complements physical and digital resources and is essential to the economic viability of the model. Overall, the resource dimension highlights that Sandvik Coromant's pay-per-part offering is **resource-intensive at the process level**, combining connected tooling assets, production data, and application engineering expertise. These resources enable

alignment between tooling performance and production output, while their complexity constrains the scalability of the model to contexts characterized by high process stability and predictability.

- **Capabilities**

The capability base underpinning Sandvik Coromant's **pay-per-part** offering is characterized by a **high level of technical, organizational, and coordination capabilities**, reflecting the complexity and risk exposure inherent in output-based pricing models. Within the framework, capabilities extend beyond basic managerial skills and require the integration of **application engineering expertise, process control competencies, and cross-functional coordination**. A core capability lies in Sandvik Coromant's ability to **analyze, stabilize, and standardize machining processes**. Implementing a pay-per-part agreement requires deep understanding of tool behavior, cutting parameters, material properties, and process variability. The provider must be capable of defining machining configurations that ensure consistent tool life and predictable output, as economic performance depends directly on maintaining stable production conditions over time. Another critical capability concerns **risk assessment and selection**. Interview evidence indicates that pay-per-part is applied only in carefully selected contexts. This implies the presence of organizational routines capable of evaluating process maturity, production stability, and customer readiness before entering into output-based agreements. Such capabilities are essential to limit exposure to uncontrolled variability and to preserve margin stability. The offering also relies on strong **cross-functional coordination capabilities**. Sales, application engineering, service, and controlling functions must collaborate closely to define the economic assumptions underlying each agreement and to monitor their validity during execution. This coordination ensures that commercial commitments are aligned with technical feasibility and operational constraints. In addition, the pay-per-part model requires advanced **customer collaboration capabilities**. Compared to other configurations, Sandvik Coromant must engage customers in a deeper and more continuous interaction, involving joint definition of scope, shared monitoring of performance, and ongoing alignment of process conditions. Managing these relationships requires trust-building skills and the ability to negotiate transparency and data sharing without compromising operational autonomy. By contrast, **advanced data-analytics capabilities** remain limited. While operational and production data are essential to validate output volumes and cost per part, there is no evidence of systematic use of predictive analytics, automated optimization, or algorithm-based decision-making. Data support validation and control rather than strategic innovation. Overall, the capability dimension highlights that Sandvik Coromant's pay-per-part offering is supported by **high-intensity, execution-oriented capabilities**, particularly in application engineering, process stabilization, and organizational coordination. These capabilities

enable close alignment between tooling performance and customer output, while their complexity constrains scalability and reinforces the selective nature of the offering.

- **Environmental Sustainability**

Environmental sustainability within Sandvik Coromant's **pay-per-part** offering is embedded indirectly through the **alignment between tooling performance and production output**, rather than being articulated as an explicit objective of the business model. The offering does not frame sustainability as a primary value driver, but incorporates environmentally relevant effects through improved process efficiency and reduced inefficiencies in tooling usage. A key sustainability mechanism relates to **resource efficiency at the process level**. By linking remuneration to the number of components produced, the pay-per-part model incentivizes the provider to optimize tool selection, cutting parameters, and tool life consistency. More stable and predictable tool performance reduces premature tool replacement, breakage, and variability, contributing to more efficient use of cutting tools and associated materials over the production cycle. The model also supports **optimization of asset use** in a broader sense. Because tooling costs are embedded in a per-part price, inefficiencies such as excessive tool consumption or suboptimal process settings directly affect economic performance. This creates structural incentives for continuous process stabilization, which indirectly reduces waste, rework, and scrap. Environmental benefits therefore arise from disciplined process control rather than from explicit sustainability initiatives. Unlike models based on asset retention or reuse, the pay-per-part configuration does not explicitly include **remanufacturing, refurbishment, or end-of-life management** mechanisms. Cutting tools remain consumables, and sustainability benefits are achieved through improved utilization rather than extended product lifetimes. Similarly, there are no formal **environmental transparency mechanisms**, such as sustainability reporting or lifecycle impact metrics, integrated into the offering. The pay-per-part model does not involve **product–service substitution** or dematerialization. Physical tools remain central to value creation, and the as-a-service logic operates at the level of pricing and risk alignment rather than at the level of replacing physical products with digital or outcome-based services. Overall, environmental sustainability in Sandvik Coromant's pay-per-part offering can be characterized as **performance-driven and implicitly embedded**. Environmental improvements result from enhanced process efficiency, reduced variability, and disciplined tooling usage, rather than from explicitly designed sustainability objectives. This positions the offering as environmentally supportive through operational excellence, while sustainability remains a secondary and indirect outcome of the XaaS configuration.

DIMENSIONS	VARIABLES	CODING
Value proposition	Offer object	Product
Value proposition	Maturity Level of the Service Offering	Consolidated
Value proposition	Coverage of the Offering	Entire product range
Value proposition	XaaS Offering Approach	Proactive
Value proposition	Ownership	Offer Provider
Value proposition	Value for the customers	optimization of usage processes
Value proposition	Offer costumization (level)	Customizable offer
Value proposition	Offer Customization (object)	Service
Value proposition	Offer Customization (object)	Payment
Value proposition	Offer communication	Limited or absent communication
Customers	Traget Customer segments	No distinction
Customers	Customer segmentation strategy	Undifferentiated
Customers	Customer acceptance	Moderate interest
Customers	Customer involvement	Collaborative
Ecosystem	Presence of strategic partners	Technical
Ecosystem	Continuity of strategic partners' engagement	Technical _development
Ecosystem	Alliance governance	Technical _ coordinated
Organization structure and culture	Level of commitment of the top management of the provider	Widespread and strategic commitment
Organization structure and culture	Internal organization	New, dedicated business unit or team
Organization structure and culture	Service strategy	Fully integrated / Strategically driven
Organization structure and culture	Sales–Service Integration level	Integrated / Unified
Organization structure and culture	Physical distribution channel	intermediated
Organization structure and culture	Digital Distribution channel	Absent
Economic and finance	Revenue model and mechanism	Payment per result
Economic and finance	Main Risk	Financial risk
Economic and finance	Main Risk	Operational risk
Economic and finance	Main Risk	Data security risk
Economic and finance	Risk mitigation strategy	No formal strategy
Economic and finance	Risk mitigation mechanisms	Contractual clauses
Economic and finance	Risk mitigation mechanisms	Customer and/or portfolio diversification
Economic and finance	Risk mitigation mechanisms	Third-party instruments involvements (insurers..)
Economic and finance	Profitability Measurement KPI	operational performance KPI

Economic and finance	Profitability Measurement KPI	life cycle KPI
Resources	Data connectivity	Fully connected system
Resources	Data Exploitation	Basic operational data
Resources	Data Exploitation	Performance and behavioral data
Resources	Data Exploitation	Integrated system & customer data
Resources	Customer Data accessibility	Limited/conditional access
Resources	Technology role	Functional monitoring for pricing definition
Capabilities	service design capabilities	Continuous innovation:
Environmental sustainability	End-of-life and reverse logistics strategies	End-of-life/contract product collection
Environmental sustainability	Product-life extension strategy	No structured life extension policy
Environmental sustainability	Resource efficiency	Implementation of eco-efficient design or processes
Environmental sustainability	Product service substitution	No substitution
Environmental sustainability	Dematerialization and transparency	No structured transparency or dematerialization
Environmental sustainability	Use and service intensity	Optimization of asset use (maximized uptime, performance-based logic)

Table 55 Sandvik Coromant pay-per-part coding results

C.12 Cavanna

Company and XaaS Offering Overview

Cavanna is an Italian manufacturing company specializing in the design and production of **packaging machinery**, with a strong focus on solutions for the food and consumer goods industries. Headquartered in Italy and operating within the Emilia-Romagna industrial district, Cavanna benefits from a long-standing tradition in mechanical engineering and automation, as well as from proximity to a dense network of specialized suppliers and technological partners typical of the packaging machinery cluster. The company's core offering consists of **primary and secondary packaging machines**, including cartoners, case packers, and integrated end-of-line solutions. Cavanna's machines are typically deployed in high-speed and high-reliability production environments, where robustness, precision, and continuity of operation are critical. The company has built its market position around an engineering-driven approach, delivering solutions that are adapted to specific customer requirements in terms of product formats, production layouts, and throughput. Traditionally, Cavanna has operated according to a **product-centric and project-based business model**, in which machinery is sold to customers through conventional capital expenditure transactions. These sales are complemented by installation, commissioning, and after-sales support,

while ownership and operational responsibility for the equipment are transferred to the customer. Long-term relationships with customers are maintained primarily through technical support and service interventions rather than through continuous contractual arrangements. In response to evolving market conditions and customer expectations, Cavanna has progressively explored alternative access models aimed at increasing flexibility and reducing the financial burden associated with machinery acquisition. Within this context, the company has introduced a **rental-based offering** that allows customers to access packaging machinery without upfront investment. This initiative does not replace Cavanna's traditional sales model but complements it, addressing specific customer needs such as temporary production requirements, uncertainty in demand, or the desire to test equipment before committing to ownership. The rental configuration represents Cavanna's primary and sole XaaS-oriented initiative and constitutes the **single unit of analysis** considered in this study. Through rental, Cavanna retains ownership of the machinery and provides customers with time-based access to equipment, while maintaining a product-centered logic. As such, the rental model can be interpreted as an incremental extension of Cavanna's established business model rather than a radical shift toward advanced servitization. Overall, Cavanna represents a case of a **traditional packaging machinery manufacturer** that has selectively adopted rental as a means to enhance commercial flexibility and customer responsiveness, while preserving its core identity as an engineering- and product-focused firm. The **rental** offering developed by Cavanna is based on providing **packaging machinery under time-based contractual arrangements**, enabling customers to access equipment without acquiring ownership of the physical assets. In this configuration, Cavanna retains ownership of the machines and grants customers the right to use them for a predefined period, during which the equipment is installed and operated within the customer's production environment. The rental solution is primarily positioned as a **flexibility-oriented access model**, addressing specific operational needs rather than representing a standardized alternative to traditional machine sales. According to the interview material, rental is typically adopted in contexts characterized by **temporary production requirements**, uncertainty regarding long-term demand, or the need to introduce additional capacity without committing to capital investment. The offering is therefore activated in response to clearly defined customer situations. From an operational perspective, the rental offering relies on **existing machinery configurations** from Cavanna's product portfolio. The equipment made available through rental is not conceived as a distinct product line, but as part of the company's standard technological base. Customization is limited and primarily concerns compatibility with the customer's production layout and operational constraints, rather than bespoke system redesign. Service activities associated with the rental offering are aimed at ensuring the **basic functionality and operability of the machinery** over the rental period. Cavanna remains responsible

for the condition of the rented equipment, while customers focus on operating the machines within their production processes. The rental configuration does not extend to performance-based guarantees or outcome-oriented commitments beyond the availability of functioning equipment. Contractually, the rental offering is structured around **time-based agreements**, with fees linked to the duration of equipment use. The contractual arrangement allows customers to avoid upfront capital expenditure and to align machinery costs with operational timelines. At the same time, Cavanna preserves the option to recover, redeploy, or reintegrate the machinery into its asset base at the end of the rental period. The rental model is clearly distinguished from more advanced XaaS configurations. The **object of the offering** remains the **physical packaging machine**, accessed temporarily rather than transformed into a performance- or output-based service. Risk transfer is therefore limited, with Cavanna primarily bearing asset-related responsibility, while customers remain responsible for production outcomes. Overall, Cavanna's rental offering can be characterized as a **product-based XaaS configuration with limited service integration**, designed to enhance commercial flexibility and respond to specific customer needs without altering the company's fundamentally product-centric business model.

Cavanna framework-based analysis

- **Value proposition**

The value proposition of Cavanna's **rental** offering is centered on providing customers with **temporary access to packaging machinery**, enabling them to deploy production capacity without committing to upfront capital investment. Within the framework, the **object of the offering** is coded as a **product-based solution**, as value creation remains anchored in the use of physical packaging machines made available through time-based contracts. The **maturity level** of the rental offering is coded as **pilot**, reflecting its selective and situational adoption. Rental does not represent a standardized or widely institutionalized alternative to traditional machine sales, but rather a complementary solution activated in specific customer contexts. Its role within Cavanna's portfolio is therefore supportive rather than strategic. In terms of **coverage**, the offering applies to **specific machines and applications**, selected from the company's existing product portfolio. The **approach** is predominantly **reactive**, as rental solutions are proposed in response to explicit customer needs related to temporary production requirements, demand uncertainty, or the desire to postpone investment decisions, rather than being proactively promoted as a default access model. **Ownership** of the machinery is retained by the **provider**, and this element is central to the value proposition. By maintaining ownership, Cavanna enables customers to use packaging equipment without bearing depreciation or long-term asset commitment, while preserving its ability to recover and redeploy

machines after the rental period. Customer value is articulated primarily in terms of **financial flexibility and risk reduction**. Rental allows customers to align machinery costs with operational timelines, reducing financial exposure in contexts characterized by uncertainty or short-term demand. The offering also supports **operational experimentation**, enabling customers to test machinery or production configurations before committing to ownership. The rental offering is characterized by **limited customization**. While basic adaptation is possible to ensure integration with the customer's production environment, the contractual and technical structure of the offering remains largely standardized. **Offer communication** occurs within project-oriented commercial discussions rather than through dedicated rental channels, reinforcing the situational nature of the model. Overall, the value proposition of Cavanna's rental offering can be characterized as **access-oriented and flexibility-driven**, providing customers with a low-commitment solution to address temporary production needs, while allowing Cavanna to extend its traditional product-centric model without engaging in deeper forms of servitization.

- **Customers**

The customer dimension of Cavanna's **rental** offering reflects the **situational and non-systematic nature** of this access model within the company's business portfolio. Within the framework, **target customer segments** are coded as **no distinction**, as rental is not designed for a specific industry, firm size, or customer category. Instead, adoption is driven by contextual operational needs rather than by stable customer characteristics. The **segmentation strategy** is coded as **ad hoc and opportunity-driven**. Rental is proposed selectively in response to specific customer situations, such as temporary production increases, uncertainty regarding future demand, or the need to introduce additional capacity without committing to a full capital investment. Customers engaging with the rental model therefore do not form a homogeneous or recurring segment, but are identified on a case-by-case basis. Customer **acceptance** is coded as **moderate**. Interview material indicates that customers perceive rental as a useful and pragmatic solution in particular circumstances, but not as a preferred or permanent alternative to machine ownership. Rental is typically considered a temporary option, aligned with short- to medium-term operational needs rather than with long-term production strategies. Customer **involvement** is coded as **passive**. The rental offering is largely defined by Cavanna, with customers selecting among predefined options rather than actively participating in the design of the service configuration. Interaction between provider and customer focuses on defining rental duration, basic technical compatibility, and installation requirements, rather than on co-design or collaborative development of the offering. Overall, the customer dimension highlights that Cavanna's rental offering targets **customers facing temporary uncertainty or exceptional**

operational conditions, rather than those seeking a structural shift in how packaging machinery is accessed or managed. Rental functions as a complementary solution activated in specific contexts, reinforcing its role as a flexible but peripheral XaaS configuration within Cavanna's predominantly product-centric business model.

- **Ecosystem**

The ecosystem supporting Cavanna's **rental** offering is characterized by a **simple, provider-centric, and operationally focused configuration**, consistent with the temporary and non-standardized nature of the model. Within the framework, the presence of strategic partners is coded as **low**, as value creation and delivery are largely controlled internally by Cavanna. The core actors of the ecosystem are Cavanna's **internal sales, technical, and service functions**, which coordinate to enable the deployment of rental machinery. Sales units identify rental opportunities in response to customer requests, while technical and service personnel support installation, basic operation, and functional continuity during the rental period. These interactions are pragmatic and project-based rather than embedded in long-term ecosystem relationships. External actors may be involved on an **episodic and transactional basis**, primarily to support logistics, transportation, and on-site installation activities. Such actors do not participate in value co-creation or decision-making and operate under Cavanna's coordination. Their role is limited to execution and does not entail shared responsibility for service outcomes or customer relationships. Partner engagement is therefore **short-term and intermittent**, mirroring the temporary duration of rental contracts. Unlike more advanced XaaS configurations, the rental model does not require continuous alignment among multiple actors, nor does it rely on financial partners, digital platform providers, or technology ecosystems to function effectively. **Ecosystem governance** is coded as **centralized and provider-led**. Cavanna defines the scope of the rental offering, selects the machinery to be deployed, manages contractual terms, and coordinates all supporting activities. Customers interact directly with Cavanna, while external partners remain largely invisible at the commercial level. Overall, the ecosystem dimension highlights that Cavanna's rental offering is supported by a **closed and low-complexity ecosystem**, designed to ensure execution efficiency and rapid response to situational customer needs. This configuration aligns with the role of rental as a complementary and opportunistic access model, rather than as a driver of broader ecosystem-based innovation or servitization.

- **Organization structure and Culture**

The organizational configuration supporting Cavanna's **rental** offering reflects a **limited and non-institutionalized integration** of access-based logics within the company's overall structure. Within the framework, **top management commitment** is coded as **selective**, indicating that rental is

acknowledged as a useful commercial option but does not constitute a strategic priority or a core pillar of the business model. The **internal organization** underpinning the rental offering relies on **existing organizational functions**, rather than on dedicated structures or roles specifically designed for rental-based activities. Sales, technical, and service units collaborate on a case-by-case basis to deliver rental solutions, leveraging established routines developed for traditional project-based machine sales. This arrangement reflects the episodic nature of rental and its role as a complementary offering. The **service strategy** associated with rental is coded as **supportive and limited**. Service activities embedded in the rental offering are primarily aimed at ensuring the basic operability of the machinery during the rental period, rather than at delivering long-term performance commitments or continuous service-based value. Rental does not trigger a redefinition of Cavanna's service strategy, which remains largely anchored in after-sales support for owned machines. **Sales–service integration** is coded as **partial**. While coordination between sales and service functions is necessary to enable rental delivery, such integration remains pragmatic and informal. Rental opportunities emerge mainly through sales interactions, and service involvement is activated to support installation and basic functional continuity, without the establishment of standardized cross-functional rental processes. With respect to channels, the **physical channel** plays a dominant role, as rental delivery depends on on-site installation and machinery handling. Digital channels, where present, support internal coordination but do not enable new organizational roles or service logics specific to rental. From a cultural perspective, the rental offering is consistent with Cavanna's **engineering- and project-oriented culture**, which emphasizes technical reliability, customization within projects, and control over machine performance. At the same time, the limited institutionalization of rental indicates a **cautious organizational attitude** toward access-based models, which are treated as exceptions to the dominant product-sale logic rather than as a catalyst for broader organizational change. Overall, the organization structure and culture dimension highlights that Cavanna possesses the **operational flexibility** required to deliver rental solutions, but that rental remains **organizationally peripheral and opportunistic**. The offering is accommodated within existing structures without significant adaptation, reinforcing its role as an incremental extension of the traditional business model rather than as a driver of servitization.

- **Economic and Finance**

The economic and financial configuration of Cavanna's **rental** offering is grounded in a **time-based revenue logic**, in which revenues are generated through periodic fees linked to the duration of machinery use. Within the framework, the **revenue model** is coded as a **fixed-period payment**, reflecting the temporary and project-oriented nature of rental contracts. The rental model allows

Cavanna to provide access to packaging machinery without transferring ownership, enabling customers to avoid upfront capital expenditure and align costs with operational timelines. From the provider's perspective, revenues are contract-specific and limited in duration, as rental is activated in response to temporary needs rather than through long-term recurring agreements. The **cost structure** associated with the rental offering includes **asset-related costs**, as Cavanna retains ownership of the machinery, as well as logistical and operational costs related to transportation, installation, and basic technical support during the rental period. These costs are embedded within the rental fee and must be managed carefully given the limited scale and episodic activation of the offering. The **main risk** associated with the rental configuration is coded as **asset utilization risk**. Because rental demand is irregular and opportunity-driven, machinery allocated to rental may remain idle between contracts, affecting overall economic efficiency. In addition, handling and installation activities introduce variability in costs, which can erode margins if not controlled. Risk mitigation is coded as **informal and pragmatic**, relying on the selective activation of rental only when customer demand and technical feasibility are clear. Rental machinery is typically drawn from existing equipment availability, allowing Cavanna to limit dedicated investments and reduce exposure to long-term financial commitments. Profitability assessment is primarily **project-based**, focusing on the balance between rental revenues and direct operational costs for each contract. There is no evidence of portfolio-level optimization or lifecycle-based financial management specifically associated with rental assets, reinforcing the interpretation of rental as a tactical rather than strategic economic model. Overall, the economic and financial dimension highlights that Cavanna's rental offering represents a **low-institutionalization and low-risk XaaS configuration**, characterized by limited financial exposure but also constrained scalability. The model supports short-term flexibility for customers and incremental revenue opportunities for the provider, without fundamentally altering Cavanna's traditional product-sale economics.

- **Resources**

The resource base supporting Cavanna's **rental** offering is primarily centered on **owned packaging machinery**, which constitutes the core physical resource of the XaaS configuration. The machines made available through rental are drawn from Cavanna's existing technological portfolio and remain under the provider's ownership throughout the contractual period. These assets are not conceived as a dedicated rental fleet, but rather as machinery that can be temporarily allocated to rental when specific customer needs arise. A key enabling resource is therefore the **availability and redeployability of packaging machines**. Cavanna must be able to select suitable equipment, prepare it for deployment, and subsequently reintegrate it into its asset base at the end of the rental period.

This requires basic asset management capabilities, although these are not formalized within a dedicated rental infrastructure. Operational resources supporting the rental model include **logistical and installation-related assets**, such as transportation arrangements, installation tools, and facilities for temporary storage of machinery. These resources enable the physical movement and on-site deployment of rental equipment, but they are shared with Cavanna's traditional project-based activities and are not specific to the rental offering. Digital resources play a **marginal role** in the rental configuration. Within the framework, the system is coded as **non-connected or minimally connected**, as there is no systematic use of digital monitoring, remote control, or data-driven optimization associated with rental machines. Data usage is limited to administrative and coordination purposes, such as contract management and internal tracking of equipment availability. Human resources represent an important supporting element, particularly **technical and service personnel** involved in machine preparation, installation, and basic functional support during the rental period. However, these human resources are embedded within existing organizational roles and do not constitute a dedicated rental-specific workforce. Overall, the resource dimension highlights that Cavanna's rental offering is **resource-light in terms of digital and analytical assets**, while relying primarily on the effective management of physical machinery and shared operational infrastructures. Value creation is enabled by the temporary allocation and redeployment of owned equipment rather than by the development of new, specialized resource configurations.

- **Capabilities**

The capability base underpinning Cavanna's **rental** offering is primarily oriented toward **operational execution and project-based coordination**, reflecting the incremental and situational nature of the model. Within the framework, capabilities are mainly coded as **managerial and operational skills**, rather than as advanced service orchestration or data-driven capabilities. A core capability lies in Cavanna's ability to **deploy packaging machinery in temporary configurations**, adapting existing machines to customer production environments within limited timeframes. This includes selecting appropriate equipment, ensuring technical compatibility with the customer's production line, and coordinating installation and start-up activities. These capabilities build directly on Cavanna's established experience in project-based machine delivery. Another relevant capability concerns **basic asset handling and redeployment**. Cavanna demonstrates the ability to manage machinery before, during, and after rental contracts, including preparation, functional verification, and reintegration of equipment into its asset base. While these activities are not governed by formalized lifecycle management systems, they enable Cavanna to support rental on an ad hoc basis without major organizational restructuring. The rental offering also relies on **cross-functional coordination**

capabilities among sales, technical, and service units. Sales functions identify rental opportunities in response to customer requests, while technical and service personnel support execution. Coordination is pragmatic and informal, relying on existing communication channels rather than on standardized rental-specific processes. From a commercial perspective, Cavanna possesses the capability to **frame rental as a temporary and complementary solution** within customer interactions. Rental is positioned as an option to address specific operational constraints or uncertainties, rather than as a strategic alternative to machine ownership. This capability allows Cavanna to respond flexibly to customer needs while preserving its core product-sale logic. By contrast, **advanced capabilities related to digital monitoring, predictive analytics, or outcome-based service management are absent**. The rental configuration does not require Cavanna to develop new analytical or service design competences, and execution remains firmly anchored in existing technical know-how and project management skills. Overall, the capability dimension highlights that Cavanna's rental offering is supported by **execution-focused and low-complexity capabilities**, sufficient to enable temporary access to machinery but not designed to sustain scalable or highly integrated XaaS models. These capabilities reinforce the interpretation of rental as an opportunistic extension of Cavanna's traditional business model rather than as a step toward advanced servitization.

- **Environmental Sustainability**

Environmental sustainability within Cavanna's **rental** offering emerges as an **implicit and secondary outcome** of the access-based configuration, rather than as an explicit objective of the business model. Within the framework, sustainability is not positioned as a core driver of the rental offering, but arises indirectly from the temporary use and redeployment of packaging machinery. A first sustainability-related mechanism concerns the **avoidance of underutilized assets**. By enabling customers to access packaging machines through rental contracts, Cavanna allows temporary production needs to be addressed without requiring the purchase of dedicated equipment. This can reduce the proliferation of machinery that would otherwise be used only for limited periods, contributing indirectly to more efficient use of physical resources. The rental model also allows for the **sequential use of machinery across different customers or projects**. Machines retained under Cavanna's ownership can be redeployed after the rental period, extending their functional use over time. However, this redeployment logic is driven primarily by commercial and operational considerations rather than by explicit environmental objectives. Energy efficiency and environmental performance of the machines are **inherent characteristics of the equipment**, but they are not actively managed or optimized as part of the rental offering. Customers remain responsible for how the machinery is operated within their production processes, and Cavanna does not assume

responsibility for monitoring or improving energy consumption or environmental impact during the rental period. The rental configuration does not include **environmental metrics, reporting mechanisms, or sustainability-related contractual clauses**. Environmental benefits are therefore neither measured nor communicated to customers and remain contingent on individual usage patterns and on the technical characteristics of the machines. Overall, environmental sustainability in Cavanna's rental offering can be characterized as **incidental and non-strategic**. While the access-based model may support more efficient use of machinery in temporary-use scenarios, sustainability is not systematically embedded in the design, governance, or communication of the offering. The rental model remains primarily oriented toward flexibility and short-term operational needs, with environmental considerations playing a marginal and indirect role.

DIMENSIONS	VARIABILES	CODING
Value proposition	Offer object	Product
Value proposition	Maturity Level of the Service Offering	Pilot
Value proposition	Coverage of the Offering	Specific product type
Value proposition	XaaS Offering Approach	Proactive
Value proposition	Ownership	Offer Provider
Value proposition	Value for the customers	guaranteed access to the product at a cost known in advance
Value proposition	Value for the customers	guarantee of functionality
Value proposition	Offer costumization (level)	Configurable offer
Value proposition	Offer Customization (object)	Product
Value proposition	Offer Customization (object)	Payment
Value proposition	Offer communication	Integration into existing channels
Customers	Traget Customer segments	New Customers
Customers	Customer segmentation strategy	Segment-Oriented
Customers	Customer acceptance	Moderate interest
Customers	Customer involvement	Passive
Ecosystem	Presence of strategic partners	Technical
Ecosystem	Presence of strategic partners	Technological
Ecosystem	Presence of strategic partners	Service delivery
Ecosystem	Continuity of strategic partners' engagement	Technical _development
Ecosystem	Continuity of strategic partners' engagement	Technological _delivery
Ecosystem	Continuity of strategic partners' engagement	Service delivery_delivery
Ecosystem	Alliance governance	Technical _ coordinated

Ecosystem	Alliance governance	Technological _coordinated
Ecosystem	Alliance governance	Service delivery_collaborative
Organization structure and culture	Level of commitment of the top management of the provider	Partial or localized commitment
Organization structure and culture	Internal organization	Existing functions or business units (es. Sales service)
Organization structure and culture	Service strategy	Partially aligned / Integrated
Organization structure and culture	Sales–Service Integration level	Partially integrated
Organization structure and culture	Physical distribution channel	Disintermediated
Organization structure and culture	Digital Distribution channel	Absent
Economic and finance	Revenue model and mechanism	Fixed period / subscription (payment per period)
Economic and finance	Revenue model and mechanism	Payment per result
Economic and finance	Main Risk	Financial risk
Economic and finance	Main Risk	Operational risk
Economic and finance	Risk mitigation strategy	No formal strategy
Economic and finance	Risk mitigation mechanisms	Contractual clauses
Economic and finance	Profitability Measurement KPI	financial economics KPI
Economic and finance	Profitability Measurement KPI	operational performance KPI
Economic and finance	Profitability Measurement KPI	life cycle KPI
Resources	Data connectivity	Disconnected product
Resources	Data Exploitation	Basic operational data
Resources	Customer Data accessibility	Full access
Resources	Technology role	Maintenance automation and/or operational continuity
Resources	Technology role	Functional monitoring for pricing definition
Capabilities	service design capabilities	Basic design:
Environmental sustainability	End-of-life and reverse logistics strategies	Remanufacturing services offered
Environmental sustainability	Product-life extension strategy	development of a durable product
Environmental sustainability	Resource efficiency	Implementation of eco-efficient design or processes
Environmental sustainability	Product service substitution	No substitution
Environmental sustainability	Dematerialization and transparency	No structured transparency or dematerialization
Environmental sustainability	Use and service intensity	Multi-contract asset utilization

Table 56 Cavanna coding results

C.13 Henkelhausen GmbH & Co

Company and XaaS Offering Overview

Henkelhausen GmbH & Co. is a German manufacturing and service company specialized in industrial diesel engines and drive solutions. The company operates primarily as a **service and system integration partner** for major engine manufacturers, including Volvo Penta, Deutz, FPT, and Scania, rather than as an original engine producer. Its activities span a wide range of engine-related services, including new engine sales, spare parts distribution, overhaul and refurbishment operations, emergency power solutions, and extensive field service activities. Henkelhausen has developed a strong service orientation over time, supported by a **geographically distributed organizational structure**. The company operates through several service offices and workshops across Germany, enabling proximity to customers and rapid response in maintenance and repair operations. Historically, the firm's business model has been centered on supporting OEMs and end customers throughout the engine lifecycle, particularly in contexts where high availability and reliability are critical, such as industrial vehicles, infrastructure equipment, and emergency or backup applications. This service-intensive background provides the organizational and operational foundation for Henkelhausen's exploration of XaaS business models. At the same time, the company's size and position within the value chain, as an intermediary between OEMs and end users, shape both the opportunities and constraints associated with the transition toward outcome-based service offerings. The XaaS configuration analyzed in this study corresponds to an **Engine-as-a-Service** concept that is currently in an **early implementation phase**. At the time of analysis, Henkelhausen is **implementing its first Engine-as-a-Service project**, which marks the transition from conceptual development to initial operational execution. The offering is therefore framed as a **pilot initiative**, in which the company is actively testing the feasibility of the XaaS model in a real customer context, while several elements of the business model are still being refined. The proposed Engine-as-a-Service model is conceived as a **service-based XaaS offering**, in which customers do not purchase the engine outright but instead access its functionality through a recurring payment. Under this logic, Henkelhausen assumes responsibility for key aspects of service delivery, including maintenance activities, system availability, and selected elements of lifecycle management. The value proposition is centered on relieving customers from the need to manage and maintain a high-cost and technically complex asset, while ensuring continuity of operation. A defining characteristic of the offering is that the **physical engine is supplied by third-party manufacturers**, primarily Volvo Penta, rather than being produced by Henkelhausen itself. In this configuration, Henkelhausen acts as the **service orchestrator** and the **contractual interface** with the customer. The company coordinates service activities, integrates the contributions of OEMs and other partners, and manages the customer relationship, positioning itself as the single point of responsibility for the service. The first Engine-as-a-Service project is targeted at a **specific and bounded operational environment**, such as an

airport, port, or other geographically constrained site. These contexts are considered particularly suitable for the pilot phase, as they allow Henkelhausen to operate within a defined service perimeter, facilitating maintenance logistics, response times, and coordination with partners. The offering is often positioned in connection with **engine replacement decisions**, where customers would traditionally invest in a new engine, and is proposed as an alternative to ownership at that decision point. Despite the initiation of the first project, the offering remains **partially exploratory**, with several dimensions, such as long-term pricing logic, ownership arrangements at contract termination, and performance measurement frameworks, still under evaluation. This reflects the pilot nature of the initiative, in which learning from initial implementation plays a central role in shaping the future evolution of the Engine-as-a-Service model.

Henkelhausen GmbH & Co framework-based analysis

- **Value proposition**

Henkelhausen's Engine-as-a-Service offering is centered on the provision of **guaranteed engine functionality**, rather than on the sale or transfer of engine ownership. The value proposition is explicitly framed around access to engine performance and availability over time, combined with the outsourcing of maintenance activities and selected lifecycle responsibilities. Customers are therefore not required to acquire the engine as an asset, but instead gain access to its functionality through a service-based arrangement, shifting attention away from the physical product toward operational continuity. At the time of analysis, the offering is positioned in an **early implementation phase**, with the first project currently being developed and deployed. This pilot status is reflected in the fact that the value proposition is still being refined through direct interaction with selected customers and partners. While the overall service logic is clearly articulated, several elements of the offering, such as contractual boundaries, pricing metrics, and long-term asset arrangements, are actively tested and adjusted in practice, rather than being fully standardized. The Engine-as-a-Service concept is deliberately applied to a **specific category of products**, namely industrial diesel engines operating in **constrained and controlled environments**. Typical application contexts include airports, ports, mining sites, and specialized vehicles, where operating conditions are relatively stable and geographically bounded. These contexts are considered particularly suitable for the service-based model, as they allow clearer definition of usage patterns, easier monitoring of performance, and more manageable service logistics during the pilot phase. Henkelhausen adopts a **proactive approach** in introducing the offering to the market. Rather than responding to explicit customer requests for an as-a-service solution, the company actively presents the Engine-as-a-Service concept to selected OEMs and end customers. This is primarily done through direct, high-level interactions, where the

service is positioned as an alternative to traditional ownership-based engine procurement, particularly in situations where customers face engine replacement decisions. A distinctive element of Henkelhausen's value proposition concerns the **ownership structure of the physical asset**. In the current configuration, engines remain owned by third-party manufacturers, most notably Volvo Penta, while Henkelhausen assumes responsibility for service delivery. This arrangement differentiates Henkelhausen's offering from other XaaS configurations in which the service provider retains asset ownership. As a result, Henkelhausen operates as a service provider and orchestrator without being the engine owner, which introduces additional coordination requirements but also reflects the company's position within the industrial engine value chain. From the customer perspective, the **primary source of value** is the **reduction of initial investment**. Industrial engines represent one of the most expensive components in vehicles and equipment, and the ability to avoid large upfront capital expenditures is perceived as particularly attractive. By shifting costs from capital expenditure to operational expenditure, the offering addresses the needs of customers operating under strong price pressure and seeking greater financial flexibility, especially in competitive or volatile markets. The offering is designed to be **configurable**, with customization applied primarily at the **product and payment level**. Rather than modifying the underlying engine technology, customization focuses on adapting the service parameters and pricing metrics to different usage patterns and operational contexts. Depending on the application, pricing may be linked to operating hours, kilometers driven, tons processed, or other output-related measures. This configurability allows the service to be tailored to heterogeneous customer needs while maintaining a common service logic. Finally, communication of the Engine-as-a-Service offering is embedded within **Henkelhausen's existing commercial channels**. The concept is presented through personal meetings and direct interactions with top management, technical decision-makers, and procurement functions on the customer side. The offering is not promoted through standardized marketing materials or digital channels, reflecting both the pilot nature of the initiative and the strategic, case-specific character of the decision to adopt a service-based engine model.

- **Customers**

Henkelhausen's Engine-as-a-Service offering is not built around a formal distinction between predefined customer segments. The company does not explicitly differentiate target customers through standardized segmentation criteria, and the offering is not restricted to a specific customer category in formal terms. At the same time, interview evidence indicates that the initiative is implicitly oriented toward **specific types of operating contexts**, rather than toward a broad and undifferentiated market. In practice, Henkelhausen focuses on customers operating in **bounded and**

intensive environments, where engine utilization levels are high and the consequences of downtime are particularly critical. Typical contexts include geographically constrained sites and applications in which operational continuity is essential. This orientation reflects a segment-oriented logic grounded in usage intensity and operational criticality, even though it is not formalized through explicit customer segmentation frameworks. Customer acceptance of the Engine-as-a-Service concept is characterized by **moderate interest**. Customers generally perceive the offering as attractive, particularly because it addresses the high upfront investment associated with industrial engines. The possibility of shifting expenditure from capital investment to operational costs is viewed positively, especially by customers facing cost pressure or capital constraints. At the same time, acceptance is tempered by a number of unresolved concerns. Interview material highlights that customers express **significant uncertainty** regarding the long-term implications of the service-based model. In particular, questions remain around ownership arrangements at the end of the contract, the allocation of responsibilities over time, and the overall risk exposure associated with a service-based engine solution. These uncertainties are further amplified by the fact that the offering concerns **a single component rather than an entire machine or system**. As a result, the XaaS logic is perceived as less intuitive and less familiar than in cases where customers outsource complete equipment or infrastructure. Customer involvement in the development of the offering is **co-creative**. The Engine-as-a-Service model is explicitly described as being developed in close collaboration with customers, rather than being predefined and then offered as a standardized solution. Customers are actively involved in shaping key elements of the value proposition, particularly with respect to pricing logic, risk-sharing mechanisms, and the definition of service boundaries. Decisions regarding what is included in the service, such as spare parts, storage arrangements, maintenance responsibilities, and response times, are negotiated on a **case-by-case basis**. This collaborative approach reflects both the pilot nature of the initiative and the need to align the service configuration with customer-specific operational conditions. Customer collaboration is therefore not optional, but a necessary condition for value creation at this stage, as the offering cannot yet be fully specified without direct input from prospective users. Overall, the Customers dimension highlights a configuration characterized by selective targeting based on operational context, cautious but interested customer attitudes, and a high degree of customer involvement in service development. This pattern is consistent with the early-stage nature of Henkelhausen's Engine-as-a-Service initiative, where customer collaboration plays a central role in shaping and validating the emerging XaaS model.

- **Ecosystem**

The ecosystem supporting Henkelhausen's Engine-as-a-Service concept is **multi-layered and highly interdependent**, reflecting both the technical complexity of the offering and the company's position within the industrial engine value chain. Rather than relying on a single category of partners, the XaaS configuration is built around the coordinated involvement of engine manufacturers, service partners, and, at least at a conceptual level, financial and insurance actors. **Engine manufacturers**, most notably Volvo Penta, represent the central actors within this ecosystem. Their role extends beyond the supply of the physical engine and includes the provision of **condition monitoring infrastructure and data analytics capabilities**. At the current stage, these technological resources are not fully developed internally by Henkelhausen and therefore constitute a critical external input for the Engine-as-a-Service model. As a result, OEMs contribute not only tangible assets but also digital and analytical components that are essential for monitoring usage, assessing performance, and supporting service delivery. In parallel, the ecosystem includes **service delivery partners**, particularly regional service providers that complement Henkelhausen's own field service capabilities. These partners become especially relevant in contexts where rapid response times are required outside Henkelhausen's core geographic coverage. Their involvement allows the company to extend the reach of the service offering without replicating physical presence across all regions, thereby supporting scalability at the pilot stage. The **continuity of partner engagement** reflects the long-standing nature of these relationships. Engagement with both technical partners (engine manufacturers) and service delivery partners is not limited to isolated or one-off projects, but builds on existing collaborations that span multiple activities and customer engagements. This continuity provides a relational foundation for the development of the XaaS concept, even though the Engine-as-a-Service offering itself is still in an early implementation phase. **Alliance governance** within the ecosystem is predominantly **collaborative**. Henkelhausen positions itself as the **single contractual interface toward the customer**, assuming responsibility for coordinating partners and integrating their contributions under an overarching service agreement. Customers do not interact directly with OEMs or service partners within the XaaS context; instead, Henkelhausen absorbs the complexity of partner coordination and presents the offering as a unified service solution. From an economic perspective, **revenue-sharing mechanisms** are conceptually defined within the ecosystem. Partner fees are embedded into the customer price through a **cost-plus logic**, ensuring that external contributions are transparently incorporated into the service economics. While these mechanisms are still being refined as part of the pilot initiative, they provide a preliminary structure for aligning partner incentives with service delivery requirements. Overall, the ecosystem configuration highlights Henkelhausen's role as a **service orchestrator** operating between OEMs, regional service providers, and customers. This orchestration function is particularly important given the company's relatively smaller organizational

scale compared to global engine manufacturers. By leveraging long-standing partnerships and coordinating complementary capabilities, Henkelhausen compensates for internal resource limitations and enables the development of an Engine-as-a-Service model despite not owning the physical asset or the full technological stack.

- **Organizational structure and Culture**

The transition toward an Engine-as-a-Service model at **Henkelhausen GmbH & Co.** is supported by a **widespread and strategic commitment from top management**, which is closely linked to recent changes in leadership and governance. Interview evidence indicates that the exploration of XaaS is embedded within a broader organizational transformation, aimed at overcoming historically fragmented structures and moving toward a more integrated, service-oriented logic. This transformation reflects an explicit recognition that the traditional organization, largely structured around product sales, spare parts, and reactive service activities, is not fully aligned with the requirements of outcome-based and long-term service offerings. As a result, Henkelhausen is actively working to dismantle internal silos and to reorient the organization around cross-functional collaboration and service value creation. From an organizational standpoint, the company is in the process of **establishing new, dedicated teams** focused on service development and business model innovation. At the time of the interview, no fully autonomous service or XaaS unit had yet been formalized. However, restructuring efforts are clearly directed toward the creation of more focused and specialized roles, particularly in areas such as sales, technical support, warranty management, and XaaS business development. These roles are intended to support the development and implementation of the Engine-as-a-Service concept, even though organizational responsibilities are still evolving. The **service strategy** is fully integrated and strategically driven. Engine-as-a-Service is not framed as a peripheral or experimental add-on, but as a core element of the company's future positioning. At the same time, there is a clear distinction between strategic intent and operational execution: while the strategic direction is well defined, the organizational structures and routines required to fully support the XaaS model are still under construction. With respect to **sales–service integration**, the company is moving toward an **integrated and unified logic**. This reflects an explicit intention to move away from department-level turnover targets and toward a more holistic view of company performance. Sales and service activities are increasingly viewed as interdependent components of a single value creation process, particularly in the context of long-term service contracts where performance, reliability, and customer satisfaction are tightly interconnected. Regarding **distribution channels**, Henkelhausen maintains **direct relationships with end customers** for service delivery, resulting in a disintermediated physical channel. This direct

interaction supports close coordination during service provision and reinforces the company's role as the primary service provider. In contrast, the **digital distribution channel is currently absent**. Digital monitoring and data-related functionalities are largely delegated to OEM partners, reflecting both Henkelhausen's current resource configuration and its reliance on external technological infrastructures during the pilot phase of the XaaS initiative. Overall, the Organizational Structure and Culture dimension portrays a company in transition. Strong top management commitment and a clearly articulated service strategy coexist with evolving organizational arrangements, reflecting the early-stage nature of the Engine-as-a-Service initiative and the broader transformation required to support a shift toward XaaS business models.

- **Economic and Finance**

The Engine-as-a-Service model developed by **Henkelhausen GmbH & Co.** is structured around a **fixed-period subscription revenue logic**, based on recurring payments over a defined contractual horizon. While the overall subscription structure is clearly articulated, the precise billing metric, such as operating hours, kilometers driven, or tons processed, is still under discussion and subject to ongoing evaluation in collaboration with customers. This reflects the pilot status of the initiative, in which the commercial logic is being tested and refined alongside technical and operational considerations. Pricing follows a **cost-plus approach**, in which the subscription fee incorporates all relevant cost components associated with service delivery. These include maintenance parts, labor, logistics activities, and the fees associated with external partners involved in the ecosystem. Rather than relying on market-based or value-based pricing mechanisms, the economic structure is designed to ensure cost coverage and transparency during the early stages of implementation, allowing Henkelhausen to manage uncertainty while gaining experience with the service model. Both **financial and operational risks** are explicitly recognized as central elements of the XaaS configuration. Financial risk arises from the long-term nature of subscription contracts and the associated upfront exposure, particularly in relation to maintenance obligations and partner commitments over the contract duration. Operational risk is linked to the technical characteristics of industrial engines, especially the potential occurrence of major failures and extended downtime events, which could significantly affect service costs and customer satisfaction. Risk mitigation is addressed through a **formalized risk management model**, which combines internal planning with external support mechanisms. In particular, Henkelhausen explicitly plans to involve **financial companies and insurance instruments** as part of the Engine-as-a-Service configuration. Unlike more experimental or loosely defined XaaS initiatives, the company places strong emphasis on the role of insurers in managing operational risk. This approach leverages the extensive historical data available for

industrial engines, which can be used to estimate failure probabilities, define coverage conditions, and calculate insurance premiums. The involvement of insurers is therefore conceived as an integral component of the economic architecture rather than as an ancillary safeguard. **Profitability measurement** relies on a combination of **operational performance KPIs** and **lifecycle-based KPIs**. Operational indicators focus on aspects such as uptime, maintenance intervals, and service responsiveness, while lifecycle KPIs capture cost and performance dynamics over the full duration of the service contract. At the current stage, particular emphasis is placed on systematic data collection to enable future benchmarking and forecasting capabilities. Building a reliable empirical basis for performance comparison and risk assessment is viewed as a prerequisite for scaling the Engine-as-a-Service model beyond the pilot phase. Overall, the Economic and Financial dimension reflects a configuration characterized by cautious structuring, explicit risk recognition, and strong reliance on formalized mechanisms. The subscription-based revenue logic, cost-plus pricing, and planned integration of insurance instruments illustrate an approach aimed at stabilizing the economic foundations of the XaaS offering during its early implementation, while laying the groundwork for more advanced and scalable configurations in the future.

- **Resources**

The resource base underpinning **Henkelhausen GmbH & Co.**'s Engine-as-a-Service concept is currently **fragmented and only partially internalized**, reflecting both the early-stage nature of the offering and the company's position within a broader ecosystem dominated by engine OEMs. Unlike other XaaS configurations analyzed in this study, Henkelhausen does not control the full technological infrastructure required to autonomously support a data-driven service model. From a **connectivity** perspective, the Engine-as-a-Service offering relies on systems that are external to Henkelhausen's direct control. The company does not own or operate a proprietary digital platform for engine monitoring. Instead, access to operational data is primarily mediated through **OEM-provided monitoring systems**, most notably those developed and managed by Volvo Penta. These systems generate basic operational information, such as operating hours, alarms, and maintenance-related indicators, which Henkelhausen can access on the basis of contractual arrangements with the OEM. As a result, connectivity is structurally dependent on partners, both in terms of data availability and continuity. This dependency has direct implications for **data exploitation practices**. The data currently available to Henkelhausen are used mainly to support reactive and preventive maintenance planning, warranty-related decisions, and high-level monitoring of engine performance. There is no evidence of advanced data analytics capabilities developed internally, nor of predictive algorithms or automated decision-making processes embedded within the service logic. Data exploitation therefore

remains limited in scope and primarily operational in nature. The absence of an internal digital backbone constrains the **scalability and standardization** of the Engine-as-a-Service offering. While basic monitoring and reporting are possible through OEM systems, the lack of proprietary digital infrastructure limits Henkelhausen's ability to independently structure data flows, develop customized analytics, or integrate data-driven functionalities directly into the service model. With respect to **customer data accessibility**, access is in principle full, as customer-related operational data are considered necessary for service delivery. In practice, however, data access is mediated by OEM platforms and shaped by contractual and legal arrangements. Issues related to data ownership, access rights, and responsibility for data interpretation are explicitly acknowledged in the interview material and remain open. As a result, **data governance** emerges as a critical but unresolved resource dimension, rather than as a stable enabling asset within the current configuration. Technology plays a role in **real-time monitoring and analysis**, but this role is largely externalized. Henkelhausen relies on partner technologies to access and interpret operational data, positioning itself primarily as a **service orchestrator** rather than as a digital service provider. The company integrates externally generated data into its service activities but does not yet control the underlying technological architecture. Overall, the Resources dimension highlights a configuration in which key technological and data-related resources are accessed through partnerships rather than owned or developed internally. This arrangement is coherent with the pilot status of the Engine-as-a-Service initiative and with Henkelhausen's current role in the value chain, while also delineating the boundaries within which the service model is presently operating.

- **Capabilities**

Henkelhausen's capability profile reflects a company that is **conceptually advanced but operationally constrained** in its transition toward an Engine-as-a-Service model. The capabilities that currently support the XaaS initiative are unevenly developed and are concentrated more on conceptual, financial, and lifecycle-related aspects than on digital service execution. One of the most developed capability areas concerns **business model conceptualization and financial structuring**. Interview evidence highlights a relatively high level of sophistication in the company's ability to reason about subscription-based revenue models, lifecycle costing, and the allocation of financial and operational risks among the different actors involved in the service configuration. Henkelhausen demonstrates a clear understanding of how costs, risks, and responsibilities should be distributed between customers, insurers, OEMs, and the service provider in order to make the Engine-as-a-Service model economically viable. This capability is reinforced by the company's explicit intention to involve **insurance partners** as part of the XaaS configuration. Henkelhausen shows familiarity

with actuarial reasoning and with the use of historical failure data for industrial engines to support risk assessment and premium calculation. The ability to integrate insurance logic into the service business model represents a distinctive capability, particularly at such an early stage of XaaS development. In parallel, Henkelhausen possesses **strong operational service capabilities** rooted in its long-standing experience in engine maintenance, overhaul, refurbishment, and emergency service interventions. These capabilities provide a solid foundation for assuming responsibility for engine availability and lifecycle management under a service-based logic. However, at the current stage, these operational capabilities are still largely deployed within **traditional, project-based or transactional contractual arrangements**. They have not yet been fully reconfigured into standardized, scalable routines suitable for long-term, outcome-based service contracts. By contrast, **digital and analytical capabilities** are clearly underdeveloped. Henkelhausen lacks internal resources dedicated to data analytics, digital platform management, and digital service design. This gap is explicitly acknowledged in the interview material and is closely linked to the company's reliance on OEM-provided monitoring systems. As a result, data-driven decision-making and advanced analytics are not yet embedded within Henkelhausen's service operations. Capability development is therefore framed as an **ongoing and forward-looking process**, rather than as a completed transformation. Interview evidence points to organizational learning, potential acquisitions, and closer collaboration with technology partners as possible avenues for strengthening digital and analytical capabilities over time. These initiatives, however, remain prospective rather than fully implemented. From an organizational and cultural perspective, Henkelhausen is in the midst of a **capability transition**. The move toward XaaS challenges existing functional silos and requires tighter integration between sales, service, finance, and technical functions. While top management commitment to this transition is strong, the capabilities required to operationalize such integration, particularly in a standardized and scalable manner, are still emerging. At present, the Engine-as-a-Service initiative relies heavily on the expertise and coordination of a **limited number of key individuals**, rather than on fully institutionalized routines and processes. Overall, the Capabilities dimension portrays a configuration characterized by strong conceptual and lifecycle-related strengths, combined with clear limitations in digital execution and organizational routinization. This imbalance is consistent with the pilot status of Henkelhausen's XaaS initiative and highlights the capability development challenges that must be addressed for the model to mature beyond its current exploratory phase.

- **Environmental sustainability**

Environmental sustainability represents one of the **most mature and structurally embedded dimensions** of Henkelhausen's service logic, even though the Engine-as-a-Service offering itself is still at an early stage of development. Unlike other XaaS cases in which sustainability is closely linked to digital monitoring, performance-based contracting, or explicit efficiency targets, Henkelhausen's sustainability profile is primarily rooted in **long-standing lifecycle management practices** associated with industrial engines. A central sustainability mechanism lies in the company's systematic implementation of **remanufacturing and refurbishment processes**. Henkelhausen operates extensive overhaul facilities in which engines are disassembled, inspected, repaired, and reassembled using a combination of reused and new components. Refurbished engines are subsequently tested and reintroduced into service with performance and reliability levels comparable to those of new products. These practices enable substantial **product-life extension** and significantly reduce the need for new engine manufacturing, thereby lowering material consumption and embodied environmental impacts. The integration of **second-hand and refurbished engines** into the emerging as-a-service logic further reinforces this circular approach. Engines are treated as long-term assets rather than as one-off products, and can be redeployed across multiple customers and applications over time. This redeployment increases **use and service intensity**, as assets are utilized across several lifecycles instead of being retired after a single ownership period. Although this logic is not yet formalized within standardized XaaS contracts, it aligns naturally with a subscription-based service model in which asset ownership and lifecycle responsibility remain with the provider or within the service ecosystem. Resource efficiency gains in Henkelhausen's model arise primarily from **avoided production and extended use**, rather than from the optimization of energy or fuel consumption during operation. Interview evidence indicates that there are currently no explicit initiatives aimed at reducing emissions or improving energy efficiency through the Engine-as-a-Service offering itself. Similarly, no product–service substitution mechanisms are in place: physical engines remain central to value creation, and the service model does not seek to replace hardware with purely digital or immaterial solutions. Finally, the offering does not include **structured mechanisms for environmental transparency or dematerialization**. Customers are not provided with environmental KPIs, lifecycle impact assessments, or sustainability dashboards as part of the service. Environmental performance is therefore not explicitly communicated or contractually defined, but remains implicit within the service logic. Sustainability outcomes emerge primarily as a **provider-driven consequence** of refurbishment, reuse, and lifecycle extension practices, rather than as explicitly articulated objectives of the Engine-as-a-Service model. Overall, the Environmental Sustainability dimension highlights a configuration in which sustainability is deeply embedded in operational practices related to asset lifecycle management, even in the absence of digitalization-driven

optimization or explicit sustainability-oriented contracting. This reflects Henkelhausen's historical strengths in remanufacturing and refurbishment, and illustrates how circular economy principles can be present in XaaS configurations well before full business model formalization.

DIMENSIONS	VARIABLES	CODING
Value proposition	Offer object	Service
Value proposition	Maturity Level of the Service Offering	Pilot
Value proposition	Coverage of the Offering	Specific category
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Customers	Customer segmentation strategy	Segment-Oriented
Customers	Customer acceptance	Moderate interest
Customers	Customer involvement	Co-creative
Ecosystem	Presence of strategic partners	Technical
Ecosystem	Presence of strategic partners	Service delivery
Ecosystem	Continuity of strategic partners' engagement	Technical _both
Ecosystem	Continuity of strategic partners' engagement	Service delivery_both
Ecosystem	Alliance governance	Technical _collaborative
Ecosystem	Alliance governance	Service delivery_collaborative
Organization structure and culture	Level of commitment of the top management of the provider	Widespread and strategic commitment
Organization structure and culture	Internal organization	New, dedicated business unit or team
Organization structure and culture	Service strategy	Fully integrated / Strategically driven
Organization structure and culture	Sales–Service Integration level	Integrated / Unified
Organization structure and culture	Physical distribution channel	Disintermediated
Organization structure and culture	Digital Distribution channel	Absent
Economic and finance	Revenue model and mechanism	Fixed period / subscription (payment per period)

Economic and finance	Main Risk	Financial risk
Economic and finance	Main Risk	Operational risk
Economic and finance	Risk mitigation strategy	Formalized risk management model
Economic and finance	Risk mitigation mechanisms	Financial company
Economic and finance	Risk mitigation mechanisms	Third-party instruments involvements (insurers..)
Economic and finance	Profitability Measurement KPI	operational performance KPI
Economic and finance	Profitability Measurement KPI	life cycle KPI
Economic and finance	Pricing	Cost-plus
Resources	Data connectivity	Disconnected product
Resources	Data Exploitation	Basic operational data
Resources	Customer Data accessibility	Full access
Resources	Technology role	Real-time monitoring and/or analysis
Capabilities	Risk assessment capabilities	Financial & operational integration
Environmental sustainability	End-of-life and reverse logistics strategies	Remanufacturing services offered
Environmental sustainability	Product-life extension strategy	Reuse or lifetime extension throught refurbishment
Environmental sustainability	Resource efficiency	No specific initiatives for resource efficiency
Environmental sustainability	Product service substitution	No substitution
Environmental sustainability	Dematerialization and transparency	No structured transparency or dematerialization
Environmental sustainability	Use and service intensity	Inclusion of second-hand products in the aaS offering

Table 57 Henkelhausen GmbH & Co coding results

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MODULO DI EMBARGO DELLA TESI
(da compilare solo se si richiede un periodo di segretazione della tesi)

Il/La sottoscritto/a…Scalvini Laura…… Nato/a il…17/07/1987……..
a (indicare anche l'eventuale paese estero)……Brescia……..
provincia di (ovvero sigla del paese estero)……BS…….
Dottorato di Ricerca in …Transizione Energetica e Sistemi Produttivi Sostenibili
……..……

DICHIARA

- che il contenuto della tesi **non può essere immediatamente consultabile per il seguente motivo**

--------presenza di dati sensibili delle aziende oggetto di caso di studio, non divulgatibili----------
La motivazione deve essere dettagliata e controfirmata obbligatoriamente dal Primo Supervisore di tesi
(Brevetto, segreto industriale, motivi di priorità nella ricerca, motivi editoriali, altro)

- che il testo completo della tesi potrà essere reso consultabile dopo:

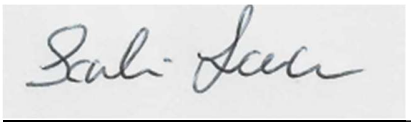
□ 6 mesi dalla data di conseguimento titolo
□ 12 mesi dalla data di conseguimento titolo
X periodo massimo di 24 mesi dalla data di conseguimento titolo – specificare il periodo esatto…26 giugno 2028…..
Per motivi eccezionali causa motivazioni scientifiche.

Motivazioni scientifiche (elaborare testo):

- che sarà comunque consultabile immediatamente l'abstract della tesi, che viene caricato in Esse3, profilo studente.

Luogo e Data
Comezzano – Cizzago 05/06/2026

Firma del Dichiarante



Controfirma del Primo Supervisore di tesi
per la motivazione di embargo e indicazione del periodo

