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Sustainable cycle-tourism for society: Integrating multi-criteria decision-making and land use approaches for route selection

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ABSTRACT

Cycle tourism is a sustainable active vacation, which is quickly growing in recent years. Although it has several benefits for society and users (e.g., social connections, amusement, and physical and mental health), cycle tourism requires an adequate route network to enjoy destinations with historical and landscape peculiarities. Past literature mainly investigated motivations and preferences for cycle tourists and proposed optimisation methods in planning routes. However, applying assessment methods for prioritising cycle-tourist routes is a seldom-explored topic. This study aims to address this gap by applying an integrated method for evaluating and prioritising cycle routes, searching for a compromise between route characteristics, service provided to users, and natural and building contexts crossed. It jointly includes Multi-Criteria Decision Methods (MCDMs) and a land use approach: AHP determines the weights of criteria and parameters describing cycle routes; GIS elaborates spatial analysis of parameters; ELECTRE I and VIKOR help find a compromise solution amongst different cycle routes. The integrated method involved a panel of experts to collect data, and it is applied to the wide-study area of Franciacorta (Italy). Some comparisons with other MCDMs are made to justify the results. The findings could support multi-institutions prioritising cycle route alternatives in deciding their building.

1. Introduction

Cycle tourism is an emerging and growing model of active vacations (or slow tourism) that joins cycling and urban sustainable development benefits. It is a wholesome activity that contributes significantly to the physical and mental health of users, reduces air and noise pollution, greenhouse gas emissions, and favours an active lifestyle which, likewise, improves public health (Filimonau, Dickinson, Robbins, & Reddy, 2013; Kim & Hall, 2022; Márquez, Cantillo, & Arellana, 2021). Cycle tourism saves energy and potentially contributes to reduce 86% of the environmental impact due to transport modes of the tourism sector (Patterson, Niccolucci, & Bastianoni, 2007). Therefore, it can decrease the effects of the tourism-traffic paradox, i.e., it lessens the incompatibility between the high tourist intensity and high environmental sensitivity typical of many tourist destinations (Bakogiannis et al., 2020a).

Cycling tourism tends to have an experiential emphasis on well-being related to environmental, social, and cultural contexts in which the travel occurs: time spent in destinations is often longer and dispersed across a wider range of smaller cities, towns and regions (Etminani-Ghasrodashti, Paydar, & Ardeshiri, 2018; Ritchie, 1998; Xu, Yuan, & Li, 2019). For instance, cycle tourism based on a single origin-destination deteriorates in favour of a "transit" valorisation between place and place (Moscarelli, Pileri, & Giacomel, 2017). Rural development initiatives and local economies can be inevitably regenerated: traditional culture and social relations become relevant priorities, and economic benefits are distributed throughout a larger territory (Bakogiannis et al., 2020b; Cox et al., 2012; Han, Heejung Lho, Al-Ansi, & Yu, 2020; Lumsdon, Downward, & Cope, 2004). Moreover, the kinaesthetic experience of cycle tourism can positively impact daily urban mobility: several people can shift towards active mobility or public transport after a cycling tourism experience (Meschik, 2012; Schlemmer, Blank, Bursa, Mailer, & Schnitzer, 2019).

The global cycle tourism market size is estimated to 2030 about 1291 million dollars, according to a growth rate of 2021–2030 equal to +14.78% (Precedence research, 2020). However, planning, assessing, and managing routes (infrastructures) for cycle tourists is a challenge. Tourism-related cycle infrastructure projects have been and are currently being planned and implemented in several countries (Chen, Li, Wang, & Jiang, 2018; Han et al., 2020; Procopiuck, Silva Segovia, &

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Procopiuck, 2021). The common factor is the provision of an adequate infrastructure that can satisfy the tourists' preferences, which vary according to their viewpoints (Watthanaklang, Ratanavaraha, Chatpattananan, & Jomnonkwao, 2016). However, Robartes, Chen, Chen, and Ohlms (2021) highlighted some barriers to plan and implement bicycle infrastructures. Barriers concern technical (e.g., geometric and typological constraints, construction of knowledge frameworks) and economic (e.g., lack of funding, right-of-way acquisition, ordinary management) issues. They concern assessment-decision issues due to its multi-objective and multi-stakeholder features: context peculiarities change case by case, users' types and preferences are several, and the geographical context is generally wide-scale multi-institution. Therefore, barriers to cycle tourists infrastructure increase in the programming and implementation phases, and the multiplicity of institutions involved (if not executors of national or regional governance) could invalidate the development of the cycle tourism upstream (Kapera, 2018).

Consequently, previous studies focused on (i) motivations and preferences of users (e.g., Deenihan & Caulfield, 2015), (ii) optimisation methods in planning cycle-tourist routes (e.g., Zhu, 2022), and (iii) qualitative analysis from previous experiences to propose integrated and collaborative planning strategies amongst territories (e.g., Petino, Reina, & Privitera, 2021). However, the application of assessment methods in programming cycle routes for cycle-tourists is a few explored realm of research, but it has practical outcomes in terms of decision-makers' ability to plan, implement and manage a sustainable cycle-tourist network.

This research addresses this issue by proposing an integrated approach for evaluating and (possibly) prioritise several cycle routes as a compromise amongst route characteristics (Infrastructure issue), service provided to users (People issue), and natural and building contexts crossed (Environment issue). Therefore, it contributes to the sustainable development of future cities by promoting a growing model of active vacations in an Infrastructure-People-Environment triple-facet relationship, which provides a holistic people-centred and place-based approach to evaluate cycle tourism routes and guarantee user experience (Tsoi & Loo, 2023). Moreover, it has a high-level direction for public administrations engaged in planning novel cycle tourist infrastructure systems by an aiding-making tool to serve public interests and support various sustainable economic activities. Owing to many conflicting criteria (e.g., route characteristics, users' types) and alternatives, this approach is framed within a hybrid multi-criteria decision-making method (MCDM). Criteria (and related parameters) mainly concern land use features because (i) they represent a crucial issue in route attractiveness and (ii) to the best of our knowledge, no study has been carried out applying a spatial analysis with a focus on accessibility, e.g., to points of interest. Therefore, the innovation does not consist in the methodological approach but in the focus on land use criteria, which must be considered in the literature.

Following an extension of Carra et al. (2023), this approach integrates MCDMs and Land use methods, which are key to tourist demand. Specifically, first, the Analytical Hierarchy Process (AHP) is used to determine the weights of criteria (and related parameters) of cycle routes. Criteria and parameters are known or built through participatory mapping. Second, the Geographical information system (GIS) is adopted to elaborate spatial analysis of criteria and parameters (e.g., accommodation in users' services and peculiarities in natural and building contexts). Third, the *ELimination Et Choix Traduisant la REalitè* I (ELECTRE I) method is adopted to find a good compromise solution amongst different alternatives for cycle routes. Next, *VlseKriterijuska Optimizacija I Komoromisno Resenje* (VIKOR) is applied to refine the results. The method is applied to the wide-study area of Franciacorta – Brescia (Italy[1]), and some comparisons with other MCDMs are made to justify the results.

The findings help support multi-institutions to rationalise and prioritise cycle routes in deciding on their building. Moreover, this method could be implemented in a cycle planning managerial system to better prioritise the building of routes within a tight budget, cross several public administrations, and help achieve sustainable development targets. Another strength is that the method can be applied and replicated in other contexts.

The remaining paper is structured as follows: Section 2 briefly reviews the planning of cycle tourism and some MCDMs. Section 3 presents the method. Section 4 shows the case study. Section 5 illustrates the application of the method for Franciacorta (Italy). Section 6 briefly discusses the results in the context of the literature. Finally, conclusions and further research directions are summarised in Section 7.

2. Theoretical background

In what follows, we review some facets of cycle tourism. Next, we switch to a concise review of multi-criteria decision-making methods. Finally, we report the gaps in the literature.

2.1. Cycle tourism

Comprehension of factors related to users' preferences and methods for cycle-tourist routes selection and assessment is a challenging and complex research topic, which includes a multidisciplinary knowledge of transport planning, landscape, tourism, sociology, and regional planning. Therefore, our review addresses this topic from various disciplines, but it focuses on criteria and methods. Generally, we can classify studies according to three main areas: a first group (U) focused on users, a second (M) on methods, and a third (C) on elements learned from case studies, as shown in Table 1.

The first group focused on comprehending cycle tourists' factors, motivations, behaviour, and preferences to respond efficiently to their needs. The approach was mainly economic and sociological and developed through surveys or diaries. The aim is twofold: (i) building recommendations for economic operators and urban and transport planners to respond to tourist needs efficiently and (ii) qualifying cycle tourism routes or experiences. However, authors have contributed differently to this research area. Ritchie (1998) defined travel patterns, infrastructural uses, and motivations of cycle tourists by examining data collected on the South Island of New Zealand. He highlighted how relevant attributes are sceneries, overall road safety (i.e., alternative routes to main rural highways), accommodations, bike hire/repair shops, and public transport linkages. Downward and Lumson (2001) focused on recreational bicycle visitors to the Staffordshire Moorlands and identified technical (i.e., signage, cycle access, traffic-free and physical challenge) and immaterial factors (i.e., symbolism, sceneries and social dimension). Later developments applied travel diaries to the North Sea Cycle Route, but just 30% of the sample were cycle tourists (Lumsdon et al., 2004). Deenihan and Caulfield (2015) analysed cycle tourists' preferences in Dublin and discovered how tourists were willing to pay for segregated cycle routes with a lane equipped for bicycles. Calvey, Shackleton, Taylor, and Llewellyn (2015) assessed users' opinions and objective vibration data to derive satisfaction and comfort level of cycle

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[1] Italian tourism was about 14% of the national GDP. Cycling was about 6% of the overall national tourist demand (until 15-20% in some Regions), with about 55 million overnight stays in 2019 (Gazzola et al., 2018). International cycle tourists were about 63% and an economic impact of 3 M€ (Isnart-Legambiente, 2020).

Table 1
Literature clustering.

References	Topic	Research focus			Location
		U	*M*	*C*	
Bakogiannis et al. (2020a)	Physical environment motivators	●			Greece
Bakogiannis et al. (2020b)	Businesses activities-related	●			Greece
Calvey et al. (2015)	Engineering condition assessment of cycling infrastructure	●			United Kingdom
Černá et al. (2014)	Modelling optimal attractiveness routes		●		Czech Republic
Deenihan and Caulfield (2015)	Preference for cycle infrastructures	●			Ireland
Di Giacobbe et al. (2021)	Cost-benefit analysis		●		Italy
Di Ruocco et al. (2020)	Decision-maintenance tool of priority interventions		●		Italy
Downward and Lumson (2001)	Recreational cycle tourists’ needs	●			United Kingdom
Gazzola et al. (2018)	Strategies for sustainable development of remote territories			●	Italy
Lumsdon et al., 2004	User profiles and the level of visitor spending	●			United Kingdom
Malucelli et al. (2015)	Modelling optimal attractiveness routes by user classes		●		Czech Republic
Meschik (2012)	Cycle tourist profiling	●		●	Austria
Moscarelli et al. (2017)	Cycle tourism as an urban regenerator activator			●	Italy
Pantelaki et al. (2022)	Choice of public transport as complementary to cycle tourism	●			Italy
Petino et al. (2021)	Strategies in rural territories			●	Italy
Ritchie (1998)	Demand side perspective	●			New Zealand
Scandiffio (2021)	Define parametric itineraries according to seasonal landscape changes		●		Italy
Watthanaklang et al. (2016)	Motivations between different tourist contexts	●			Thailand
Zhu (2022)	Modelling optimal route choices to satisfy cycle tourists’ preferences		●		-

* U = Users; M = Methods; C = Case Studies.

infrastructure and identified the relevance of surface quality. Watthanaklang et al. (2016) focused on motivational factors (i.e., self-development, contemplation, exploration, physical challenge, stimulus seeking, and social interaction) for bicycle use in natural-based tourism (Thailand), comparing different contexts. Results showed how motivations for mountain and sea tourists were different and context-dependent. Bakogiannis et al. (2020a) applied the AHP to qualitative social research to define physical environmental motivators that attract cycle tourists in Greece. They derived the most comprehensive list of factors and highlighted the relevance of appropriate infrastructural (i.e., low slopes, cycle lane, quality of surfaces) and natural elements along the cycle route (e.g., scenic views). Next, Bakogiannis et al. (2020b) focused on business activities and selection criteria preferred by cycle tourists in choosing stores and accommodations. Finally, Pantelaki, Crotti, and Maggi (2022) focused on multimodal transport behaviour between cycle tourism and public transport in Italy. Results showed a large group of cycle tourists (about 45%) expressing strong demand for joint public transport connections, tourism destinations and cycle routes.

The second group of studies proposed/applied methods for evaluating cycle-tourism routes according to different approaches. Although distinct from the previous group, it can overlap regarding derived factors or criteria. Different studies applied optimisation methods. For instance, Černá et al. (2014) proposed a quantitative method to design a cycle tourist network in the Trebon Region (Czech Republic) and provided an economic tool to local administrators. Authors maximised a utility function of the attractiveness of routes (i.e., the sum of points of interest). Constraints included the maximum travel duration and construction budget of cycle routes. Elaboration used a graph of potential cycle routes (i.e., unpaved roads, natural trails, low vehicular traffic), origin-destination and points of interest were selected from a pool of local experts for cycle tourism and territory knowledge. Malucelli, Giovannini, and Nonato (2015) enhanced the method by maximising utility for different classes of users (i.e., gastronomic, cultural, and naturalistic). Similarly, Zhu (2022) maximised points of interest but considered a wider set of utilities (i.e., travel time, bicycle level of service of the trip, number of interactions on cycle routes) and constraints (i.e., monetary and time budget) according to an optimisation multi-objective model. Moreover, the author formulated a derivation of route choices to satisfy cycle tourists’ preferences. Differently, Di Giacobbe, Di Ludovico, and D’Ovidio (2021) introduced an eco-compatible development model to revamp economies and building fabric in the post-earthquake shrinking of the Gran Sasso area (Italy). Elements of valorisation are consolidated, i.e., historical-environmental resources. They presented a Cost-Benefit Analysis of the cycle-tourist network planned according to three criteria: providing dedicated lines, intercepting the greatest number of heritage points of interest, and intermodal exchange. From CBA, the study estimated the minimum number of users to guarantee the effectiveness of the investment/policies. Di Ruocco, Iglesias, Blandón, and Melella (2020) used the most qualitative method based on the project of a greenway of about 600 km in the Cilento National Park as an enhancement strategy for shrinking territories. The authors proposed a qualitative decision-maintenance tool for additive priority interventions. It was based on user and environmental risk, potential strategies, and costs/impact ratio. The priority is a sum of scores acquired from descriptive/numerical values of the same weight. Finally, Scandiffio (2021) proposed a method based on spatial analysis. He applied a GIS-based method and Sentinel-2 data acquisition to define parametric slow tourism itineraries according to seasonal landscape changes (e.g., blooms, foliage, controlled flooding). Although focused on a single aesthetical criterion, the study elaborated an interesting decision-making tool for fruition users year-round. The method has been tested in the historical landscape of paddies between the cities of Turin and Milan.

The last group of works focused on a qualitative analysis of case studies to establish the characteristics of cycle tourists, qualitative and descriptive experiences, and finally, propose strategies for planning and/or designing cycle-tourism itineraries. Through semi-structured interviews, Gazzola, Pavione, Grechi, and Ossola (2018) examined strategies and differences in cycle-tourist development of three Italian cases (Appennine Hill of Colli di Coppi and the mountain area of Varese and Liguria Region). The authors showed the relevant potential of cycle-tourism in the economic and social growth of remote territories, both in preserving the environment. Results highlighted long-term and low-impact strategies, which were easy to implement; however, success depended on structuring a unified strategy, articulated, shared, coordinated and integrated amongst several local authorities. Petino et al. (2021) examined the Taormina–Etna District (Sicily) of 60 municipalities and proposed a collaborative decentralisation of cycle tourist activities from coastal areas to rural areas characterised by socio-economic issues. Moscarelli et al. (2017) proved the cycle tourism strategy as a territorial infrastructure able to activate urban regeneration processes in inland areas. Specifically, authors focused on the urban regeneration of small and medium-sized stations, empty containers mostly unused of ghost buildings or merest *non-lieu* of transit points. The cycle tourist route VENTO showed a mutual development project amongst cycle tourism, rail transit, and urban, regional and social reactivation.

2.2. Multi-criteria decision-making methods

MCDMs have become more prevalent in recent years in assessing transportation systems and projects, with a wide range of applications. Scholars have proposed various MCDMs and fuzzy MCDMs in the past three decades, which differ in the theoretical foundation, question type, and results (e.g., Broniewicz & Ogrodnik, 2020; Macharis & Bernardini, 2015). MCDMs applied to transportation problems can be clustered mainly according to their problem-solving methods. Usually, they include: i) value-based methods, ii) outranking methods and iii) goal-based methods.

Value-based methods are founded on partial or complete compensation of contributing factors. For instance, in the case of a cycle route, a strong performance in user services (e.g., bike grill) can compensate for a weak performance in construction costs. As shown by Broniewicz and Ogrodnik (2020), Simple Additive Weighting (SAW), Analytic Hierarchy Process (AHP) and the Multi-Attribute Utility Theory (MAUT) are amongst the most popular methods. For instance, some applications of SAW and MAUT methods in transportation evaluated public transport companies in a sustainability governance framework in developing countries (Daimi & Rebai, 2022) and best sustainable alternative of urban transportation during design and planning stages (Gulcimen, Aydogan, & Uzal, 2023).

Outranking methods are practised universally in transportation fields. They compare pairs of alternatives for each criterion at hand to determine the preference. Once these preferences are aggregated, these methods favour selecting one alternative over the other. They can consider various preferences, including linear, nonlinear, and threshold, and do not require a standard scale or unit for the criteria. They also enable partial or hazy comparisons, representing how human judgement and decision-making work. However, these methods have some drawbacks. For instance, they can be challenging to comprehend and communicate, particularly for stakeholders or non-experts. Furthermore, they frequently involve intricate parameters, weights, and calculations that might not be clear-cut or understandable. Outranking techniques might only offer a collection of unrelated or undifferentiated options rather than a clear or distinct ranking of the alternatives, necessitating further investigation or discretion. These methods differ accruing to the way the preferences were aggregated. ELECTRE and Preference Ranking Organization METHod for Enrichment of Evaluations (PROMETHEE) are amongst the most popular outranking methods (e.g., Broniewicz & Ogrodnik, 2020). Specifically, the ELECTRE family has captured the attention of many worldwide scholars. For instance, Peng, Wang, and Wu (2019) recently proposed an extended multi-hesitant fuzzy ELECTRE I method for choosing a third-party logistics service. Based on the ELECTRE I method, their study specifically defined three outranking relations of multi-hesitant fuzzy numbers, namely strong dominant, weak dominant, and indifferent relationships. Recently, Chen, Zhu, Zu, Lyu, and Yang (2022) applied a simplified ELECTRE to rank the alternatives of road safety attainment in 11 countries in Southeast Asia. The simplification was operated by applying the net preference concept; moreover, the CRITIC method was applied for weighting methods and Fuzzy C-Means to cluster alternatives with similar characteristics.

Goal-based methods, such as goal or compromise programming, compare the alternatives to a desired or ideal solution and minimise the deviation or distance from this goal. Therefore, the compromise solution is the closest to the ideal. Amongst these methods, Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and VIKOR are amongst the most adopted (e.g., Broniewicz & Ogrodnik, 2020). Both methods are based on an aggregating function representing “closeness to the ideal”, which originated in the compromise programming method. The inability to resolve conflicts and the neglect of factor interactions are the main problems. Güner (2018) applied a model including AHP-TOPSIS to measure public transportation systems’ quality and rank the bus transit routes. Recently, Tian, Peng, Zhang, Wang, and Goh (2021) applied an extended VIKOR method based on a picture fuzzy similarity environment to construct a sustainability evaluation framework for water environment treatment public-private-partnership projects. Kaya, Tortum, Alemdar, and Çodur (2020) integrate a new approach using GIS, AHP, PROMETHEE and VIKOR to rank alternative electric charging station locations.

To summarise, MCDMs are constantly evolving, and recent methodological studies showed that advancements were in the use of fuzzy sets that include the current type of their modification. Moreover, according to Broniewicz and Ogrodnik (2020), and Velasquez and Hester (2013), each MCDM presents advantages and disadvantages; hence, a hybrid (integrated) approach is ever more used in recent research. This approach includes combining some methods or their selected algorithms.

2.3. Literature gaps and motivation

Undoubtedly, all these studies have enhanced the knowledge of cycle tourism. The literature showed multiple factors that characterise it, and they are often recurrent amongst the different studies. The analysis showed a general prevalence of studies orientated on user preferences. In addition, a lot of MCDMs could be applied for prioritising cycle routes.

However, the literature highlights some gaps.

First, even if MCDM approaches have been applied to provide a weighted rank amongst criteria and in the planning of routes (Bakogiannis et al., 2020a), no specific application of this method results in the selection and ranking of cycle routes. Second, the integration with a land use approach by applying a spatial analysis GIS-based to support MCDM still needs to be investigated. Third, even if previous literature profiled cycle-user tourists, no research defined target users in selecting criteria, considering a generical cycle tourist. Specifically, several authors did not define the type of tourist cycle user, considering, in the same way, leisure and competitive cycle tourists, or, again, infrequent, occasional, and frequent users and sportive, as opposed to what was suggested in Ritchie (1998). Fourth, several authors suggested the involvement of different stakeholders to help in evaluating criteria and priorities planning interventions (e.g., Gazzola et al., 2018; Petino et al., 2021). However, studies have yet to apply participatory mapping and evaluate cycle-tourism routes according to the engagement of stakeholders of a multi-institution-wide-area system. Finally, few previous studies evaluated proximity scale to points of interest; generally, they have adopted main descriptive values or Euclidean distances (e.g., not exceeding 5 km in Di Ruocco et al., 2020) whose measurement is mostly unknown.

Therefore, despite this high-quality literature, research on prioritising cycle-tourist routes is still emerging. Thus, this study aims to cover these gaps.

3. Method

The integrated method of MCDM and Land use approach is conceived as an aiding decision-making tool to help prioritise cycle routes for multi-institutions in the area-wide planning.

The method is organised into four main phases (and seven related steps) according to the scheme of Fig. 1. Specifically, Phase I identifies the cycle route alternatives and a set of criteria related to types of cycle tourists. Moreover, it engages several stakeholders to collect their opinions about each criterion. Phase II collects a service mapping in a GIS tool and processes criteria in spatial analysis. Finally, Phase III combines and applies existing and consolidated (AHP) and European methods (ELECTRE I and VIKOR) to achieve the best compromise solution amongst alternatives. The AHP is selected for factor-weighing criteria and sub-criteria. The ELECTRE I is incorporated as it can

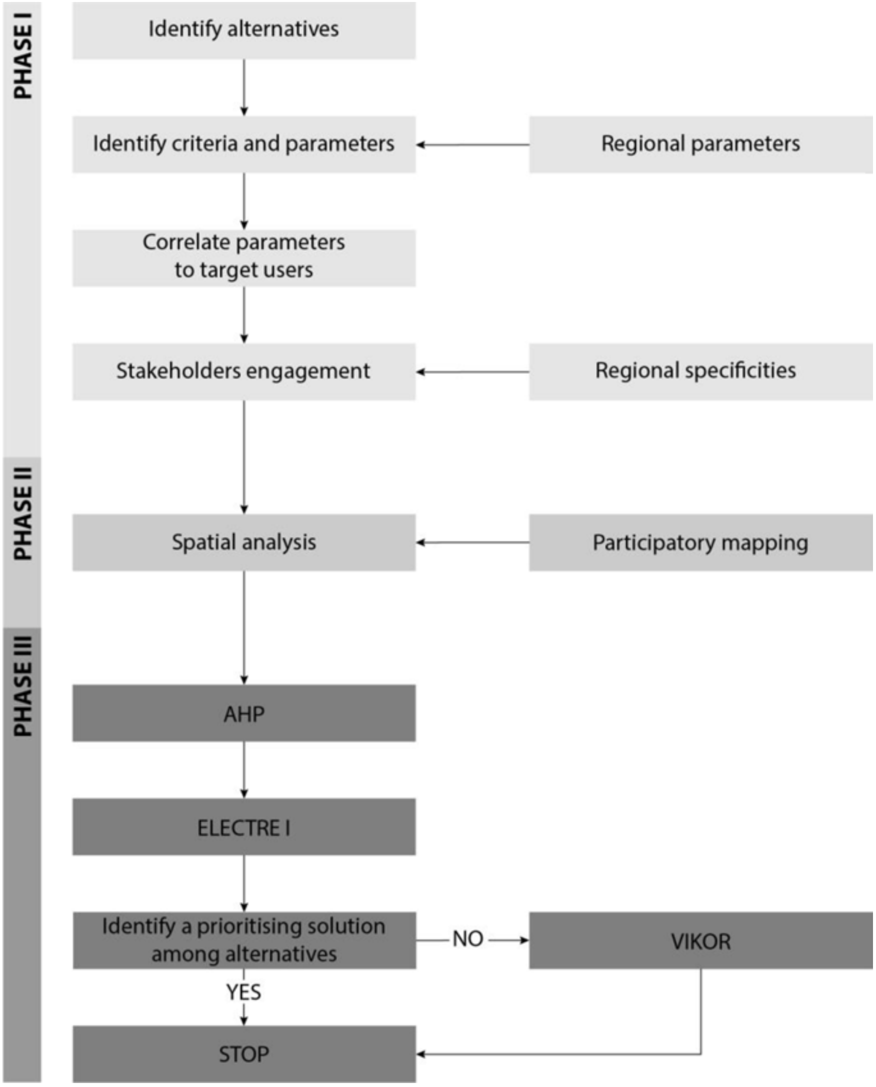

Fig. 1. The flowchart of the integrated method.

manage more than three heterogeneous criteria (e.g., distance, cultural, sites, monuments), which makes it difficult to aggregate all the criteria in a common and unique scale (e.g., Figueira, Mousseau, & Roy, 2016). Moreover, it addresses the selection of a small subset of alternatives, i.e., a single (possible) one might be chosen. Finally, it is second in terms of applications in the transportation field (Broniewicz & Ogrodnik, 2020). The VIKOR is adopted to develop a final ranking based on defined goals easily. It can analyse quantitative data and generate multiple solutions instead of one and is applied in the transportation field.

3.1. *Alternatives, criteria, user types, and stakeholders' engagement*

The assessment of cycle-tourist routes is a decision-making issue with various criteria (or objectives) that contribute to the multiple perspectives of observations and, consequently, evaluations.

Therefore, Phase I identifies planned cycling routes (Step 1) that represent the alternatives (they are finite numbers and predetermined) and identifies a set of criteria (and related parameters) against how each cycle-tourist route is evaluated (Step 2). Specifically, each criterion is the main "cluster" of a set of related parameters representing the unit of reference. Clustering aims to hierarchise the problem: once the objective is fixed (i.e., identification of the 'best' cycle routes), the problem is split into criteria and parameters (or factors), which are identified according to the research objective. Moreover, clustering facilitates stakeholders in managing pairwise comparisons in the next step. The cluster of criteria includes qualitative and quantitative factors that characterise cycle-tourism routes and considers the viewpoints of stakeholders involved in planning and implementation processes. Thus, the set was built to gather two perspectives: the political and technical arguments of the decision-maker about the feasibility, opportunities, and territorial synergy deriving from cycle-tourist routes.

In step 3, the applicability of criteria (and related parameters) to the specific target user type is checked according to the literature, as several types of users can utilise cycle-tourism routes (e.g., leisure or recreational, competitive, and sportive). The selection of tourist types first derived from Ritchie (1998), who considered "*a person who is away from their home town or country for a period not less than 24 h or one night, for the purpose of a vacation or holiday*…". Next, the decision-makers selected the kind of user to be considered in this study according to the planning specifications of the routes to be assessed.

For convenience, in what follows, criteria and related parameters will generally be referred to as "criteria".

Finally, in Step 4, a panel of stakeholders is engaged, and their judgments on criteria are solicited to define the importance of each criterion (and related parameters). Defining this importance is not a trivial task because specific knowledge is required. The involvement of stakeholders (i.e., academics, practitioners, public or private decision-makers, users, and tour operators) in judging each criterion is a relevant task that characterises this phase. Moreover, it is strongly recommended because the different opinions could lead to several judgments for each criterion. Therefore, as these opinions can vary due to the specific knowledge of criteria and, thus, provide different perceptions, a weighing process is required to derive the relative importance as also required in the application of MCDM (e,g., da Silva, Santos, & Setti, 2022). Hence, weights of importance are attached to the criteria. Weights of criteria are not entrusted to directly questioning stakeholders for every criterion owing to possible inconsistencies when many criteria are evaluated. As a result, this study uses the AHP amongst the many methods because it: (i) effectively reduces bias concerns (Saaty, 1987; 1994); (ii) enables to obtain 'objective' evaluation of weights from subjective opinions by eigenvectors; (iii) lead to a unidimensional scale for priorities of criteria (Figueira et al., 2016; Wind & Saaty, 1980). Moreover, several studies have applied this method in the integrated field of transport and spatial planning (e.g., Broniewicz & Ogrodnik, 2020; Carra, Maternini, & Barabino, 2022).

Stakeholders' engagement falls in the topic of inclusive, participatory, or decision-making processes, defining co-planning and co-design strategies for better effectiveness and quality of policies (Carra, Levi, Sgarbi, & Testoni, 2018). In this study, the participatory process applies to refine the set of criteria by completing the literature review according to the case study and the panel of stakeholders engaged and defining the criteria weights. Although the stakeholders could be engaged in various ways (e.g., interviews, open space technologies, outreach, and focus groups), this study adopts mixed ways based on a web survey. The engagement is supported by public presentations and one-on-one online or face-to-face meetings with each stakeholder.

3.2. GIS

Phase II follows the criteria selection, transfers criteria to the Geographical Information System (GIS) module and elaborates a spatial analysis of criteria, harmonising route features and land use. The land use approach is the key to cycle-tourist routes quality since it estimates the relevance of criteria in the function of boundary conditions. Moreover, it accurately describes the route by improving the link-node segmentation. The GIS tool has been adopted because it can integrate functions such as collecting, filing, analysing, handling, and depicting large datasets of different natures (e.g., discrete, continuum, ordinal, nominal). It can handle data in both vector and raster formats and uses a graphical model to make comprehending the relationships between data easier. However, it is not only a set of information to read, such as the "space", but it is a tool that may be used to develop, build new data information, and contribute to the dual purpose of increasing knowledge, spatial planning, and its changes (Cialdea, 2023).

Therefore, phase II collected a huge amount of data in the GIS tool. It associated the measurement data of the criteria with the planned cycle-tourist routes and processed them through geoprocessing devices from the tool and plugins. However, the measurement of criteria considered two issues. First, open-source datasets could not provide the information layers of parameters (e.g., paved segments of route/lane, priority public transport stops, enogastronomic peculiarities, and landscape values). Participatory mapping processes were performed to build cognitive frameworks with the stakeholders and incorporate local knowledge about existing environmental and infrastructural data; data were promptly geometrised and georeferenced (Nasr-Azadani, Wardrop, & Brooks, 2022). Second, types of spatial analysis related to proximity or distance of the criteria were measured as multiple spatialised isochrones based on cycling travel times (speed adopted equal to 10 km/h).

3.3. Data processing and ranking

Phase III processes data collected amongst stakeholders. In this study, the AHP method computes the weighting of each criterion. The ELECTRE I method finds cycle-tourist routes to present the best compromise alternative. VIKOR is applied to refine the results of ELECTRE I. This phase runs according to steps 6), 7) and 8) as follows.

3.3.1. AHP

Step 6) processes data by the AHP, which is a pairwise comparison amongst criteria that generates a stable weight assignment. Moreover, the AHP generates a ratio scale for each set of pairwise comparisons to evaluate the consistency/inconsistency of the judgements provided. This ratio scale is required to reduce possible biases in a decision-making process. The AHP raises subjective comparisons on a couple of criteria. Next, it aggregates these results into objective weights, addressing the greater or lower subjectivity of the expert involved. Concisely, the AHP translates subjective judgments into objective weights. Its results can be a valuable output considering the different facets and several measurements that characterise the criteria for touristic cycling routes.

Specifically, for each expert, a matrix of pairwise comparisons is required while comparing criteria. In this matrix, rows and columns report criteria, while each entry is the weight assigned to a criterion against each other. Next, a vector of weights for each criterion is computed and normalised. Since some inconsistency of judgement can be observed, a consistency test is performed to verify the reliability of judgments of the matrix.

More formally, let:

- J be the set of criteria (or sub-criterion) at hand.
- K be the set of experts.
- v_j/v_h be the numerical judgement of the pairwise comparison between criterion $j \in J$ and $h \in J$.
- V_j be the overall unnormalised weight of criterion $j \in J$.
- CI be the consistency index, which measures whether judgments provided by expert $k \in K$ are logical and consistent with the choices reported in the survey.
- λ_{max} be the maximum eigenvalue needed to compute the measure of consistency.
- RI be the random consistency index, a tabulated CI function of the maximum number of items.

The following four-step algorithm computes the weights and check the consistency of the judgments. For each expert $k \in K$:

1) Build the matrix of pairwise comparison V^k amongst criteria. Table 2 shows an example.
2) Compute the vector of weights V_j as follows (amongst the several available approaches):

$$V_j = \sqrt[|J|]{\prod_{h \in J} \frac{v_j}{v_h}} \quad \forall j \in J \tag{1}$$

3) Normalise the vector of weights V_j by computing the arithmetic mean as follows:

$$v_j = \frac{V_j}{\sum_{h \in J} v_h} \quad \forall j \in J \tag{2}$$

Table 2
Numerical judgement of the pairwise comparison between criteria.

Criteria	1	2	…	h	…	n
1	1	v_1/v_2	…	v_1/v_h	…	v_1/v_n
2	v_2/v_1	1	…	v_2/v_h	…	v_2/v_n
…	…	…	…	…	…	…
j	v_j/v_1	v_j/v_2	…	v_j/v_h	…	v_j/v_n
…	…	…	…	…	1	…
n	v_n/v_1	v_n/v_2	…	v_n/v_h	…	1

Table 3
Random Consistency Index.

j	1	2	3	4	5	6	7	8	9	10
RI	0	0	0	0	11	1	15	1.40	1.45	1.49

4) Check the consistency as follows.

$$\text{Compute } \lambda_{max} = \frac{\sum_{j \in J} \left[\frac{\sum_{h\ \in\ J} \left(\frac{v_j}{v_h} * \ v_j \right)}{v_j} \right]}{|J|} \tag{3}$$

$$\text{Verify } \lambda_{\max} \geq |\mathrm{J}|$$

$$\text{Compute } CI = \frac{(\lambda_{\max} - |\mathrm{J}|)}{(|\mathrm{J}|-1)} \tag{4}$$

If $\lambda_{\max} = |J|$, the evaluations are perfectly consistent, thus $CI = 0$.

$$\text{Compute the consistency ratio } CR = \frac{CI}{RI} \tag{5}$$

where RI is taken from Table 3 according to the number of criteria considered.

If $CR < 0.1$ (10%), the pairwise comparisons are consistent, thus the weights computed according to the judgement of expert $k \in K$ are reliable. Conversely, expert $k \in K$ should be re-involved to revise her/his evaluations. More details on the application of AHP can be retrieved in Saaty (1987; 1994). Notably, different matrices are returned for criteria and related parameters (if any) for each expert $k \in K$. Experts that do not respect the consistency constraint are disregarded because only consistent judgments contribute to the weights. The final weights are computed for each 'consistent' expert by averaging 'consistent' weights for each criterion and parameter. They are called Global Weights, used as input in the decision matrix when ELECTRE I is applied, as shown in the next step.

3.3.2. ELECTRE I

Step 7) applies the ELECTRE I preference aggregation method, which helps derive a compromise solution amongst alternatives. ELECTRE I begins by building a decision matrix. The rows of this matrix report the alternative (cycling touristic routes); the columns show the criterion at hand. Each entry shows the performance of each alternative against each criterion. Next, each criterion is classified as a benefit or a cost. For instance, the higher the number of Points of Interest (POI) reached by the cycling route, the better the alternative: in this case, POI are considered as a benefit. Conversely, the lower the average slope of the cycling touristic route, the better the alternative: in this case, the average slope is a cost. Since the decision matrix contains different criteria (and different units of measures), a process to make the performance of each criterion homogeneous is required to compare the different alternatives. This process translates the decision matrix into a new matrix by utility functions assumed to be linear in this study for ease. A utility function is built for each criterion, taking the original performance value associated with each alternative as input. The utility function ranges from a minimum to a maximum value according to the criterion. If the criterion at hand is considered a benefit, the minimum value of the utility function is assigned to 0, whilst the maximum value can be set to 1. Conversely, if the criterion is considered a cost, the maximum value is attributed to routes with the lowest cost. Intermediate values of the utility functions are computed for the other alternatives by linear interpolation amongst intermediate performance values of the criterion at hand against each alternative. More formally, if the value of the weights v_j of criteria $j \in J$ are available, the ELECTRE I method can be formulated as follows. Let:

Table 4
An example of the Decision matrix.

	v_1 1	v_2 2	… …	v_j j	… …
1	f_{11}	f_{12}	…	f_{1j}	…
2	f_{21}	f_{22}	…	f_{2j}	…
…	…	…	…	…	…
i	f_{i1}	f_{i2}	…	f_{ij}	…
…	…	…	…	…	…

- I be the set of routes (alternatives) and $i \in I$ a route;
- F be the set of performances of $i \in I$ with respect to $j \in J$, and f_{ij} an individual performance
- V be the set of weights and $v_j \in V$ is the normalised weight of criterion $j \in J$;
- U be the set of utilities $i \in I$ with respect to $j \in J$, and u_{ij} an individual performance.

The ELECTRE I searches the optimal solution $I^* \subset I$, as having the best overall compliance with criterion $j \in J$ found by associating the appropriate weights to each criterion.

A simple example of the decision matrix is shown in Table 4.

The utility matrix is derived from the decision matrix using the value returned by the utility functions instead of individual performance $f_{ij} \in F$.

Next, ELECTRE 1 builds one or more outranking relations, which can compare each pair of alternatives. It requires the computation of concordance/discordance indexes that enable the implementation of an 'elimination' process in which the less 'satisfactory' alternatives are excluded, leaving instead the others that are a good compromise concerning the final objective.

The concordance index (I_c) represents the sum of normalised weights $v_j \in V$ (derived from the AHP) of criterion $j \in J$, which forms the coalition of criteria for which alternative $i \in I$ is preferable to $g \in I$.

The discordance index (I_d) represents the maximum value of the greater difference in utility for each criterion $j \in J$ in favour of alternative $g \in I$ over $i \in I$. These indexes indicate the degree of 'satisfaction' and 'dissatisfaction' in choosing one alternative.

I_c and I_d are computed by using the following algorithms.

As for I_c, for each pair of alternatives $i \in I$ and $g \in I$ and criterion $j \in J$, select u_{ij} and u_{gj}

If $u_{ij} \geq u_{gj}$ then select v_{ij}; else, select $v_{gj;}$next compute

$$Ic_{ij=}\sum_{j \in J} v_{ij} \quad \forall i, g \in I \tag{6}$$

$$Ic_{gj=}\sum_{j \in J} v_{gj} \quad \forall i, g \in I \tag{7}$$

As for I_d, for each pair of alternatives $i \in I$ and $g \in I$ and criterion $j \in J$, select u_{ij} and u_{gj}

If $u_{gj} \geq u_{ij}$ then compute

$$\Delta u_{gj} = \left(u_{gj} - u_{ij}\right) \tag{8}$$

$$\Delta u_{maxj} = Umax_j - Umin_j \tag{9}$$

$$R_{gj} = \frac{\Delta u_{gj}}{\Delta u_{maxj}} \tag{10}$$

$$Id_{gj} = Max\ (R_{gj} \tag{11}$$

else compute

$$\Delta u_{ij} = \left(u_{ij} - u_{gj}\right) \tag{12}$$

$$\Delta u_{maxj} = Umax_j - Umin_j \tag{13}$$

$$R_{ij} = \frac{\Delta u_{ij}}{\Delta u_{maxj}} \tag{14}$$

$$Id_{ij} = Max\ (R_{ij} \tag{15}$$

Once the indexes have been computed for each pair of alternatives, selecting the best compromise solution involves exploiting the joint outranking relationship of I_c and I_d, respectively. Specifically, for each pair of alternatives, $i \in I$ is preferable to $g \in I$ if Ic_{ij} is close to 1; conversely, $g \in I$ is preferable to $i \in I$ if Id_{gj} is close to 1. Nonetheless, because the information should be provided in the same direction (for ease in reading the results), we can argue that $i \in I$ is preferable to $g \in I$ if Ic_{ij} is close to 1 and Id_{gj} is close to 0. A pair of threshold values for I_c and I_d is required to include/exclude alternatives. These thresholds are set by $\underline{I_C}$ and $\underline{I_d}$, respectively. These limit values enable discarding all those pairs of alternatives that do not fall within these thresholds. Specifically, alternatives $i \in I$ and $g \in I$ such that $I_{c_{ig}} > \underline{I_C}$ and $I_{d_{ig}} < \underline{I_d}$ are retained, whereas the opposite does not hold. However, alternative $i \in I$ could be preferred to $g \in I$ for the I_c, whereas alternative $g \in I$ could be preferred to $i \in I$ for the I_d: an indication of outranking is not possible. In addition, these indexes suffer from the needing to establish threshold values. The removal of these value thresholds may be obtained by computing the global concordance ($\widehat{Ic}$) and discordance ($\widehat{Id}$) indexes as follows:

$$\widehat{Ic}_i = \sum_{j \in J} Ic_{ij} - \sum_{j \in J} Ic_{ji} \quad \forall i \in I \tag{16}$$

$$\widehat{Id}_i = \sum_{j \in J} Id_{ij} - \sum_{j \in J} Id_{ji} \quad \forall i \in I \tag{17}$$

The higher $\widehat{Ic}_i$ and the lower $\widehat{Id}_i$ return the better alternative. Therefore, alternatives with a negative $\widehat{Ic}$ and a positive $\widehat{Id}$ are excluded from the final set.

3.3.3. VIKOR

Step 8) applies the VIKOR method to enlarge the results of ELECTRE I and refine the comprehension of alternatives, identifying a priority of the best compromise alternative amongst alternatives (Opricovic & Tzeng, 2004). Therefore, it represents a compromise ranking in solving cycle-tourist routes selection decision-making problem, just like ELECTRE I is an outranking method that develops a partial "ranking". However, VIKOR provides a compromise between a maximum group utility, i.e., the decision tends toward the "majority" rule, and a minimum of the individual regret (or disutility), i.e., the decision tends toward the "opponent". Similarly to ELECTRE I, VIKOR determines the best and worst performance of all alternatives to a criterion (i.e., cost and benefit). Next, it determines two scalar quantities for each criterion and alternative. These quantities are S_i, which is the measure of the utility and R_i, which is the value of the regret measure. Finally, an aggregating index Q_i is the VIKOR index of each alternative. Let:

- f_j^+ be the best value, and f_j^- is the worst of all criterion functions.
- υ be a variable (value between 0 and 1) which gives different weight to S_i and R_i ($\upsilon = 0.5$ equal relevance; $\upsilon > 0.5$ favour utility measure values; $\upsilon < 0.5$ regret measure values);
- S^+ and S^- be the minimum and the maximum value of S_i, respectively.
- R^+ and R^- be the minimum and the maximum value of R_i, respectively.

All scalar quantities are computed as follows:

$$S_i = \sum_{j \in J} \frac{V_j \left(f_j^+ - f_{ij}\right)}{f_j^+ - f_j^-} \tag{18}$$

$$R_i = max_j \left[\frac{V_j \left(f_j^+ - f_{ij}\right)}{f_j^+ - f_j^-} \right] \tag{19}$$

$$Q_i = \upsilon \frac{S_i - S^+}{S^- - S^+} + (1 - \upsilon) \frac{R_i - R^+}{R^- - R^+} \tag{20}$$

Therefore, each alternative is assessed according to all criteria, and the related ranking depends on the minimum value of Q_i amongst them, i.e., from the proximity of a compromise solution to the ideal solution. The ranking of the compromise solution is verified if the following K1 and K2 conditions are satisfied.

(1) Acceptable (or sufficient) advantage (K1) of the first ranked alternatives ($A_i^{(1)}$) vs the next ranked alternative ($A_i\ ^{(2)}$). This advantage depends on the number I of alternatives considered.

$$Q\left(A^{(2)}\right) - Q\left(A^{(1)}\right) \ \geq DQ \tag{21}$$

$$DQ = \frac{1}{|I| - 1} \tag{22}$$

(2) Acceptance of Stability in Decision Support (K2) of the alternative best ranked over the others by S or/and R values. If conditions are not satisfied, the compromise solution is determined as follows:
   - The first-ranked alternative satisfied K1 but not K2: a collection of compromise solutions is set and includes first-ranked and second-ranked alternatives.
   - The first-ranked alternative satisfied K2 but not K1: a collection of compromise solutions is set and includes first-ranked and all alternatives over which the first-ranked alternative has no "sufficient advantage", i.e., are "in closeness". $Q(A^{(M)}) - Q(A^{(1)}) < DQ$.
   - The first-ranked alternative did not satisfy K1 and K2: it is not ''sufficiently'' the best than the second. Therefore, a collection of compromise solutions includes all alternatives (Opricović, 2009).

4. Research context

The method was applied to the wide-study area of Franciacorta, which is in Northern Italy (Province of Brescia) and includes 22 municipalities with about 200,000 inhabitants (Fig. 2).

Franciacorta constitutes a wide area of high environmental, historical, and cultural value between Lake Iseo to the northwest, the southern foothills of the Pre-Alps to the north-northeast, and the Po valley to the south. Elements of high national and international tourist attractions are environmental, such as Lake Iseo, historical-architectural and cultural (i.e., the numerous artefacts scattered throughout most of the territory), and the significant and valuable cultures widespread in the area, i.e., vineyards. Concurrently, Franciacorta has become highly anthropised, characterised by transport network infrastructures, manufacturing, and commercial activities. Moreover, different conurbation processes characterise many of the urban centres of the area, which could be considered a unified sprawl city.

Recently, those municipalities have joined forces in an aggregated association, "Terra della Franciacorta", to promote sustainable synergistic area-wide planning using an integrated system of accessibility and cycle-tourist soft mobility to enhance the naturalistic, landscape, and historical-cultural heritage. The area-wide planning of Terra della Franciacorta has identified five cycle-tourist routes (i.e., A. Brescia-

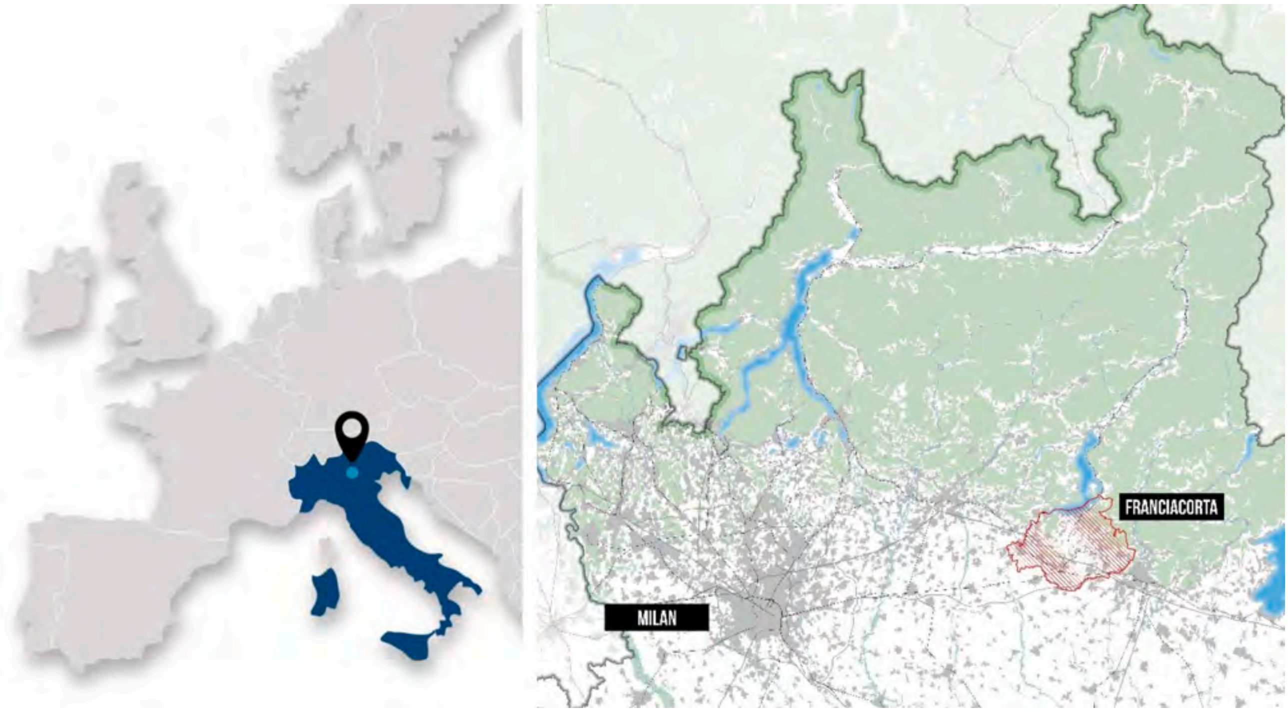

Fig. 2. Location overview of the research context.

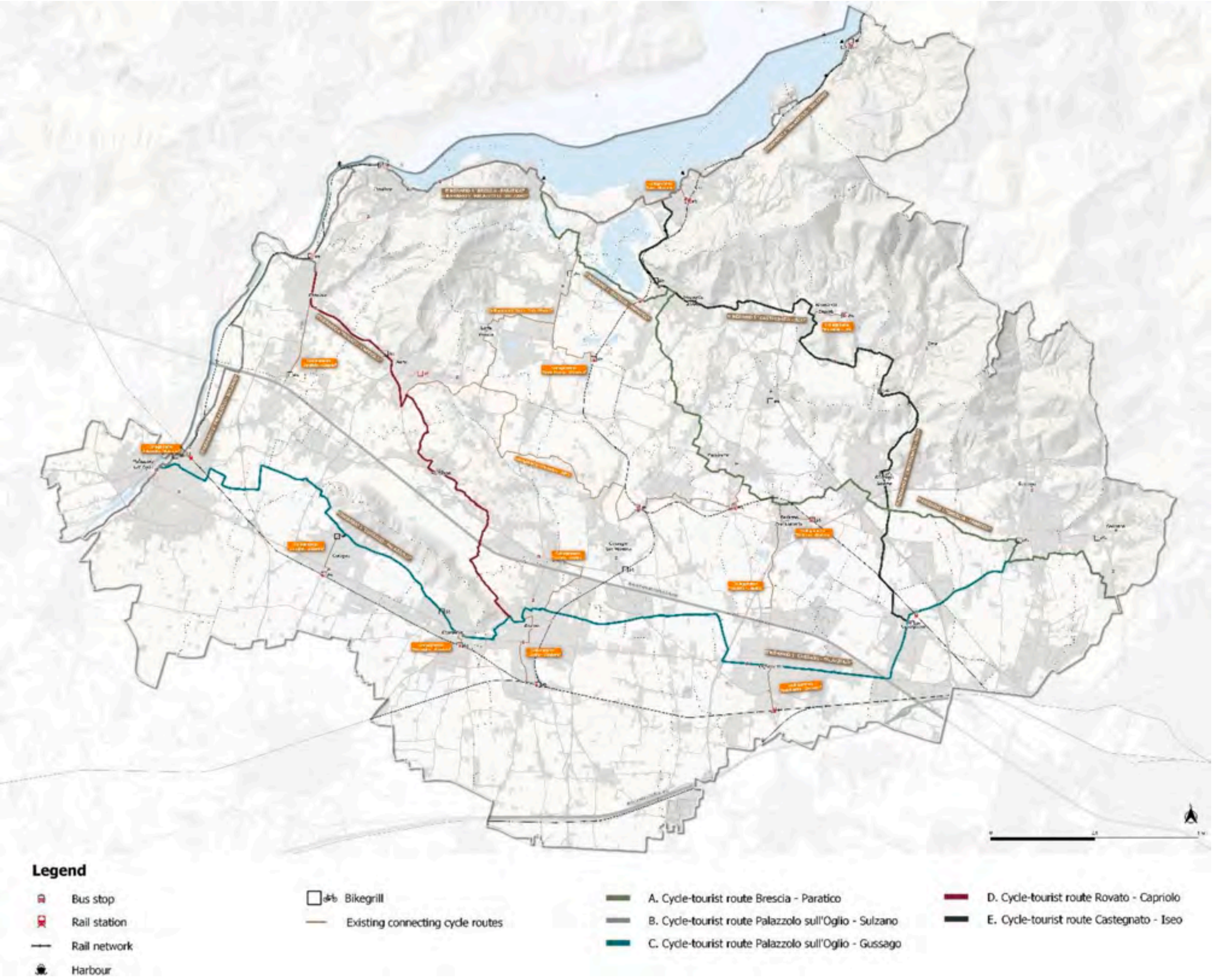

Fig. 3. The cycle-tourist routes masterplan of Franciacorta.

Paratico; B. Palazzolo sull'Oglio-Sulzano; C. Gussago-Palazzolo sull'Oglio; D. Rovato-Capriolo; E. Castegnato-Iseo) according to a co-planning process. These routes are integrated into the urban-regional framework of places, peculiarities, and intermodal nodes with public transport (Fig. 3). The five routes represent the alternatives of our study (Step 1, Phase I).

5. Results

5.1. Criteria selection, user types and stakeholders' engagement

According to Step 2) of Phase I, criteria representing common facets of available routes and related parameters are specified and described as shown in Table 5. Moreover, Table 5 reports their classification according to how these parameters were selected for their measurement. The last column shows the type of users to which these parameters are referred.

A comprehensive set of four criteria and 18 parameters was selected by a literature review of academic research, i.e., examining which were currently accessible and recurring in a theoretical and operational environment (e.g., Bakogiannis et al., 2020a; Di Giacobbe et al., 2021; Watthanaklang et al., 2016; Zhu, 2022). In addition, the set was further refined during the stakeholders' engagement to add regional specificities to the case study. A final shared set of 23 parameters was obtained. The collected parameters were of different natures and considered intrinsic and extrinsic characteristics of cycle routes, services, and context. Therefore, parameters were clustered according to four (main) criteria.

The criterion *Route features* includes parameters focused on technical issues of cycle-tourist route planning, which can influence users' feasibility and physical/psychological propensity in applying the route. Concurrently, it includes the economic feasibility of building and managing the cycle infrastructure.

The criterion *User services* considers parameters that account for the accessibility to elements necessary to satisfy the needs of cycle-tourism users during the journey, from catering to overnight stays to watering, repairs, and alternative movements.

The *Natural* and *Building contexts* criteria include parameters expressing the attraction or repulsion degree that the context exerts on the cycle-tourist user. They are expressed both in psychological terms of the "beauty" or "pleasantness" of the routes and in functional terms of tourist destination polarity (e.g., cultural, historical).

Each parameter was explained and defined in segments of cycling tourism users that characterise the primary purpose of the trip (Step 3). Specifically, cycle tourism is characterised by recreational visits (both infrequent, occasional, frequent, and enthusiastic) that include three segments: sportive (*S*), adventurous (*A*), and multi-generational/family travellers (*M*). Moreover, additional parameters were defined according to the stakeholders' interests (*E*). The definition was addressed to derive the primary cycle-tourist segment's focus of the assessment process. The focus was on multi-generational/family travellers, representing the largest segment of tourism cyclists (Filimonau & Robbins, 2022). They are attracted by rights-of-way and safe routes, on low-traffic roads (e.g., countryside), close to nature and scenic points, and interested in

Table 5
The set of criteria and parameters.

Code	Criteria	Code	Parameter	Description	Parameter selection	User types			
						S	*A*	*M*	*E*
1	**Route features**	1.1	Slope (minor)	The average slope of cycle route by non-expert users (<6%)	L			●	
		1.2	Slope (high)	The average slope of cycle route by expert users (>=6%)	L	●	●		
		1.3	Segregated line	Segregation of cycle routes from vehicular traffic with higher user safety	L		●	●	
		1.4	Paved route/lane	Surface quality that affects the comfort, recognition and environmental integration of the route	L	●		●	
		1.5	Unpaved route	Natural surface (e.g., rough, uneven, muddy ground) that affects the difficulty and experience of the route.	L		●		
		1.6	Construction cost	The unit cost of unrealised route sections	L				●
		1.7	Operating cost	The unit cost of unrealised route sections	L				●
		1.8	Length	Route length greater than 30 km	L	●	●		
		1.9	Speed	Straight course	L	●			
2	**User services**	2.1	Water point	Number of water points served by cycle route	L	●	●	●	
		2.2	Bike grill	Multi-service facilities for cycle users (i.e., refreshment points and technical assistance), planned by the Stakeholders Association	S	●	●	●	●
		2.3	Accommodation	Hotel, hostel, bed and breakfast, farmhouse, camping, hut/bivouac, guest house, holiday village, vacation home/apartment	L	●	●	●	
		2.4	Catering	Restaurant, farmhouses, café, bar, pub	L	●	●	●	
		2.5	Public transport stops/stations	Modal interchange degree to priority stations and stops	L			●	
3	**Natural context**	3.1	Waterscapes	Lakes, rivers, seas, beaches, wetlands, dunes	L		●	●	
		3.2	Protected area	Points of interest with high environmental value (i.e., Biodiversity/Natura 2000, park, woods, "*bellezze d'insieme*")	L		●	●	
		3.3	Vineyards	Land use equal to the vineyard	S		●	●	●
		3.4	Landscape peculiarities	Points of interest with environmental and landscape value but not protected (e.g., scenic point) highlighted by stakeholders	S		●	●	●
4	**Building context**	4.1	Historical town unit	Traditional urban fabrics with historical, typological, and morphological characteristics, recognisable by the stratification of formation processes	L			●	
		4.2	Manufacturing area	Functionally unattractive areas and incompatible with cycle-tourism	L			●	
		4.3	Cultural peculiarity	Points of interest with high historical and cultural values (e.g., castles, museums, archaeological zones)	L			●	
		4.4	Eno gastronomic peculiarity	Points of interest with high Eno gastronomic value, i.e., wineries Franciacorta (PDO, PGI)	S			●	●
		4.5	Municipalities	Number of municipalities served by cycle route	S			●	●

S = Sportive cycle tourist types; *A* = Adventurer cycle-tourist types; *M* = multi-generational/family cycle tourist types; *E* = parameters added from stakeholders; *L* = parameters derived from the literature review; S = parameters derived from stakeholders' engagement.

Table 6
Value of adjusted Saaty scale.

Value	Definition	Explanation
1	Equivalent importance	Two criteria contribute equally to the objective
3	Moderate importance	Experience and judgements slightly favour one criterion over the other.
5	Strong importance	One criterion is strongly favoured over the other
2–4	Intermediate value	Intermediate situations

experiencing the distinctive features of a place, including its culture, landscape, and history. Consequently, parameters that did not meet segments M and E were eliminated from the set (i.e., 1.2, 1.5, 1.8, and 1.9), and a final list of 19 parameters was defined.

Next, according to Step 4, the stakeholders involved were public decision-makers of the 22 municipalities of “Terra della Franciacorta” and the Association itself. The public decision-makers were of two types to include different viewpoints: (i) political as mayors and/or city council members; (ii) chiefs of technical offices in the urban and/or transport planning sector. The engagement was elaborated in a web survey programmed in PHP language[2] and organised in a single stage. The stakeholders were asked to perform pairwise comparisons between pairs of criteria and parameters to facilitate data collection for the AHP. Therefore, they compared the four criteria and related parameters in an adjusted 1–5-point Saaty scale, as shown in Table 6.

The web survey was exhibited by public presentations and submitted between September and October 2022. Moreover, it contained information on the aim and scope of the study, definitions and examples of criteria and parameters, and how to perform a pairwise comparison. Nevertheless, individual online and/or face-to-face meetings were arranged for those who requested it. This last approach was mainly chosen by the “political” stakeholders, probably not experts in some technical elements.

A total of 18/22 municipalities completed the web survey. A total of 31 stakeholders were interviewed, of which 18 were politicians and 13 were technicians.

5.2. GIS

In Phase II, each parameter was mapped through spatial analysis with the Esri ArcGIS (ArcMap) 10.3 and QGIS Desktop 3.22.5 software to increase the panel of available tools and functionalities. Spatial data of the parameters were accurately collected from several sources; they were mainly institutional geo-portals, while the remaining spatial data were built through participatory mapping processes with public administrations. Participatory mapping was developed through interviews and meetings with each municipality. We used visual materials (digital and paper) to associate the information layers through drawings and/or words, then transferred them to GIS. The mapping consisted of in-depth information associated with existing and new georeferenced geometries. For instance, in the case of existing geometries, the features of cycle routes have been implemented in section typologies (e.g., segregation of the cycleway, flooring, cross-section) or priorities public transport stops/stations were classified in terms of intermodally degree and the number of gravitating municipalities. In the case of new geometries, a dataset of #518 tourist peculiarities was mapped, categorised in Landscape, Cultural and Eno gastronomic according to stakeholders' knowledge of each municipality and finally, described (e.g., if they were

Table 7
Explanation of criteria analysis, tools and data source.

Code	Parameter	Type of analysis	Software	Tool	Data source
1.1	Slope (minor)	Slope	ArcMap 10.3	3D Analyst, Add surface information	ISPRA*
1.3	Segregated line	Length	QGIS 3.22.5	Statistics by categories	Urban plans, Participatory mapping
1.4	Paved route/lane	Length	QGIS 3.22.5	Statistics by categories	Participatory mapping
1.6	Construction cost	Parametric cost estimation	QGIS 3.22.5	Statistics by categories	Lombardia Region
1.7	Operating cost	Parametric cost estimation	QGIS 3.22.5	Statistics by categories	Lombardia Region
2.1	Water points	Euclidean distances	ArcMap 10.3, QGIS 3.22.5	Open Route Service, Join attributes by location (summary)	Lombardia Region vector data
2.2	Bike grill	Euclidean distances	ArcMap 10.3, QGIS 3.22.5	Open Route Service, Join attributes by location (summary)	Participatory mapping
2.3	Accommodation	Spatialised isochrones	ArcMap 10.3, QGIS 3.22.5	Network analyst (Service area), Join attributes by location (summary)	Lombardia Region vector data
2.4	Catering	Spatialised isochrones	ArcMap 10.3, QGIS 3.22.5	Network analyst (Service area), Join attributes by location (summary)	Lombardia Region vector data
2.5	Public transport stops/ stations	Spatialised isochrones	ArcMap 10.3, QGIS 3.22.5	Network analyst (Service area), Join attributes by location (summary)	Lombardia Region and Brescia Province vector data, participatory mapping
3.1	Waterscapes	Coverage ratio	QGIS 3.22.5	Open Route Service, Statistics by categories	Lombardia Region vector data
3.2	Protected area	Coverage ratio	ArcMap 10.3, QGIS 3.22.5	Open Route Service, Statistics by categories	Lombardia Region vector data
3.3	Vineyards	Coverage ratio	QGIS 3.22.5	Open Route Service, Statistics by categories	Lombardia Region vector data
3.4	Landscape peculiarities	Spatialised isochrones	ArcMap 10.3, QGIS 3.22.5	Network analyst (Service area), Join attributes by location (summary)	Participatory mapping
4.1	Historical town unit	Coverage ratio	QGIS 3.22.5	Open Route Service, Statistics by categories	Lombardia Region vector data
4.2	Manufacturing area	Coverage ratio	QGIS 3.22.5	Open Route Service, Statistics by categories	Lombardia Region vector data
4.3	Cultural peculiarity	Spatialised isochrones	ArcMap 10.3, QGIS 3.22.5	Network analyst (Service area), Join attributes by location (summary)	Participatory mapping
4.4	Enogastronomic peculiarity	Spatialised isochrones	ArcMap 10.3, QGIS 3.22.5	Network analyst (Service area), Join attributes by location (summary)	Participatory mapping
4.5	Municipalities	Euclidean distances	QGIS 3.22.5	Join attributes by location (summary)	Lombardia Region vector data

* Digital Elevation Model with 20 m resolution.

** Coverage ratio considered Euclidean distances of 50 metres.

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[2] The database function in the PHP programming was performed to collect the response data efficiently for the following data processing phase.

public or private, permanent, or temporary).

The types of spatial analysis applied to the interested parameters were 3D analyst, Euclidean distance, spatialised isochrones, and coverage ratio. 3D analyst calculated cycle routes percentage slope from Digital Elevation Model.

Euclidean distance analysis calculated the high proximity of routes from “bike grill” and “water points” (i.e., 50 m).

Spatialised isochrones simulated cycle-routes accessibility to parameters (i.e., accommodation, catering, public transport stops/stations, and peculiarities). Using isochrones instead of Euclidean distance seemed more suitable for describing the quality of accessibility (Caselli, Carra, Rossetti, & Zazzi, 2021; Handy & Clifton, 2001). The accessibility timing evaluated considered three proximity scales equal to 5, 10 and 15 minutes. The cycling speed value was 10 km/h, enabling an inclusive approach to multi-generational/family travellers (NACTO, 2016).

Coverage ratio calculated the percentage of pleasantness and visual amiability land use in the context of the route, as “protected area”, “vineyards”, and “historical town unit”. Further qualitative values of the cycle-tourist routes were analysed from numerical values to linearly describe the intrinsic qualities of the routes (i.e., rights-of-way,

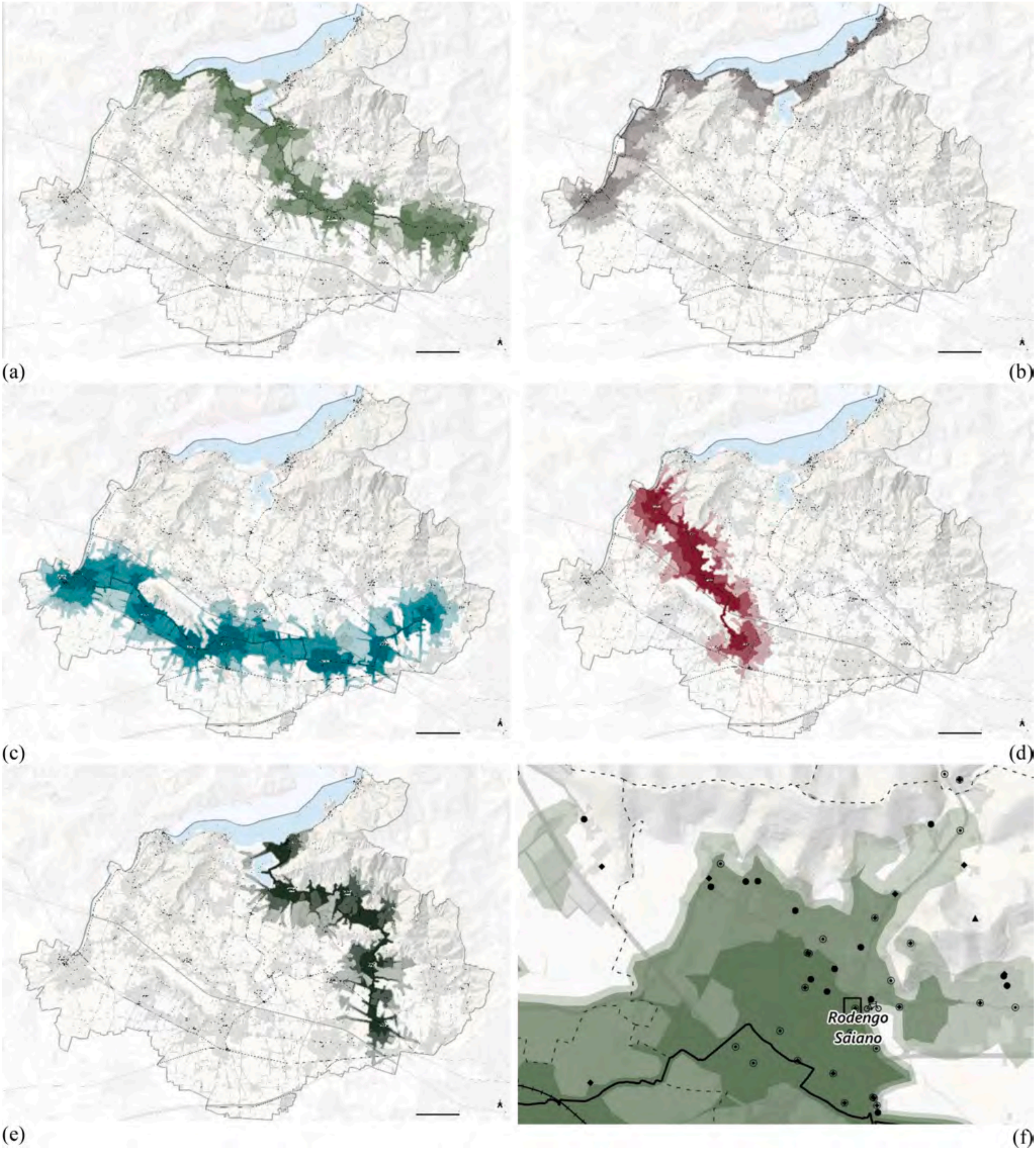

Fig. 4. Spatialised isochrones of each criterion: (a) cycle route A; (b) cycle route B; (c) cycle route C; (d) cycle route D; (e) cycle route E; (f) detail of several points of interest.

pavement) and their capillarity on the territory (i.e., municipalities served). Finally, quantitative economic values were calculated as parametric cost estimation [€/m] by cycle-way typologies.

Table 7 summarises the type of analysis, tools and data source applied to the criteria.

Fig. 4 shows details of the resulting spatial analysis.

5.3. Data processing and ranking

5.3.1. AHP

AHP determined the weight of criteria and parameters affecting the performance of cycle-tourist routes. Specifically, criteria and parameters selected in phase 1 were evaluated according to Eqns. from (1-5). Table 8 shows the aggregate average weight, standard deviation, and coefficient of variation of each criterion (1st level) and related parameter (2nd level) of cycle-tourist routes. The relevance obtained from the stakeholders' judgement determines each weight of criterion and parameter.

As for 1st level, the most important criterion was (C3) Natural context, followed by (C2) User services and (C1) Route features. The importance is low for criterion (C4) Building context. The judgement of stakeholders appeared homogeneous in the score distribution as it has relatively low standard deviation and coefficients of variation values.

As for 2nd level, stakeholders considered the Segregated line parameter (C1.3) as the most relevant of the *Route features*, followed by the Maintenance cost (C1.6). However, the two categories of stakeholders evaluated these parameters according to opposite relevance: technicians favoured the route feature of Segregated line (C1.3), and politicians the Maintenance costs (C1.6) according to a managerial viewpoint. Similarly, in *User services*, technicians favoured the proximity to Water points (C2.1) over public transport stops/stations (C2.5) preferred by politicians. The weighting of the *Natural context* is relatively homogeneous except for the Waterscapes parameter (C3.1) with low relevance, probably due to punctual localisation of it in the north-western sector of Franciacorta (i.e., Iseo lakes and beaches, Oglio River). Again, the viewpoints of technicians and politicians were various: the first group highlighted the importance of Vineyards (C3.4) surrounding the cycle-tourist route; the second preferred the Protected area (C3.2) with high environmental value. Differently, the weighting of *Building context* was consistent between groups of stakeholders, and the most important main criterion was Historical town units (C4.1), followed by Cultural and Eno gastronomic peculiarities (C4.3; C4.4). The parameter of Manufacturing area (C4.2) was almost none weight with a high standard deviation. Probably, this is due to the "negative" nature of the parameter, which has been interpreted differently by stakeholders; a relevant parameter as it repels tourist attractiveness, or an irrelevant parameter compared to others of greater interest to the tourist user.

A two-tailed z-test comparison (p-*value* < 0.05) of each pair of weightings revealed no significant differences between those attached to the criteria and related parameters provided by politicians and technicians. Thus, further analysis adopted the weights of the column labelled B in what follows.

5.3.2. ELECTRE I

The prioritisation process for the five planned cycle-tourist routes followed ELECTRE I. Once performance measures are attached to each parameter for each route, the decision matrix is built. Each column of this matrix has been evaluated as a cost or benefit. In this study, the parameters C1.1, C1.4, C1.5, C1.7, C3.1 and C4.2 were considered a cost, the others as a benefit. Moreover, three matrices were built, one for a well-established value of accessibility time, depending on the proximity of the route to the facility measured from a parameter. Specifically, the values of the accessibility time are 15–10–5 cycling minutes: thus, interested parameters were computed considering a threshold of 'n' minutes between the route and the facility. For the other parameters, a refined analysis of accessibility is unnecessary because the base distance measured is close to 50 metres, according to the location of essential services along the route. Next, the decision matrix was normalised by the utility functions defined. Once extreme values are fixed, the intermediate values are obtained by linear interpolation for ease

Table 8

The weighting of criteria and parameters.

Level	Criterion/parameter	Aggregate average weight (μ)			Standard deviation (σ)			Coefficient of variation % (σ/μ)		
		Te	*Po*	*B*	*Te*	*Po*	*B*	*Te*	*Po*	*B*
1	C3 - Natural context	0.324	0.335	0.330	0.111	0.124	0.116	34.3	36.8	35.2
	C2 - User services	0.291	0.286	0.288	0,145	0.135	0.137	49.7	47.2	47.5
	C1 - Route features	0.263	0.253	0.258	0.087	0.082	0.083	33.1	32.2	32.1
	C4 - Building context	0.121	0.126	0.124	0.045	0.066	0.057	37.4	52.3	46.0
2	*C1 - Route features*									
	C1.3	0.327	0.259	0.289	0.107	0.105	0.110	32.8	40.4	37.9
	C1.7	0.217	0.306	0.268	0.092	0.119	0.115	42.5	38.8	43.1
	C1.6	0.173	0.199	0.188	0.074	0.070	0.072	43.0	35.0	38.2
	C1.4	0.148	0.124	0.134	0.063	0.062	0.063	42.9	50.4	46.9
	C1.1	0.135	0.111	0.122	0.094	0.045	0.071	69.7	40.8	57.9
2	*C2 - User services*									
	C2.1	0.276	0.270	0272	0.138	0.091	0.112	50.0	33.8	41.0
	C2.5	0.239	0.277	0.261	0.112	0.112	0.112	47.0	40.2	42.8
	C2.4	0.182	0.178	0.180	0.097	0.086	0.089	53.1	48.4	49.7
	C2.3	0.151	0.143	0.147	0.076	0.055	0.064	50.2	38.3	43.5
	C2.2	0.151	0.132	0.141	0.063	0.061	0.061	41.9	45.8	43.7
2	*C3 - Natural context*									
	C3.2	0.251	0.291	0.274	0.094	0.102	0.099	37.6	35.2	36.3
	C3.4	0.284	0.263	0.272	0.133	0.116	0.122	46.7	44.2	44.8
	C3.3	0.277	0.262	0.269	0.102	0.116	0.109	36.7	44.3	40.4
	C3.1	0.187	0.183	0.185	0.087	0.114	0.102	46.7	62.1	54.9
2	*C4 - Building context*									
	C4.1	0.259	0.267	0.264	0.063	0.070	0.066	24.2	26.3	25.1
	C4.3	0.245	0.260	0.254	0.078	0.068	0.071	31.8	26.0	28.2
	C4.4	0.236	0.219	0.226	0.105	0.073	0.087	44.5	33.3	38.5
	C4.5	0.185	0.201	0.194	0.101	0.089	0.093	54.7	44.3	48.0
	C4.2	0.074	0.052	0.062	0.075	0.012	0.050	100.9	22.2	81.0

Te = Technician judgement; Po = Political judgement; B = Technician and Political judgement. The entries in 'grey' represent the difference in the importance of criteria and parameters between technicians' and politicians' judgement.

Table 9

Decision and utility matrix within 5, 10 and 15 minutes accessibility time.

		Route	C1.1	C1.3	C1.4	C1.6	C1.7	C2.1	C2.2	C2.3	C2.4	C2.5	C3.1	C3.2	C3.3	C3.4	C4.1	C4.2	C4.3	C4.4	C4.5
Decision matrix of route alternatives	*15-minutes*	A	2.95	64.09	53.70	2.69	4.05	6	2	148	89	17	5.94	38.50	14.32	7	9.06	3.76	39	28	9
		B	3.64	52.51	65.46	2.61	4.29	8	3	206	144	16	5.23	80.34	6.49	9	4.47	4.17	25	11	5
		C	1.82	27.47	89.11	3.98	7.92	4	1	44	111	17	0.33	16.19	4.70	4	17.47	9.49	33	22	9
		D	2.49	39.30	68.60	2.35	5.54	1	2	40	47	11	0.00	46.39	20.00	1	12.03	3.20	27	47	4
		E	3.82	64.52	77.51	2.26	4.65	12	3	120	89	13	1.11	27.43	12.83	5	8.86	6.11	22	24	6
	10-minutes	A	=	=	=	=	=	=	=	121	68	13	=	=	=	4	=	=	27	16	=
		B	=	=	=	=	=	=	=	185	121	15	=	=	=	5	=	=	23	5	=
		C	=	=	=	=	=	=	=	36	91	15	=	=	=	3	=	=	27	18	=
		D	=	=	=	=	=	=	=	32	29	8	=	=	=	1	=	=	24	29	=
		E	=	=	=	=	=	=	=	88	74	11	=	=	=	4	=	=	21	14	=
	5-minutes	A	=	=	=	=	=	=	=	76	49	8	=	=	=	4	=	=	13	5	=
		B	=	=	=	=	=	=	=	162	103	11	=	=	=	4	=	=	20	2	=
		C	=	=	=	=	=	=	=	24	57	10	=	=	=	3	=	=	25	12	=
		D	=	=	=	=	=	=	=	25	17	4	=	=	=	1	=	=	21	15	=
		E	=	=	=	=	=	=	=	51	49	10	=	=	=	3	=	=	11	9	=
		Unit	*%*	*%*	*%*	*€*10^6*	*€*10^4*	*#*	*#*	*#*	*#*	*#*	*%*	*%*	*%*	*#*	*%*	*%*	*#*	*#*	*#*
		Utility	*Co*	*Be*	*Co*	*Co*	*Co*	*Be*	*Be*	*Be*	*Be*	*Be*	*Be*	*Be*	*Be*	*Be*	*Be*	*Co*	*Be*	*Be*	*Be*
Utility matrix of route alternatives	*15-minutes*	A	0.44	0.99	1.00	0.75	1.00	0.45	0.50	0.65	0.43	0.63	1.00	0.35	0.63	0.75	0.35	0.91	1.00	0.47	1.00
		B	0.09	0.68	0.67	0.80	0.94	0.64	1.00	1.00	1.00	1.00	0.88	1.00	0.12	1.00	0.00	0.85	0.18	0.00	0.20
		C	1.00	0.00	0.00	0.00	0.00	0.27	0.00	0.02	0.66	0.75	0.06	0.00	0.00	0.38	1.00	0.00	0.65	0.31	1.00
		D	0.67	0.32	0.58	0.95	0.62	0.00	0.50	0.00	0.00	0.00	0.00	0.47	1.00	0.00	0.58	1.00	0.29	1.00	0.00
		E	0.00	1.00	0.33	1.00	0.85	1.00	1.00	0.48	0.43	0.63	0.19	0.18	0.53	0.50	0.34	0.54	0.00	0.36	0.40
	10-minutes	A	=	=	=	=	=	=	=	0.58	0.42	0.71	=	=	=	0.75	=	=	1.00	0.46	=
		B	=	=	=	=	=	=	=	1.00	1.00	1.00	=	=	=	1.00	=	=	0.33	0.00	=
		C	=	=	=	=	=	=	=	0.67	0.67	1.00	=	=	=	0.50	=	=	1.00	0.54	=
		D	=	=	=	=	=	=	=	0.00	0.00	0.00	=	=	=	0.00	=	=	0.50	1.00	=
		E	=	=	=	=	=	=	=	0.49	0.37	0.43	=	=	=	0.75	=	=	0.00	0.38	=
	5-minutes	A	=	=	=	=	=	=	=	0.38	0.37	0.57	=	=	=	1.00	=	=	0.14	0.23	=
		B	=	=	=	=	=	=	=	1.00	1.00	1.00	=	=	=	1.00	=	=	0.64	0.00	=
		C	=	=	=	=	=	=	=	0.00	0.47	0.86	=	=	=	0.67	=	=	1.00	0.77	=
		D	=	=	=	=	=	=	=	0.01	0.00	0.00	=	=	=	0.00	=	=	0.71	1.00	=
		E	=	=	=	=	=	=	=	0.20	0.37	0.86	=	=	=	0.67	=	=	0.00	0.54	=

* Co: Cost; Be: Benefit.

'=' means the performance measure is the same of rows labelled '*15-minutes*'.

Table 10
Concordance and discordance indexes in pair of alternatives.

Route	Route	Ic_{ij}			Id_{ij}			Thresholds		
Alt. (i)	*Alt. (j)*	*15*-min	*10*-min	*5*-min	*15*-min	*10*-min	*5*-min	$\underline{Ic} > 0.70$; $\underline{Id} < 0.50$	$\underline{Ic} > 0.60$ $\underline{Id} < 0.60$	$\underline{Ic} > 0.50$ $\underline{Id} < 0.75$
A	B	0.5579	0.4828	0.5414	0.6522	0.6522	0.6255	-	-	15;5
A	C	0.8842	0.7811	0.7497	0.6469	0.6469	0.8571	-	-	15;10
A	D	0.6728	0.6728	0.6414	0.5278	0.5417	0.5714	-	15;10;5	15;10;5
A	E	0.7582	0.7064	0.6550	0.5455	0.5455	0.5455	-	15;10;5	15;10;5
B	A	0.4421	0.5172	0.5486	0.8235	0.8000	0.8000	-	-	-
B	C	0.7775	0.8527	0.8527	1.0000	1.0000	1.0000	-	-	-
B	D	0.7319	0.7319	0.7319	1.0000	1.0000	1.0000	-	-	-
B	E	0.6253	0.6253	0.6253	0.4144	0.4144	0.5385	-	15;10;5	15;10;5
C	A	0.2150	0.2743	0.2743	1.0000	1.0000	1.0000	-	-	-
C	B	0.2225	0.2225	0.1473	1.0000	1.0000	1.0000	-	-	-
C	D	0.5184	0.5184	0.4761	1.0000	1.0000	1.0000	-	-	-
C	E	0.2463	0.2743	0.3643	1.0000	1.0000	1.0000	-	-	-
D	A	0.3678	0.3678	0.3991	1.0000	1.0000	1.0000	-	-	-
D	B	0.2681	0.2681	0.2681	1.0000	1.0000	1.0000	-	-	-
D	C	0.4816	0.4816	0.5239	1.0000	1.0000	1.0000	-	-	-
D	E	0.3448	0.3448	0.3448	1.0000	1.0000	1.0000	-	-	-
E	A	0.2936	0.3837	0.3968	1.0000	1.0000	0.8131	-	-	-
E	B	0.4152	0.4152	0.4152	0.8248	0.8248	0.8248	-	-	-
E	C	0.7537	0.7257	0.8009	1.0000	1.0000	1.0000	-	-	-
E	D	0.6552	0.6552	0.6552	0.6650	0.6650	0.7143	-	-	15;10;5

Table 11
Best compromise alternatives by global concordance and discordance indexes.

Cycle-tourist	*15-minute*		*10-minute*		*5-minute*	
routes	$\widehat{Ic}_i$	$\widehat{Id}_i$	$\widehat{Ic}_i$	$\widehat{Id}_i$	$\widehat{Ic}_i$	$\widehat{Id}_i$
A	1.5547	-1.4512	1.1000	-1.4137	0.9687	-0.9869
B	1.1130	-0.2391	1.3385	-0.3526	1.3864	-0.1385
C	-1.6949	0.3531	-1.5516	0.4431	-1.6651	0.1429
D	-1.1159	0.8072	-1.1159	0.7933	-0.9686	0.7143
E	0.1431	0.5300	0.2290	0.5300	0.2786	0.2683

* The ranking is relative, as the values should exclude the alternatives from the analysis. In grey, the excluded values are reported.

(Table 9).

Next, concordance/discordance indexes for each pair of alternatives and each proximity utility were calculated by Eqns. 6-15. The results are shown in Tables 10 and 11. Thresholds considered limit values of $Ic_{ij} >$ 0.70; 0.60; 0.50 and $Id_{ij} <$ 0.50; 0.60; 0.75 (i.e., adapting limit values to a greater comprehension of relationships *i-j* between pairs of alternatives, where the opposite relationship *j-i* was the worse) and it was applied for each proximity range. Several thresholds have been considered until the most comprehensive values of the cycle-route alternatives relationship are reached.

Results showed a complex framework of relationships where the predominance shines through in some range of proximity: (i) of route A over D, and E; (ii) of route B over E; (iii) of route E over D and D. The predominance relationship between routes A and B, and A and C were less strong and more variable according to the degree of proximity assessed. Route A over B has a higher priority by evaluating the criteria for a 15- and 5-minute cycle accessibility, and over C in 15- and 10-minute cycle accessibility. Differently, route D priority was confirmed within 5 minutes. However, the dominant relationship between A and B within 10 minutes is unclear, and identifying a priority was not possible. This also occurred in the relationship between A and C in the 5-minute cycle accessibility and between relationships of B, C and D, C and D, and E and C.

Consequently, the global concordance ($\widehat{Ic}$) and discordance ($\widehat{Id}$) indexes were computed, and a final best compromise alternative was defined. Table 11 partially confirmed previous results: the cycle-tourist route A has top priority within 15 minutes, followed by B. The priority changes between 10 and 5 minutes of accessibility, assuming the cycle-tourist route B is the highest priority in the global concordance index and route A in discordance. Next, route E follows the concordance index; however, the discordance index resulted in positive values, invalid. Finally, the values of routes C and D were invalid as they were negative in concordance indexes and positive in discordance; therefore, they cannot be considered.

5.3.3. VIKOR

Nevertheless, the results have been more clarified by applying the VIKOR method. The compromise ranking confirmed previous results and showed the priority of route A followed by B, E, D and C (see Table 12). The results can be clearly explained. The cycle-tourist route B has a lower priority due to the physical land conformation, which, on one side, runs alongside Lake Iseo. Consequently, above half of the positive externalities (hypothetical) were reduced compared to route A. However, by reducing the accessibility time, the priority of route A decreased with an unverified condition of C2. Therefore, the priority of route A over B was not the best alternative but a compromise solution.

Differently, the priority of cycle-tourist routes C and D in the ELECRE I method was biased by the maximum values of the discordance index. These values were due to the different features of routes: the cycle-tourist route C develops in the flat part of the territory, highly urbanised with a greater extension than D, with a delta of about 15 km, according to a greater number of opportunities (#). Therefore, parameters such as the (minor) route slope and percentage of historical town units intercepted resulted in the highest. The compromise ranking showed the prevalence of route D over the C according to higher average performance amongst all parameters. Finally, the ratio between numerical parameters and the extension of a cycle-tourist route would also increase the performance of route E over B, which showed mutual sensitive proximity for verification C1.

5.4. Comparison results

To justify our results, we compared the proposed method with well-known MCDMs. Specifically, for this comparison, we considered a value-based method, i.e., the SAW; an outranking method, i.e., PROMETHEE and, finally, a goal-based method, i.e., TOPSIS (Table 13). The ranking results of the five alternative cycle tourist routes derived using these methods are summarised in Table 14.

As highlighted in Table 13, the ranking scores showed a similar trend in the performance of each criterion for each alternative concerning any

Table 12
Compromise ranking of alternatives.

Range	Route		S_i	R_i	Q_i*	Ranking S_i	Ranking R_i	Ranking Q_i	Verify Alt ij	Verify K1**	Verify K2
15-min	A		0.2889	0.0590	0.0000	1	1	1	1–2	y	y
	B		0.3116	0.0784	0.3348	2	2	2	2–3	n	y (S_i)
	C		0.7142	0.0905	1.0000	5	5	5	-	-	-
	D		0.6317	0.0900	0.8961	4	4	4	4–5	n	y
	E		0.4664	0.0746	0.4568	3	3	3	3–4	y	y
		S^+; R^+	*0.2889*	*0.0590*							
		S^-; R^-	*0.7142*	*0.0905*							
10-min	A		0.3141	0.0590	0.0256	2	1	1	1–2	y	y (R_i)
	B		0.2941	0.0784	0.3082	1	3	2	2–3	n	y (S_i)
	C		0.6845	0.0905	1.0000	5	5	5	-	-	-
	D		0.6253	0.0900	0.9172	4	4	4	4–5	n	y
	E		0.4383	0.0746	0.4328	3	2	3	3–4	y	y
		S^+; R^+	*0.2941*	*0.0590*							
		S^-; R^-	*0.6845*	*0.0905*							
5-min	A		0.3470	0.0590	0.0779	2	1	1	1–2	y	y (R_i)
	B		0.2844	0.0784	0.3082	1	3	2	2–3	n	y (S_i)
	C		0.6858	0.0905	1.0000	5	5	5	-	-	-
	D		0.6183	0.0900	0.9089	4	4	4	4–5	n	y
	E		0.4223	0.0746	0.4199	3	2	3	3–4	y	y
		S^+; R^+	*0.2844*	*0.0590*							
		S^-; R^-	*0.6858*	*0.0905*							

y = verified; n = unverified.

[*] for υ equal to 0.50

[**] for DQ equal to 0.25.

given range of proximity: route B values improved incrementally as proximity increased. In the same way, also, the values of route E improve. Conversely, the scores of route A decrease.

The comparison reported in Table 14 shows the robustness of the results, whereby the priority alternatives are A and B, followed by E, and finally by D and C. However, the preference between routes A and B changes in favour of route B with 10 and 5 minutes of proximity, respectively. Furthermore, they highlight the advantage of ELECTRE and VIKOR methods, which can show the ranking sensitivity amongst the choices. Although the study aims to rationalise and prioritise cycle

Table 13
Scoring of alternatives with SAW, PROMETHEE, and TOPSIS methods.

Method	Route	Scoring *15*-min	*10*-min	*5*-min	*15*-min	*10*-min	*5*-min	*15*-min	*10*-min	*5*-min
SAW		*Global score*								
	A	0.2744	0.2593	0.2456						
	B	0.2678	0.2701	0.2792						
	C	0.1128	0.1190	0.1181						
	D	0.1460	0.1459	0.1488						
	E	0.1990	0.2057	0.2084						
PROMETHEE		*Leaving flow*			*Incoming flow*			*Net outranking*		
	A	0.3353	0.3030	0.2867	0.0932	0.1066	0.1310	0.2421	0.1964	0.1557
	B	0.3592	0.3630	0.3682	0.1455	0.1415	0.1343	0.2137	0.2214	0.2339
	C	0.1361	0.1482	0.1402	0.4257	0.4147	0.4079	-0.2896	-0.2665	-0.2678
	D	0.1715	0.1719	0.1762	0.3580	0.3644	0.3596	-0.1865	-0.1925	-0.1834
	E	0.2251	0.2341	0.2376	0.2049	0.1929	0.1760	0.0202	0.0412	0.0616
TOPSIS		*Euclidean distance-ideal best solution*			*Euclidean distance-ideal worst solution*			*Relative closeness*		
	A	0.0562	0.0569	0.0618	0.0872	0.0834	0.0849	0.6083	0.5943	0.5789
	B	0.0538	0.0537	0.0538	0.1055	0.1027	0.1051	0.6622	0.6568	0.6616
	C	0.1098	0.1068	0.1075	0.0390	0.0433	0.0479	0.2620	0.2884	0.3081
	D	0.1031	0.0998	0.1020	0.0613	0.0615	0.0619	0.3728	0.3812	0.3777
	E	0.0742	0.0707	0.0745	0.0779	0.0804	0.0802	0.5121	0.5322	0.5183

Table 14
Comparison of ranking amongst MCDMs.

	15-minute						*10-minute*						*5-minute*					
Routes	$E_{I\hat{c}_i}$	$E_{I\hat{d}_i}$	P	S	V	T	$E_{I\hat{c}_i}$	$E_{I\hat{d}_i}$	P	S	V	T	$E_{I\hat{c}_i}$	$E_{I\hat{d}_i}$	P	S	V	T
A	1	1	1	1	1	2	2	1	2	2	1**	2	2	1	2	2	1**	2
B	2	2	2	2	2**	1	1	2	1	1	2**	1	1	2	1	1	2**	1
C	*	*	5	5	5	5	*	*	5	5	5	5	*	*	5	5	5	5
D	*	*	4	4	4	4	*	*	4	4	4	4	*	*	4	4	4	4
E	3	*	3	3	3	3	3	*	3	3	3	3	3	*	3	3	3	3

$E_{I\hat{c}_i}$: Global concordance; $E_{I\hat{d}_i}$: Global discordance; P: PROMETHEE; S: SAW; V: VIKOR; T: TOPSIS.

[*] Unsuitable values.

[**] Unverified condition of K1 or K2.

routes, ELECTRE and VIKOR methods enable us to read the proximity or possible instability of solutions, which in other methods is confirmed as stable. This can lead to a greater awareness of the decisions of public administrators.

6. Discussion

The results above highlight that infrastructural and environmental-related features and user preferences (targeting multi-generational/ family travellers) can contribute each all to the selection of cycle routes. The weighting process of criteria highlights a close relevance amongst routes, services, and natural environment features. Moreover, they stressed three crucial issues.

First, the integrated approach highlighted the importance of participatory processes in developing a future sustainable infrastructural network for resilient cities and society, i.e., the involvement of people who live in and administrate them. This study involved technical and political decision-makers and land experts: (i) in enriching the set of criteria representative of territorial specificities and in weighing their importance; (ii) in the participatory mapping of these specificities. The approach made it possible to combine the participants' knowledge with spatially specific information, improving the spatial rendering of information often entrusted to open-source tools that are sometimes not perfectly correct or simplified (Brown, Kyttä, & Reed, 2022). Simultaneously, data become new cognitive elements to support public administrations in future projects. Participatory approaches, e.g., interviews or diaries, have already been used in the topic as assessment tools for users' preferences (Deenihan & Caulfield, 2015; Ritchie, 1998; Watthanaklang et al., 2016). Differently, this study focused on public decision-makers, but the weights of parameters generally confirm the results of previous studies (e.g., Bakogiannis et al., 2020a; Lumsdon et al., 2004; Pantelaki et al., 2022).

Second, the overall method shows the relevance of the land use-based approach, i.e., the acceptable description of route parameters point-by-point and conditioning the assessment effectiveness for a specific type of cycle tourist and stakeholders' feasibility. Therefore, it has managed the interaction amongst infrastructural, service, and environment-related features. Results on criteria and parameters are consistent with Watthanaklang et al. (2016) because the nature-based experiential relevance, e.g., environmental and cultural, makes the evaluation depend on the territorial specificities. However, this principle requires two elements: (i) the correlation with the elements of the surrounding environment; (ii) the definition of a proximity scale of these elements and the attractions considered by users and policy-makers. This approach increases route usability and minimises travel time by rationalising the time spent at the attractions. For instance, Di Ruocco et al. (2020) defined a deviation scale of the attractor location not exceeding 5 km (a very high limit). However, the authors do not spatialise the scale. Černá et al. (2014) and Malucelli et al. (2015) considered a sum of scores of POI on the graph of potential cycle-tourism routes. This setting does not define the limited extent of the link. In the same way, specific analysis is critical if compared to a polygonal surrounding analysis. These critical issues are also encountered by Zhu (2022). Nevertheless, the methods of previous studies were appreciable, and the mathematical focus on optimisation justified such simplifications. The application of different proximity scales has clearly shown how priorities of cycle-tourism routes can vary. This variation is further different by applying space-based proximity as in Carra et al. (2023) or temporal-based one as applied in this study.

Finally, the results returned the higher priority of cycle-tourist routes within the already developed areas with a strong tourist vocation. This is intrinsic to parameters: e.g., "waterscapes" and "protected areas" are landscape elements that have already been widely exploited in the case study of Franciacorta; "catering" and "accommodation" services are greater where the generic tourist presence is high. However, excellent priority results have been obtained from the cycle-tourist route E, which extends over areas with less tourist development. Therefore, results identified competitive areas with positive tourist potential. The general advantage of territories characterised by a tourist economy over inner ones is obvious, in contrast to a collaborative approach of wide-area planning. Therefore, results highlighted the relevance of collaborative decentralisation strategies between touristic developed and underdeveloped areas, as Petino et al. (2021) showed. This issue still needs to be solved in the method, and future advancements are needed, e.g., by applying a reduction factor for tourist-developed areas.

7. Conclusion

Cycling tourism is a developing and expanding kinaesthetic experience of active vacations able to achieve several benefits for users and urban and regional contexts. Therefore, it represents a relevant mobility mode to make the tourism of future cities and society resilient and sustainable. Several multidisciplinary studies have been implemented mainly on factors, user profiling and case studies for cycle-tourist route planning. However, only some studies addressed assessment methods to support cycle tourist routes future implementations: most focused on design and *ex-post* evaluation, and none on the programming of implementations in a multi-institution context (*ex-ante*). Moreover, to the best of our knowledge, no studies integrate infrastructural, environmental and people-related issues to evaluate cycle tourism routes and contribute to a people-centred and place-based approach that guarantees user experience and project sustainability collaboratively between territories.

Therefore, this study contributed to the growing literature and practice to define a priority ranking of cycle-tourist routes as a compromise between users satisfaction and project feasibility in terms of infrastructural features (i.e., economic and managing feasibility and physical/psychological propensity of users), travel services, and environment attraction. Specifically, the contributions of the study are as follows:

- Integration of AHP, ELECTRE and VIKOR as Multi-Criteria Decision-Making approaches in a single method supported by a land use approach with a GIS-based spatial analysis. The spatial approach ensures the accuracy of the analysis, usually based on a data association with routes, i.e., lines segmented according to several ways (e.g., administrative borders, links and nodes, route denominations). Therefore, they were unable to provide a fine description of environmental values. Moreover, the integration of approaches can return the best compromise solution in the choice of cycle route alternatives managing several issues: a multi-institution framework where each municipality contributes to its interests, a multi-stakeholder perspective where several viewpoints concur, and a multi-factors problem where different criteria have to be considered.
- Identification of criteria and parameters according to a multi-stakeholder perspective engaged in the decision-making and participatory mapping processes. This study identified target users in criteria selection and the choice's orientation.
- Application of a priority ranking by a proximity scale to points of interest. The accessibility was performed at a time distance of 15-, 10-, and 5-minutes; therefore, spatialised isochrones were built for each cycle-tourist route planned.
- A comparison of results obtained with this method and other, well-known, MCDMs.

The relevant implications of this study are as follows:

- The high degree of applicability of the method is not strictly linked to the evaluation of cycle route alternatives. It can be effectively reproducible and adaptable to several contexts, which will be orientated to low-carbon tourism and mobility, able to minimise the tourism-traffic-environment paradox. Moreover, the method is orientated towards integrated and collaborative planning between several local authorities and planning typologies, i.e., urban, regional, and transport planning.

- The specification of 4 criteria measured according to 19 parameters may help public administrations articulate and coordinate the planning and implementation of novel cycle tourist infrastructure systems in a user-centred that integrates infrastructural, environmental and people-related criteria.
- The accessibility analysis of points of interest criteria favours cycle tourism and sustainable travel modes. It may help support public administrations or tourist activities in developing future services and cycle routes integrated into peculiarities and transport systems in a place-based approach.

Nevertheless, this study indicates several developments. First, even if users' preferences on criteria and parameter selection were largely collected from the literature, the panel of stakeholders considered only technicians and political. Therefore, the involvement of cycle users should be applied in further research. Second, we included as many parameters to accurately describe cycle route quality, users' preferences and behaviour, and decision-makers' motivations in our analysis as possible. Other parameters, such as the noise pollution or silence required in the cycle-tourist routes, could also be relevant. Third, the analysis considered users with a classic bicycle that could be affected by, e.g., the maximum average slope and maximum speed (here equal to 10 km/h). New vehicle types, e.g., e-bikes, could be included in future development as correlated variables and implications.

CRediT authorship contribution statement

Martina Carra: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Filippo Carlo Pavesi:** Data curation, Formal analysis. **Benedetto Barabino:** Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Visualization, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare that there is no potential conflict of interest.

Data availability

Data will be made available on request.

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