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# Exploring How Usage-Focused Business Models Enable Circular Economy through Digital Technologies

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**Abstract:** Recent studies advocate that digital technologies are key enabling factors for the introduction of servitized business models. At the same time, these technologies support the implementation of the circular economy (CE) paradigm into businesses. Despite this general agreement, the literature still overlooks how digital technologies enable such a CE transition. To fill the gap, this paper develops a conceptual framework, based on the literature and a case study of a company implementing a usage-focused servitized business model in the household appliance industry. This study focuses on the Internet of Things (IoT), Big Data, and analytics, and identifies eight specific functionalities enabled by such technologies (improving product design, attracting target customers, monitoring and tracking product activity, providing technical support, providing preventive and predictive maintenance, optimizing the product usage, upgrading the product, enhancing renovation and end-of-life activities). By investigating how these functionalities affect three CE value drivers (increasing resource efficiency, extending lifespan, and closing the loop), the conceptual framework developed in this paper advances knowledge about the role of digital technologies as an enabler of the CE within usage-focused business models. Finally, this study shows how digital technologies help overcome the drawback of usage-focused business models for the adoption of CE pointed out by previous literature.

**Keywords:** circular business model; sustainability; servitization; Product-Service System (PSS); Internet of Things; Big Data & Analytics; Industry 4.0; household appliances

## 1. Introduction

The circular economy (CE) paradigm has reached increasing attention among academia and practitioners as a mean to promote sustainability [1], i.e., development that meets the need of the present without compromising the ability of future generations to meet their own needs [2]. Moreover, recent studies [3] show that the application of CE principles may increase the European Gross Domestic Product (GDP) as much as 11%, with a net benefit of about €1.8 trillion by 2030, and savings on material costs up to USD 1 trillion [4,5].

The introduction of servitized business models (BMs), where the use or the function of a product is sold instead of the product itself, has been acknowledged as one possible enabling factor of the CE paradigm into companies [3,6,7]. For instance, in the mobility sector, car sharing offerings where the providers do not sell cars, but offer turnkey solutions through a servitized scheme [8], have been often used in literature as examples of the application of the CE principles [5,9]. Car2go represents a practical example of a business-to-consumer (B2C) car sharing BM, where cars can be taken and left at any place within the city area, and users are charged with a price-per-minute fee [10].

Over the years, several works have discussed how servitized BMs can enable CE. A remarkable example is a study by Mont et al. [11], which shows how leasing and reconditioning models applied to baby prams can lead to environmental benefits, such as a reduced amount of waste generated at the end of life and the reduced consumption of virgin materials. Other notable examples encompass the clothing sector, where companies like Mud Jeans have started to lease jeans to customers for a monthly price, collecting them back for repair or recycling [9], or the lighting sector, where Philips have started to offer “light-as-a-service” under a pay-per-lux BM [6]. The literature has pointed out the potential benefits that companies may gather from servitized BMs, such as strengthening customer relations, creating higher barriers for competitors, and generating new and resilient revenue streams [12–14]; it also notes the great challenges implied [15–17], since servitization requires fundamental changes in the way of delivering value and dealing with customers and stakeholders [18].

In this context, the role of new digital technologies that constitute the backbone of the fourth industrial revolution (such as Internet of Things (IoT), 3D printing, Big Data and relating analytics, virtual and augmented reality, etc.), has been indicated as “disruptive”. In fact, these technologies are radically reshaping the way companies deliver existing services [14], enabling the introduction of servitized BMs into companies and facilitating the transition towards CE [12,14,19–21]. A practical example is the “Power-by-the-Hour” program provided by Rolls-Royce [22]. In fact, this program can be considered as a servitized BM, where airline manufacturers no longer buy engines but pay a variable fee for their availability. In this model, providing effective engine maintenance is crucial [12]. To do so, Rolls-Royce has implemented specific IoT technologies to monitor the engine data received via satellites in real time, and automatically elaborates the collected data through appropriate analytics [17]. Thus, preventive and predictive maintenance may be executed, and the useful life of engines may be extended, therefore achieving CE.

However, the way in which digital technologies favor the transition towards CE has not been analyzed in detail yet [5], and more conceptual and empirical investigation is required in the field [5,23]. To contribute to the building of knowledge on this aspect, this paper focuses on how new digital technologies, such as IoT, Big Data, and analytics act in the deployment of usage-focused BMs to increase resource efficiency, extend product lifespan, and close the loop, i.e., to attain the fundamental CE value drivers recognized in literature [20]. More specifically, the paper identifies and empirically explores, through a case study, eight functionalities of usage-focused BMs enabled by digital technologies, thus explaining how they support the transition towards CE. This is formalized through the development of a conceptual framework.

The paper is organized as follows. Section 2 sets the background of the study, providing a review of the literature in the fields of CE, servitized BMs, and the selected digital technologies. Section 3 describes the research design, process, and methodology, introducing the conceptual framework and designing its structure. Section 4 presents the empirical investigation, and Section 5 includes a discussion of the results, and provides the conceptual framework. Lastly, in Section 6, conclusions, research contributions, managerial implications, as well as limitations and future research directions are illustrated.

## 2. Background

### 2.1. Circular Economy

Notwithstanding the increasing attention that the CE concept has gained from academia, practitioners, and policy makers in recent years [24,25], a detailed definition of CE is still missing in the literature [26]. So far, the most prominent definition of CE has been provided by the Ellen MacArthur Foundation [3], who defines CE as a “system restorative and regenerative by design, which aims to maintain products, components and materials at their highest utility and value” [2,25,27–29]. The CE concept has its roots in other schools of thought, such as industrial ecology, industrial symbiosis, blue

economy, Product-Service System, cradle-to-cradle, and biomimicry [2,27,29,30]. However, the body of knowledge regarding CE is still in its infancy [4].

In general, CE contrasts the linear economy, where products are manufactured from raw materials, sold to consumers, and then disposed as waste after their use [3]. In fact, CE decouples economic growth from environmental losses and resource extraction, by enabling several closed-loop cycles of reuse, remanufacturing, and recycling [31]. Thus, CE needs to give equal attention to both the reverse and forward flows of products, components, and materials [13], by the implementation of reverse logistics and closed-loop supply chains [32]. A hierarchy among the several reverse logistics activities should be followed [33]: reuse is generally preferable to recycling, since much of the product intrinsic value remains intact [34]. Moreover, products should be redesigned with the aim of enhancing multiple lifecycles [35], in order to improve reuse, refurbishment, remanufacturing, and recycling. Thus, several design-for-x strategies for eco-design [36], product life extension [37], modularization [5], remanufacturing [30], standardization, and material selection [38] may be pursued.

CE implementation projects may take place at three different implementation levels, which differ by their scale and unit of analysis: micro, meso, and macro [1,24,39]. The micro level highlights the transition towards CE made by a single company [29]. At the meso level, the focus of the study is extended from the single company to comprise inter-firm collaboration through industrial symbiosis, in order to establish so-called eco-industrial parks [24]. The macro level highlights a broader view, putting emphasis on the efforts that cities, regions, or countries do in promoting the adoption of the CE paradigm [39]. Furthermore, the implementation of CE may follow a top-down or a bottom-up approach [25]. In the first case, the transition towards CE is mainly driven by regulation and legislation, following a “command and control” principle [1]. In the latter, the transition towards CE is instead mainly driven by the perspective of gathering economic benefits by single economic actors [25].

Following the directives of the Ellen MacArthur Foundation [20], companies who desire to adopt the CE paradigm may convert their value proposition by the means of three CE value drivers. First, the company should offer a solution that increases the utilization of their assets and products, thus pursuing *resource efficiency*. Second, the company should aim to *extend the lifespan* of products. Third, the company should *close the loop*, i.e., enhance multiple product lifecycles of reuse, remanufacturing, and, as an ultimate option, recycling [33]. If appropriately designed, the CE value drivers may bring economic and environmental benefits to the company [3]. Moreover, in order to pursue sustainability, the social dimension of CE must also be considered [39]. Thus, the company should adjust its value proposition to embrace also social aims.

## 2.2. Servitized Business Models

To incentivize companies in adopting CE, previous literature envisages a shift from the sales of products to the provision of services [38]. In this regard, companies should convert not only their value proposition, but also their entire BM [3,18,28,40,41], thus moving towards a servitized one, which is an excellent vehicle to enhance competitiveness and foster sustainability simultaneously [42]. However, moving from products to product service is not only related to the integration of the most advanced service offerings. Indeed, this transformation is a complex concept, both for practitioners and for scholars, and still remains poorly understood. In particular, there seems to be a lack of research related to the transformation needed in the BM elements to successfully move to servitized BMs [18].

The works describing the servitization journey often point out that between pure product sales and pure service provision, a spectrum of different options can exist, where products and services are combined to varying degrees [42]. Over the years, the typology concept, generally understood as delineating types of things where the types are decided conceptually [43], has been used to describe the transition from product to servitized BMs. Existing literature reveals various typologies that could identify the different types of BMs. For instance, Wise and Baumgartner identify four BM types [44]: embedded services, comprehensive services, integrated solutions, and distribution control. This classification is based on service content, but product ownership is not considered. The concept

of product ownership is instead presented in Michelin and Razzoli [45], who distinguish between the provision of tangibles with included lifecycle services, the provision of tangibles under leasing arrangements, and the provision of shared products and function delivery. Baines and Lightfoot [12] observe three different types of services, depending on the focus of the company outcome: in base services, the outcome is focused on the product provision; in intermediate services, it is focused on the maintenance of product condition; in advanced services, it is focused on the delivery of a capability through the performance of the product [12].

Tukker [42], instead, proposes three categories of BMs, namely product-oriented, use-oriented, and result-oriented [42]. This classification of BMs is agreed upon by several authors and refined by others [22,46,47]. Tukker's classification remains the most widely accepted point of reference, which is used extensively in the literature [22,47] and also in this paper. Below, the Tukker's classification is introduced, using the BM perspective to describe each option and its potential impact on the three Ellen MacArthur Foundation CE value drivers [20]:

- *Product-focused BMs*: In this BM type, the main purpose is to deliver tangible value to the customer [42]. Value is considered as an embedded attribute of the product being exchanged, and it mainly refers to the four P's of the marketing mix: price, product, promotion, and place [48]. The product ownership (property rights to the product) is transferred to the customer, while the company can sell a combination of single standard products and industrial services, which are usually not customized. The aim of this kind of services is to improve or restore the functionality of the product, such as through maintenance and repair (basic field services and inspection). As the service is seen as non-core business, the company can define a network of third party service suppliers [49]. Moreover, information exchange is limited, and mostly related to technical and operational aspects. In this BM category, the company has no (or lower) responsibility for product lifecycle, and transactions are often single and independent from each other [47]. However, some extra services may be added [42]. Extended warranties, as well as repair and maintenance contracts can represent a source of value for the customer within these BMs. The main revenue stream is represented by product sales, in which is often included a pre-sales service related component. Thus, product-focused BMs do not change the incentive for companies to maximize the product sales [7]. Therefore, through this BM type it is uncommon for companies to achieve CE objectives, since rarely do the offered solutions increase resource efficiency, extend the product lifespan, or close the loop.
- *Usage-focused BMs*: In this BM type, the customer does not buy the product. In fact, customers pay a fee to gain access to it [42,50]. The company also takes responsibility for providing lifecycle services such as maintenance, repair, and control [49]. Moreover, the company has also a powerful incentive to design a product in terms of which elements can be re-used after the product's useful life. Again, the product should be easy to maintain when a maintenance contract is signed, or for the parts to be easily reused when a take-back agreement is made [18]. Because the company retains the product ownership, and users can change during the product lifetime, the product should allow upgrades, thus achieving a longer lifetime [51]. In this BM type, advanced services, such as remote monitoring and diagnosis, advanced training, consultancy on product-enabled processes, as well as predictive maintenance are crucial [18]. Internal costs for these activities have to be better quantified than in product-focused BMs—leasing or renting products instead of selling them would increase the company costs, since it would require high initial capital investments. Thus, financial resources become critical, and the payback period is often longer than for physical product sales [42]. Usage-focused BMs are more promising than product-oriented ones in achieving CE objectives, since they intensify the use of materials e.g., through sharing [7], thus increasing resource efficiency. If advanced maintenance or take-back agreements are signed, the other CE value drivers (i.e., extend product lifespan and close the loop) may also be pursued through this BM type. However, usage-focused BMs (such as sharing, leasing, pay-per-use) could

bring to a less careful usage by the customer base, leading to a quicker wear and tear [7], thus questioning the pursuing of the second CE value driver.

- *Result-focused BMs*: In this BM type, the customer does not buy the product or system, but pays a variable fee that depends on the achievement of a contractually-set result, in terms of product/system performance or outcome of its usage [42]. Thus, the value is generated by an individualized and integrated combination of products and services to produce the expected results [47]. A field service network is a prerequisite for successful service delivery of traditional and advanced services, where field technicians interact frequently with customers, and customers tend to trust them more. In this sense, online or web-based collaboration systems serve as an additional tool [50]. Payments are generally based on outcome units, which are paid for their results [50]. The core of this concept is that the customer buys the performance, not the product and the related services. Thus, the company is responsible for all lifecycle costs [18]. This, in turn, provides a powerful incentive to design products for CE, following the design policies introduced in Section 2.1. Moreover, the company has the incentive to minimize the overall lifecycle cost, thus minimizing operating costs (for instance, by increasing resource efficiency), extending the product lifespan, and collecting back products to allow multiple lifecycles [7]. Thus, this BM type allows companies to achieve CE by the means of all the three CE value drivers. In accordance with Tukker [7], result-focused BMs may be the most effective ones to move towards CE. However, it is generally difficult to measure outcomes and results in term of product/system performance, and reach an agreement between customer and supplier in this regard.

Table 1 provides a summary of the literature findings regarding the relations among the different servitized BMs and the CE value drivers, as well as the main drawback of each servitized BM type.

**Table 1.** Servitized business models (BM) and their relations with the three circular economy (CE) value drivers.

Servitized BM Type	Circular Economy Value Driver			Main Drawback with Respect to CE Adoption
	Increase Resource Efficiency	Extend Lifespan	Close the Loop	
Product-focused (customers have the product ownership)		+ : After-sales services such as repair, extended warranties, maintenance contracts		This BM type incentivizes companies to maximize product sales, alongside the negative environmental impact of more products that probably will become waste
Usage-focused (customers pay a fee to gain access to a product)	+ : Product sharing among users	+ : Extra-Services such as extended warranties, predictive maintenance, repair + : Design-to-last products + : Upgrade − : Quicker wear and tear due to less careful usage by customers	+ : Take-back agreement + : Design for closing the loop	This BM type could bring a less careful usage by the customers base, leading to a quicker wear and tear
Result-focused (customers pay a variable fee depending on the achievement of agreed results)	+ : Product sharing among users	+ : Extra-Services such as extended warranties, predictive maintenance, repair + : Design-to-last products + : Upgrade	+ : Take-back agreement + : Design for closing the loop	It may be difficult to measure results in terms of product/system performance and reach an agreement between customer and supplier

Key: “+” means a positive effect of the BM type on the CE value driver, while “−” means a negative effect.

### 2.3. The Role of the Internet of Things, Big Data, and Analytics for Servitized Business Models and Circular Economy

Both scientific and grey literature acknowledge IoT, Big Data, and analytics as enablers for the transition towards servitized BMs [52] and CE [4,6,20,21]. While the enabling role of digital technologies for the servitization of companies has been investigated by previous studies (see,

for instance, the work of Ardolino et al. [53]), their specific role as enabler for CE has been quite under-investigated to date [5,23].

The Internet of Things (IoT) technology refers to supplying devices with sensors, which give them the ability to communicate and to become active participants in an information network [52]. The application of the IoT technology turns stand-alone products into smart and connected ones [54]. Allmendinger and Lombreglia [55], in their seminal paper, have pointed out that the monitoring product status and condition is crucial to this regard. Thus, through IoT, companies may obtain real-time remote monitoring of product usage, status, and location [12,13,23]. Therefore, companies have a great opportunity to gain knowledge on how customers are using products, achieving a closer proximity with them [52], and thus transforming the interactions between manufacturer and their customers from negotiation to communication [12,19,56]. When products become smart, companies may upgrade only their digital components, such as the product firmware, thus enhancing product upgradability [52]. Product upgradability may in turn contrast product obsolescence and its resulting material waste, thus enhancing the transition to CE [51]. In their study, Cheng, Barton, and Prabhu [57] have pointed out the crucial role of sensors like radio frequency identification (RFID) in tracing spare parts. Consequently, the IoT technology may also support material tracking [6,29], playing a crucial role and contributing greatly to the collection of end-of-life products and waste management [5], thus helping to close the loop through reuse, remanufacturing, and recycling.

The IoT technology allows companies to collect a large amount of data [5]. Big Data are usually defined in literature through the four V's: volume, variety, velocity, and veracity. In fact, they are characterized by (i) a massive amounts of data generated in a continuous way; (ii) unstructured and distinct formats, such as imaging, texting, and so on; (iii) a high data generation frequency; and (iv) a good quality and a direct and proven application [4,23]. As a result, Big Data cannot be analyzed using traditional software or database techniques, since they are too large and change too much rapidly [23]. Big Data are usually seen in literature as a valid approach to enable a better decision making, if combined with appropriate analytics techniques [23]. In fact, analytics leverages software and data mining techniques to extract useful information from data, by developing business intelligence and decision support systems to identify patterns in the data and make predictions [23,53]. To find the proper application, analytics need to work with large amounts of data [53]. In this case, analytics allow companies to transform data into insights, which provides the basis for a better decision making [52,58]. Thus, the combination between Big Data and analytics can positively advance management towards CE, by feeding sustainability-oriented decision-making processes with the required information [4]. Finally, Big Data and analytics are required in the provision of advanced services, such as preventive and predictive maintenance [12,13,52,54], as exemplified by the Rolls-Royce "Power-by-the-Hour" case [22].

### 3. Research Design, Framework, and Methods

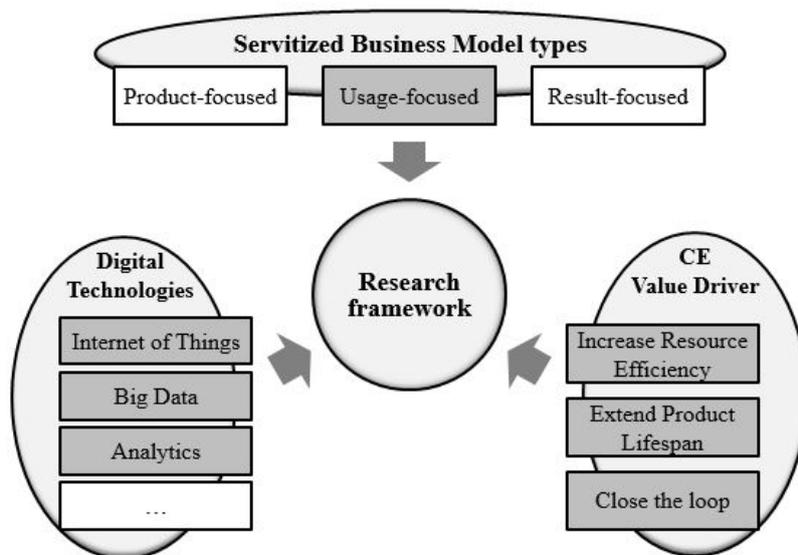
#### 3.1. Research Design

The previous sections have highlighted that, despite a general agreement that digital technologies may speed up the deployment of servitized BMs and the transition towards CE, little attention has been devoted to their specific role. In fact, "how" digital technologies support the transition to CE has been quite overlooked by extant literature. On the other hand, previous studies have investigated how servitized BMs may affect the three CE value drivers (see Table 1). The literature has also addressed the role of digital technologies in the development of servitized BMs [52,58].

Therefore, the research objective lies in the interplay among the three different topics investigated in literature, which are (i) servitized BMs; (ii) digital technologies; and (iii) CE and its three value drivers. More specifically, it was decided to consider only one specific servitized BM type, i.e., the usage-focused one. The literature suggests that in moving away from traditional product-focused BMs, the potential for circular economy increases [7]. Despite the drawbacks

of usage-oriented BMs towards CE, with respect to result-oriented BMs, we decided to focus on usage-oriented BMs, since they are nowadays reaching an ever-increasing diffusion in both the business-to-business (B2B) and business-to-consumer (B2C) sectors, also thanks to the growing popularity of the “sharing” paradigm [3]. Moreover, among the several digital technologies highlighted by the fourth industrial revolution, only IoT, Big Data, and analytics have been considered, in accordance with recent works in this field [5,52,53].

Thus, the study in particular focuses on how IoT, Big Data, and analytics act in the deployment of usage-focused Business Models to increase resource efficiency, extend product lifespan, and close the loop, i.e., to attain the fundamental circular economy value drivers. Therefore, the following research question has been formulated: how can IoT, Big Data, and analytics enable the transition to circular economy at the micro level through the deployment of usage-focused BMs? This research question is addressed by pointing out (through a literature review) how digital technologies support the implementation of usage-oriented BMs, and investigating how such functionalities contribute to the achievement of the three CE value drivers (through an empirical study and contrasting the findings with the literature in the discussion). This is illustrated in Figure 1: the research framework is meant to describe how the functionalities through which IoT, Big Data, and analytics enable usage-oriented BMs affect the CE value drivers.



**Figure 1.** Overview of the research design.

To address the research question at hand, the research steps depicted in Figure 2 were followed. The first step of the research consisted in the analysis of the existing literature in the fields of CE, servitized BMs, and digital technologies (see Section 2). Then, a conceptual framework has been designed (see Section 3.2 below). The framework collects a set of functionalities of servitized BMs that are enabled by the digital technologies being investigated. To explore how these functionalities enable the transition to CE, case study research was chosen as the methodology of the paper. The case study design process is provided in detail in Section 3.3. Findings from the empirical application have been used to fill the conceptual framework, which aims to explain how IoT, Big Data, and analytics act in the deployment of usage-focused BMs to increase resource efficiency, extend product lifespan, and close the loop, thus attaining the three fundamental CE value drivers.

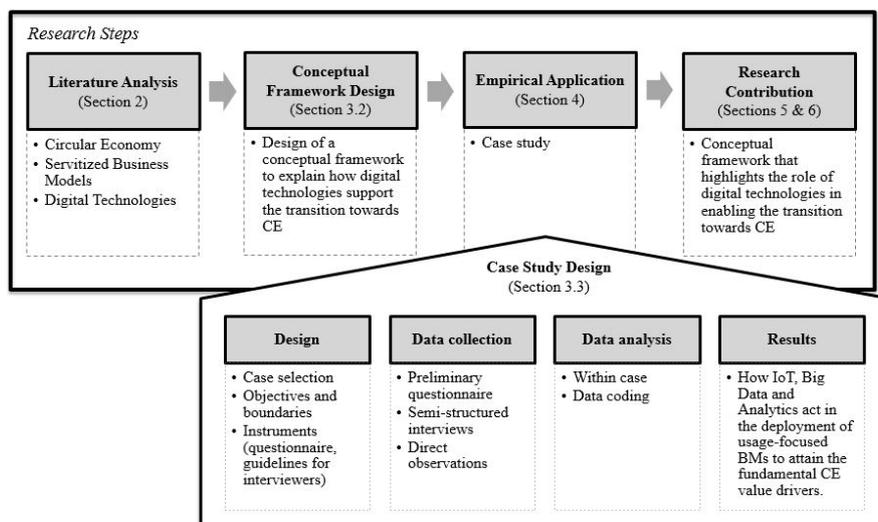


Figure 2. Research design.

### 3.2. The Conceptual Framework: The Functionalities of Digital Technologies in Servitized Business Models

Starting from the main evidences of the literature analysis, a new framework that points out a specific set of functionalities enabled by IoT, Big Data, and analytics in servitized BMs has been designed. More specifically, we identified eight functionalities, namely: improving product design, attracting target customers, monitoring and tracking product activity, providing technical support, providing preventive and predictive maintenance, optimizing the product usage, upgrading the product, enhancing renovation and end-of-life activities. Table 2 illustrates the framework. While the functionalities have been taken from the literature, and their relations with the digital technologies addressed is known from previous studies, the way in which they contribute to CE by achieving the three CE value drivers is the object of the empirical research described in Section 4. Therefore, in Table 2, the columns corresponding to the three CE value drivers are not filled. Each functionality is briefly described in the following, and referenced through a number after the symbol “#”.

First, by equipping products with IoT sensors to collect usage data, and by analyzing them through appropriate analytics, companies may improve the design of their products to better respond to customers’ needs (Table 2, #1) [12,54]. Moreover, an elaboration of the information gathered through IoT from the base of products installed, regarding how customers are using products, allows companies to improve marketing activities (Table 2, #2), with the aim to attract new and targeted customers [13,19,50,52,54]. Through IoT, companies monitor product condition, status, location, and usage; this information must be collected and easily made available to each single customer, in order to enable product sharing between multiple users (Table 2, #3) [4,5,12,13,19,22,52,54]. Moreover, information collected through IoT helps companies and their field network to provide technical support and other services, such as repair, spare parts management, etc. (Table 2, #4) [12,13,52]. Furthermore, the analysis of Big Data by analytics entails the provision of preventive and predictive maintenance (Table 2, #5) [12,13,52,54].

By analyzing the Big Data collected through IoT with appropriate analytics, companies may provide to their customers personalized advice, with the aim to optimize the usage phase (Table 2, #6), such as suggestions on how products should be used in order to reduce their energy consumption [12,50,52,54]. When the product offered becomes smart [54], companies may upgrade only their digital elements, e.g., the product firmware or software, thus enhancing the feasibility of an upgrade (Table 2, #7). Finally, through the IoT technology, companies can access real-time product location and condition. This information may be used for a better execution of end-of-life collection, refurbishment, remanufacturing, and recycling activities (#8) [12,23].

**Table 2.** The conceptual framework. Columns referring to CE value drivers are empty and will be filled through the empirical investigation.

ID	Functionality	Digital Technologies		Ref.	Description	CE Value Driver		
		IoT	Big Data & Analytics			Increase Resource Efficiency	Extend Lifespan	Close the Loop
1	Improving product design	X	X	[12,54]	By collecting usage data through IoT and by analyzing them through appropriate analytics, companies may improve the design of their products to better respond to customers' needs.			
2	Attracting target customers	X	X	[12,13,19,22,50,52,54]	An elaboration of the information gathered from the products installed base (through IoT) regarding how customers are using products allows companies to improve marketing activities, with the aim to attract new and targeted customers.			
3	Monitoring and tracking products activity	X		[4,5,12,13,19,22,52,54]	Through IoT, companies monitor product condition, status, location and usage. To enable product sharing between multiple users, this information must be collected and easily made available to each single users.			
4	Providing technical support	X	X	[12,13,52]	Information collected through IoT helps companies and their field network to provide technical support and other services such as spare parts management, repair, etc.			
5	Providing preventive and predictive maintenance	X	X	[12,13,52,54]	The analysis of Big Data collected through IoT by appropriate analytics entails the provision of preventive and predictive maintenance.			
6	Optimizing the product usage	X	X	[12,50,52,54]	By analyzing with appropriate analytics the Big Data collected through IoT, companies may provide to their customers personalized advice with the aim to optimize the usage phase, e.g., how product should be used to reduce energy consumption.			
7	Upgrading the product	X		[52]	When the product offered becomes smart [54], companies may upgrade only its digital elements, e.g., the product firmware, thus enhancing the feasibility of upgrade.			
8	Enhancing renovation and end-of-life activities	X	X	[12,23]	Through the IoT technology, companies can access in real-time product location and condition. This information may be used for a better execution of end-of-life collection, refurbishment, remanufacturing, and recycling activities.			

### 3.3. Case Study Research

Given the exploratory nature of the research and the fact that the body of knowledge about CE is in its infancy [4,29], a case study was considered as the most suitable methodology for the empirical investigation [59]. In fact, case studies allow “how” questions to be answered with a relatively full understanding of the complexity and nature of the phenomenon [60]. Moreover, the case study methodology is suitable for exploring the detailed working of an organisation [12], and qualitative case studies are needed at the initial stage of investigation [4].

A research protocol was utilized in order to enhance reliability and validity of case research, encompassing case study design, data collection, data analysis, and results formalization [59]. According to the research protocol, a judgmental sampling technique was adopted to select a company [61], following three main criteria. First, the company should have adopted IoT, as well as Big Data and analytics, for the provision of its offering. Second, the company should adopt a usage-focused BM, in accordance with the classification provided in the Background section above. Third, the company should have adopted the CE paradigm into its vision or mission. Furthermore, it was decided to select a company operating in a sector particularly promising for the adoption of the CE paradigm. To this regard, the household appliances sector was chosen [3,36]. Thus, one company who retails household appliances was contacted and accepted to participate in the study. However, to protect its business interest, the company identity has been concealed here.

Following the research protocol, data collection was performed through different methods. A preliminary questionnaire was utilized to gather general information about the context in which the company operates, the turnover, the number of employees, and so forth. Semi-structured interviews were used to gather other specific data related to the company BM, the digital technologies adopted, and the company CE involvement. To this regard, the research protocol included the “guidelines for interview”, i.e., the document outlining the topics to be covered by the interviewers during each interview, along with the questions to be asked and the data to be collected [60]. Each interview lasted between one and two hours. To enhance the study’s reliability, more than one researcher participated simultaneously in the interviews. Each interview was transcribed and coded, and the text was eventually sent back to respondents for clarification and validations [59].

Data were analyzed within the case, in order to allow researchers to become intimately familiar with the case as a stand-alone identity [60]. Moreover, the case story was built by visual displaying and highlighting the sequence of events coded [60]. To enhance construct validity, all the gathered information was triangulated with secondary sources, such as the company website and other company documentation [60]. Then, the last phase of the research protocol was conducted, looking for explanations of the coded sequence of events, and thus trying to answer the research question. Findings from the case study have been used to fill the conceptual framework designed in Table 2. The case study is presented in the following.

## 4. The Alpha Case

### 4.1. Company Overview and Usage-Focused Business Models

Alpha is a household appliance retailer that operates in Northern Europe. It provides washing machines, dishwashers, and tumble dryers, adopting a servitized business model. In fact, instead of selling appliances to households, the company offers contracts (subscriptions) that give customers the right of access and usage of the appliance under a pay-per-month or a pay-per-use scheme. Besides the traditional subscription offering, the company has recently started their first “shared laundry” pilot project, to test the feasibility of sharing appliances among households. The pilot project has involved about 100 users, who have agreed to share washing machines and washer-dryers. Thus, the company adopts three different servitized BM options: (i) a pay-per-month solution; (ii) a pay-per-use solution; and (iii) a sharing solution. These three options may be classified as three different forms of the usage-focused BM type described in Section 2.

The company, founded in 2014, employs less than 10 employees. As of 2016, Alpha had achieved an installed base of more than 1000 products, which generate a turnover of about €0.5 million.

Alpha generates customer value through a reduction of the initial investment required to access to the appliance performance [62]. Indeed, the acquisition, transportation, and installation costs are included in the fee. Thus, users may access a highly efficient appliance directly at their home, without having to pay for its initial price, which is typically high. Moreover, since the usage cost affects more than the 60% of the total cost of ownership of washing machines [63], Alpha is able to guarantee a lower total cost to its customers, offering appliances characterized by low energy and consumable consumption [62].

Since in usage-focused BMs, the company is usually responsible for all the product lifecycle costs [62], products may be designed for CE (see Section 2.1). However, Alpha does not execute the design phase of the appliances internally, given its retailer role. Conversely, the company can count on a partnership with a high-quality appliance manufacturer, who provides highly efficient products. Moreover, a network able to perform field support (e.g., transport, repair, maintenance, upgrade, collection, etc.) is a prerequisite for a successful delivery of the company offering. As in the case of design, Alpha does not perform these activities internally, but can count on a strong relationship with a logistics and technical service provider.

When users end the subscription, the appliance is collected by the company. A full performance check is executed and, after that, Alpha provides the appliance to a new user, within a new subscription. When appliances become technologically obsolete, they are collected and replaced—old appliances are repaired, refurbished, and cleaned. When they become energy inefficient, they are sent to secondary markets, such as developing countries.

#### 4.2. Digital Technologies in the Alpha Case

To deliver its usage-focused BMs, Alpha supplies an IoT kit developed in-house to households. This IoT tool connects appliances to the internet through a plug-and-bridge instrument. Thus, the kit transforms stand-alone appliances into smart and connected products [54], allowing Alpha to leverage IoT, Big Data, and analytics in the provision of its usage-focused BMs. In fact, digital technologies enable the eight functionalities considered in the framework (see Table 2). Empirical evidence shows that each functionality, in turn, allows Alpha to achieve CE objectives by the means of the three CE value drivers [20].

Thanks to its IoT tool, Alpha gains insights on how households use their appliances. Literature suggests to use this information to improve the design of products [12,54]. However, since the design phase of the appliances provided by Alpha is not performed internally, this functionality has not been observed empirically. Nevertheless, design policies introduced in Section 2.1 may be pursued, in order to design products that are easier to maintain, upgrade, disassemble, and recycle. This product re-design thus extends product lifespan, as well as closing the loop.

Moreover, an elaboration of the information gathered from the base of products installed regarding how customers are using those products allows companies to improve marketing activities, thus attracting new target customers [50,52,54]. In the Alpha case, the company is able to learn the users' habits regarding appliances usage, such as when they prefer to use the appliance, the appliance load, etc. Thus, Alpha may adapt its offerings to the actual usage of appliances by households. Therefore, a marketing activity that highlights these characteristics may increase the number of users who adopt Alpha's CE offering. Therefore, this functionality increases resource efficiency, since appliances provided by Alpha are high-efficiency and sometimes shared among several households. It also extends product lifespan, since appliances are repaired and maintained, following the CE hierarchy [33], and closes the loop, since collected appliances are renovated, and appliance components are disassembled and reused.

The IoT technology enables the tracking and monitoring of product activity during the usage phase [4,5,12]. Alpha uses this functionality to control users' activities on products, thus discouraging

careless behavior that may lead to a quicker wear and tear, and to enable appliances sharing between multiple households. In fact, in order to share the same appliance within multiple users, real-time data regarding, e.g., the availability of appliances (free or busy) must be collected and shared among households. Sharing, in turn, increases product utilization. Thus, this functionality increases resource efficiency. Moreover, this functionality extends the product lifespan, since improper user behavior during product usage, which may lead to a quicker wear and tear, is prevented.

The information gathered through IoT is also useful for providing better technical support in the field [13,52]. The analysis of this information, by the means of appropriate analytics, provides a useful support for external Alpha technicians. For instance, repair and spare parts management is improved by learning which, among the appliance components, breaks down with the greatest frequency. A better execution of these activities extends the product lifespan, thus affecting the related CE value driver.

Moreover, an appropriate analysis of Big Data, performed by analytics, entails the provision of preventive and predictive maintenance [12,52,54]. For instance, Alpha is able to know the expected life of components that fail most frequently, when working in operational fields (i.e., at the households' houses). Again, this information may be utilized for the execution of preventive and predictive maintenance. This kind of service, in turn, extends the product lifespan.

Monitoring and analyzing information regarding the use phase allows the company to optimize the product usage [12,50]. For instance, when Alpha offers the access of its washing machines, the company monitors the consumption of electricity, water, and detergents, as well as the washing load, number of cycles, etc. The analysis of these Big Data enables Alpha to know the usage pattern that reduces the consumption of appliances, and to compare it with each specific household's consumption habits. Therefore, Alpha may provide personal advice, such as a better washing cycle duration or the best washing cycle load to reduce energy and water consumption. More specifically, a mobile application provides hints to each user about when to use fewer detergents, as well as how to reduce water and energy consumption. Users are therefore incentivized to reduce their washing environmental impact, because if they decide to follow this tailored advice, they are awarded with a fee reduction. Thus, this feature contributes to increase the appliances resource efficiency.

Making products smart [54] entails an easier product upgrade for Alpha. In fact, Alpha is able to remotely upgrade only the firmware that controls the appliance's usage of consumables, thus incorporating the most up-to-date programs. This, in turn, achieves a reduction of consumables. Therefore, this feature increases resource efficiency. Moreover, this feature extends the product lifespan, since old appliances remain competitive for a longer time, thus postponing their replacement.

At the end-of-life, IoT enhances renovation and end-of-life activities [12,23]. Indeed, Alpha knows the appliance position in real time. Therefore, it may use this information when each subscription ends, to organize better collection activities. Moreover, information regarding product status and condition may be useful to enhance other closed-loop activities, such as refurbishment, remanufacturing, and recycling. For instance, knowing the condition of components or other aspects, such as the number of usage cycles carried out, provides insights regarding which components should be substituted in the renovation process. Thus, this feature enhances closing the loop.

The empirical findings are summarized in Table 3, which provides a preliminary mapping of the linkages between the eight functionalities, enabled by digital technologies and the CE value drivers, in the Alpha case. Moreover, each functionality has been associated with the main product life cycle phase affected, distinguishing between three stages: (i) beginning of life, which includes design and production activities; (ii) middle of life, which includes logistics (distribution), use, service and maintenance; and (iii) end of life, which includes reverse logistics and "renovation" activities such as reuse (with or without upgrade), remanufacturing, and recycling [64].

**Table 3.** Empirical findings: linkages between the functionalities of Alpha usage-focused BMs and the CE value drivers.

ID	Functionality	Product Life Cycle Stage	Empirical Evidences from Alpha Case and Role for CE	CE Value Driver [20]		
				Increase Resource Efficiency	Extend Lifespan	Close the Loop
1	Improving product design	Begin of life	This functionality has not been encountered in Alpha case, since the company does not perform this activity internally.			
2	Attracting target customers	Begin of life	Thanks to an elaboration of the information gathered from the Alpha installed base, the company may improve its marketing activity. This, in turn, increases the number of users that access the Alpha sustainable offering, thus enhancing resource efficiency, extending lifespan and closing the loop.	X	X	X
3	Monitoring and tracking products activity	Middle of life	Through IoT, Alpha monitors the appliances condition, location and usage. This is an essential requirement for enabling appliances sharing between multiple households. Therefore, it increases the product utilization, resulting in an improvement in resource efficiency. Moreover, product monitoring prevent wrong users' behavior in product usage, which may lead to a quicker wear and tear. Thus, this functionality extend product lifespan.	X	X	
4	Providing technical support	Middle of life	Information collected through IoT helps Alpha and its field network to provide technical support and other services such as spare parts management, repair, etc. This, in turn, extends the product lifespan.		X	
5	Providing preventive and predictive maintenance	Middle of life	The analysis of Big Data by appropriate analytics entails the provision of preventive and predictive maintenance. For instance, Alpha knows the expected life of appliances components that fail most frequently while working in an operational field (i.e., the households' houses). This information may be utilized for the execution of preventive and predictive maintenance. Thus, the lifespan of the product is extended.		X	
6	Optimizing the product usage	Middle of life	By analyzing with appropriate analytics the data collected through IoT, Alpha knows the best operational way that reduces the consumption of appliances consumables. Thus, by comparing it with each user's habits, Alpha provides personal advice to its customers (by the means of the Mobile App) in order to reduce the consumption of consumables. This feature contributes to increase resource efficiency.	X		
7	Upgrading the product	End of life	Thanks to the provision of smart products, Alpha may upgrade only the digital part of the appliances, i.e., the software that controls the appliances usage phase. The aim is to upgrade the appliance firmware, in order to incorporate the most up-to-date programs, which allows achieving a reduction of consumables. Therefore, resource efficiency may be achieved, by the means of a reduction in the appliances consumables. Moreover, also the lifespan of the appliances is extended, since old appliances remain competitive, and their replacement is postponed over time.	X	X	
8	Enhancing renovation and end-of-life activities	End of life	Through the IoT technology, Alpha knows in real-time the product location and condition. Thus, Alpha may use the information regarding product location for a better organization of the collection activities when subscription ends. Moreover, the information regarding products and components status may be used for a better performance of other CE end-of-life activities such as refurbishment, remanufacturing, recycling. This, in turn, enhances closing the loop.			X

## 5. Discussion

The empirical findings provided by the Alpha case have been used to fill the conceptual framework designed in Table 2, and are discussed in the following, where we address how the functionalities illustrated in the framework interact with the three CE value drivers.

Companies may improve the design of their products (Table 2, #1) to respond better to customers' needs, by collecting usage data through IoT, and by analyzing them through appropriate analytics [12]. In this case, products can be redesigned to be maintained, upgraded, disassembled, and recycled in an easier way [30,37], thus extending products lifespans as well as closing the loop through repair, remanufacturing, and recycling.

In the same way, companies may improve marketing activities (Table 2, #2), by elaborating the information gathered from the installed base (through IoT) regarding how customers are using products [13,19]. The overall aim is to attract new and targeted customers, who access the CE offering instead of the traditional one. Generally, the CE solutions intrinsically increase resource efficiency, extend product lifespan and close the loop [20], as exemplified by the Alpha case. Thus, digital technologies, in this case, may attain all the three CE value drivers.

Moreover, companies through IoT may monitor the product condition, status, location, and usage (Table 2, #3) [12,52], thus discouraging careless users' behavior that may lead to quicker wear and tear—therefore, product lifespan is extended. This monitoring and tracking product activity also allows the company to introduce sharing BMs, because when products are shared among several users, the information regarding product condition, usage, status, etc., must be collected and made available to each single user. Sharing, in turn, increases the product utilization, thus resulting in an improvement in resource efficiency [42].

Companies and their technical assistance field network may improve the provision of technical support and other services, such as repair, assistance, spare parts management, etc. (Table 2, #4), thanks to the analysis of Big Data collected through IoT [12,52]. A better execution of such services extends the product lifespan, as exemplified by the Alpha case.

Moreover, the analysis of Big Data collected through IoT by appropriate analytics entails the provision of preventive and predictive maintenance (Table 2, #5), as exemplified by the Rolls-Royce and the Alpha cases [12,54]. Thanks to the execution of this advanced maintenance, the lifespan of the product may be extended.

Furthermore, companies may provide to their customers personalized advice with the aim of optimizing the usage phase (Table 2, #6), through an analysis of the Big Data collected by the IoT sensors [50,52]. This feature helps increase the resource efficiency, as shown by the Alpha case.

When the products offered become smart [52,54], companies may “replace” only digital elements, such as the product firmware or software, thus enhancing the feasibility of upgrading (Table 2, #7) in a remote way [51]. Upgrading generally allows a reduction of the product consumables (e.g., energy) during the usage phase, thus increasing resource efficiency. Moreover, the lifespan of the product may also be extended, since with an upgrade, old products remain competitive, and their replacement is postponed over time.

Finally, companies may execute end-of-life collection, refurbishment, remanufacturing and recycling activities in a proper way (Table 2, #8), because thanks to IoT, they can access real-time product information, e.g., geo-localization and condition [23]. Therefore, collection activities when products reach end-of-life may be optimized, since companies know each product location in real time. In addition, other renovation activities, such as remanufacturing, may be improved, since remanufacturers know product status as well as the expected residual life of each “smart” component (thanks to analytics), which is an important task to ensure that the component may maintain its reliability for another lifecycle [35]. This, in turn, attains closing the loop.

Thanks to the generalization of the empirical findings provided by the Alpha case, the framework depicted in Table 2 has been completed, and the final version is presented in Table 4. More specifically, the framework highlights the role of the digital technologies investigated (i.e., IoT, Big

Data, and analytics) in enabling the transition towards CE, by pointing out the relationship between the functionalities of usage-focused BMs and the CE value drivers. The framework encompasses four dimensions, which are the digital technologies investigated (i.e., IoT, Big Data, and analytics), the eight identified functionalities of usage-focused business models, the product's life cycle phase (i.e., begin of life, middle of life, end of life), and the three circular economy value drivers (increasing resource efficiency, extending product lifespan, and closing the loop).

From a digital technologies perspective, it can be noted that only two of the eight functionalities presented may be enabled through IoT without investing in appropriate analytics to analyze the data. These two functionalities are monitoring and tracking products activity and upgrading the product. These functionalities allow for increasing resource efficiency and extending the product lifespan. Therefore, it is important to stress that, if companies want to close the loop (i.e., attain the third CE value driver), they must invest on technologies able to analyze the Big Data collected.

From a life-cycle perspective, digital technologies play a relevant role in enabling the transition to CE at each life cycle stage. However, four functionalities out of eight come into play at the middle of the product life, i.e., during the usage phase of the product. This is consistent with the existing literature in the fields of servitization and digital technologies, which shows that when products become smart, the value generation shifts from the initial stages of design and production to the usage phases, involving the so-called "value-in-use" [19,54]. However, the framework shows that none of the functionalities covering the middle of life is related to the third CE value driver, i.e., closing the loop. Therefore, companies who want to invest in digital technologies in order to close the loop must intensify their efforts at the beginning of life, e.g., following appropriate strategies such as design-for-remanufacturing or design-for-recycling [35,37], or directly at the end of life, e.g., by implementing appropriate reverse logistics [32].

From a CE value driver point of view, it can be noted that six functionalities out of the eight help extend product lifespan, four increase resource efficiency, and only three close the loop. Thus, extending product lifespan seems to be the most common way to enable CE when investing in IoT, Big Data, and analytics.

Finally, the framework of Table 4 should be read in the light of the usage-focused BM type drawback highlighted in the Background section (see Table 1). In fact, the literature points out that usage-focused BMs could lead to careless product usage by the customer base, leading to quicker wear and tear, since users no longer own the products [7,42]. However, this drawback is prevented thanks to the IoT monitoring functionality: when products become smart and connected [54], companies can monitor their usage, and inappropriate behavior by the users is discouraged. Therefore, it can be concluded that, despite what acknowledged by previous research, usage-focused BMs can also effectively lead to a transition towards CE, if appropriately supported by digital technologies.

**Table 4.** Final version of the conceptual framework, which highlights the role of digital technologies in enabling the transition towards CE.

ID	Usage-Focused BMs Functionality	Digital Technologies		Product Life Cycle Stage	CE Value Driver [20]		
		IoT	Big Data & Analytics		Increase Resource Efficiency	Extend Lifespan	Close the Loop
1	Improving product design	X	X X	Begin of life		X	X
2	Attracting target customers	X	X X	Begin of life	X	X	X
3	Monitoring and tracking products activity	X		Middle of life	X	X	
4	Providing technical support	X	X X	Middle of life		X	
5	Providing preventive and predictive maintenance	X	X X	Middle of life		X	
6	Optimizing the product usage	X	X X	Middle of life	X		
7	Upgrading the product	X		End of life	X	X	
8	Enhancing renovation and end-of-life activities	X	X X	End of life			X

## 6. Conclusions

### 6.1. Contribution to Research

The literature acknowledges digital technologies' enabling role for the deployment of both servitized BMs and CE by companies [12,14,19–21]. However, how digital technologies favor the transition towards CE has not been analyzed in detail yet [5], thus requiring more empirical investigations in the field [5,23]. To contribute to building knowledge on this aspect, this paper focuses on how IoT, Big Data, and analytics act in the deployment of usage-focused BMs to attain the three fundamental CE value drivers pointed out by literature, i.e., increasing resource efficiency, extending product lifespan, and closing the loop [20]. More specifically, this study has pointed out eight digital technologies functionalities enabling the transition towards CE:

1. Enhancing product design, thus extending product lifespan and closing the loop.
2. Enhancing marketing activities by attracting target customer segments, thus reaching a wider diffusion of the CE offering and therefore creating value through all the three CE value drivers.
3. Allowing the monitoring and tracking of product activity, thus preventing incorrect usage behavior and enabling the sharing of products among multiple users, extending product lifespan and increasing resource efficiency.
4. Enhancing the provision of technical support, thus extending product lifespan.
5. Allowing the provision of preventive and predictive maintenance, thus extending product lifespan.
6. Optimizing the usage of the product, thus increasing resource efficiency.
7. Enhancing product upgrading, therefore increasing resource efficiency and extending product lifespan.
8. Enhancing the execution of renovation and end-of-life activities such as refurbishment, remanufacturing, and recycling, thus closing the loop.

These eight functionalities point out the important role that IoT, Big Data, and analytics play at each product life cycle stage (i.e., beginning of life, middle of life, end of life) as an enabler of the CE paradigms in usage-focused BMs, by means of the three CE value drivers. This role has been investigated in practice through a case study.

This paper adds to current research, since it highlights the relationship between IoT, Big Data and analytics, the product life cycle stage, the three CE value drivers, and the functionalities of usage-focused BMs. Thus, the paper develops an original conceptual framework (Table 4) to operationalize the linkages between the above-mentioned digital technologies and the three CE value drivers. More specifically, the conceptual framework provides the following contributions.

First, it shows that, in order to move towards CE, companies should couple investments in IoT with Big Data and analytics technologies. In fact, only two out of the eight functionalities presented are enabled by implementing the IoT technology alone, and none of them allows for closing the loop.

Second, the framework shows that four out of eight functionalities concern the usage phase of installed products (middle of life). These functionalities act on resource efficiency increase and lifespan extension, but not on the third CE value driver (closing the loop). The latter is instead enabled by functionalities that come into play in the initial or final product life cycle stage. Therefore, to close the loop, companies should rely on functionalities acting at the start and at the end of product life.

Third, the framework shows that extending product lifespan is the CE value driver most impacted by IoT plus Big Data and analytics, implying that companies may achieve great benefits in this area.

Finally, the paper adds to current research since it shows how digital technologies help overcome the drawback of usage-focused BMs to achieve CE. Indeed, the IoT functionality to monitor product usage prevents the risk of less careful usage by customers, which otherwise may lead to a quicker wear and tear. Therefore, even though result-focused BMs were recognized by previous literature as

the most promising ones for introducing the CE paradigm, usage-focused BMs can also effectively lead to a transition towards CE, if appropriately supported by digital technologies.

### 6.2. Managerial Implications

The paper also constitutes a useful reference for managers who desire to start converting the BMs of their companies towards servitization and CE.

As a first contribution, this paper provides managers with a clear understanding of the role of IoT, Big Data, and analytics in the transition towards CE. Such increased conceptual clarity may support a full exploitation of the potential of these digital technologies in the company.

Moreover, the identification of the relations among digital technologies, CE value drivers and life cycle phases allows managers to align their company strategy to the desired path, in order to achieve CE at the micro level. Managers may use the conceptual framework developed in this paper in order to design a BM digitalization path, by purposively choosing a set of functionalities of usage-oriented BMs. More specifically, the framework shows, for each functionality, (i) which digital technology should be adopted, i.e., if it is required to invest in only the IoT technology, or if the IoT sensors must be combined with analytics to analyze the collected Big Data; (ii) which life cycle phase should be affected, thus giving an idea about the order of magnitude required by the digitalization path; (iii) which CE value driver would be attained, thus explaining how CE should be reached with the digitalization path.

### 6.3. Limitations and Future Research Directions

The study has some limitations. Since only one case study has been performed, generalization is difficult to achieve [60]. Moreover, only a small number of digital technologies from the wider range of those impacted by the fourth industrial revolution have been explored in this study. For instance, this paper has not investigated the role of technologies such as additive manufacturing, cloud computing, cyber-physical systems, and augmented/virtual reality. Furthermore, only BMs included in the usage-focused BM type have been investigated empirically.

All these limitations provide additional avenues for research. First, future studies should address a wide empirical sample, to validate the findings from this paper with additional qualitative data. Moreover, future research may comprise other 4.0 technologies, to give a broader view on the role that digital technologies play in enabling the transition towards CE. Finally, additional emphasis should be put on other BM types, such as product-focused and result-focused ones. Table 1 has provided some specific drawbacks of each BM type, which gives potential indications for future research. Through a more detailed formalization of the characteristics of such BMs, their potential role in a CE approach could be more thoroughly investigated.

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