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A comparative cycling path selection for sustainable tourism in Franciacorta. An integrated AHP-ELECTRE method

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Abstract

Cycle tourism is a form of sustainable itinerant tourism expanding in Italy and the rest of the world, with prospects for growth in coming years. Europe and North America have already developed a wide range of cycling infrastructures tied to tourism experiences. Benefits induced are generally recognised: first, it is a sustainable solution that increases local economics while conserving the environment; second, it guarantees advantages on social connections, amusement, and physical and mental health. However, it requires an adequate network to enjoy destinations as historical and landscape peculiarities. Currently, literature provides some methods for planning itineraries dedicated to cycle tourism. Despite that, there is less attention on how evaluating existing or already planned tourist itineraries.
This study covers this gap, by applying an integrated method to assess bicycle connections for tourism experiences within municipalities. Since this evaluation may contain many conflicting criteria (e.g., preferences of public administrator, technical and economic viability) and possible alternatives, this study frames the method as a multi-criteria decision-making problem (MCDM). Specifically, at first, the Analytical Hierarchy Process (AHP) is adopted to calculate weights for each criterium; next, the ELimination Et Choix Traduisant la REalitè (ELECTRE) method is applied to provide a (possible) priority ranking of cycling tourist paths among alternatives, by computing indices of discordance and concordance between pairs of alternatives.
The framework is applied to the Franciacorta area (North-East Italy), a national and international tourist relevance territory encompassing 22 municipalities. This study may be useful for public administrators to rationalise and prioritise cycling routes.

Keywords: Multi-criteria decision-making; Cycle tourism; Bike tourism; Active mobility tourism; AHP; ELECTRE

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1. Introduction

In the context of sustainable development, a new model of tourism based on different modes of transport and experiential, including cycle tourism, has been emerging for some time (Perkumienė et al., 2020). Cycle tourism represents a successful form of itinerant tourism that is becoming more and more global: Europe and North America have long invested and developed extensive cycling infrastructures linked to tourism experiences (Han et al., 2020). On a national scale, several countries, such as the United Kingdom, Canada, Taiwan, Denmark, have developed strategies to promote cycle tourism (Procopiuck et al., 2021), and still, others foresee important investments shortly (i.e., Recovery fund). Even in Italy, where tourism represents between direct and indirect effects of about 14% of the national GDP, cycling is growing with about 55 million overnight stays in 2019. It characterises on average 6% of the overall national tourist demand, which reaches 15-20% in Regions such as Valle d'Aosta, Friuli Venezia Giulia, Trentino Alto Adige and Lombardy (Gazzola et al., 2018). Furthermore, the cycling movement comprises international tourists (63%) with an economic impact of 3 million euros (Isnart-Legambiente, 2020).

Within the debate on sustainable development and resilience to climate change, this form of tourism is characterised from a better use and enjoyment of environmental resources and greater economic and socio-cultural benefits. The scientific literature has highlighted the multiple benefits induced to territories and cities. First, cycle tourism is a solution that preserves the environment, reducing air pollution, noise and greenhouse gas emissions (Filimonau et al., 2013) while satisfying the objectives of the Sustainable Urban Mobility Plans (SUMPs) and the strategic documents of the European Union (European Commission, 2011). In particular, Patterson et al. (2007) showed the potentialities of cycle tourism in reducing the environmental impact due to modes of transport by tourists, which accounts for about 86% of the entire impact linked to the tourism sector. Furthermore, cycle tourism enables overcoming the tourism-traffic paradox that characterises areas with a high tourist intensity and, at the same time, ecologically sensitive by minimising side collateral effects (Bakogiannis et al., 2020). Second, cycle tourism contributes significantly to physical and mental health, both indirectly for better air quality and directly through physical activity (Kim and Hall, 2022). Thirdly, it favours the local economies of remote rural destinations (Lumsdon et al., 2004) and, finally, it constitutes a recreational alternative to a rediscovery of traditional culture that favours social connections (Bakogiannis et al., 2020; Han et al., 2020).

However, if cycle tourism is defined as a vacation or holiday, it requires adequate planning and design to make paths suitable and destinations usable according to certain criteria and factors (Ritchie, 1998).

1.1. Literature review: models and factors

The state of the art analysis has shown how studies focused on wide-area planning tourist cycle mobility are still relatively scarce today being relatively recent. Studies mainly focused: (i) on the identification of long-term strategies and/or action plans (Petino et al., 2021); (ii) on the composition, motivations and preferences of cyclists (Lumsdon et al., 2004; Deenihan and Caulfield, 2015; Chen et al., 2018; Bakogiannis et al., 2020; Khajehshahkoohi et al., 2021); (iii) on the experiences of existing itineraries (Robartes et al., 2021) and (iv) on the assessment of cycle paths surfaces (Calvey et al., 2015).

Conversely a handful small part of studies focused on applying methodologies for assessing the quality of entire cycle paths. Some of them focused on Cost-Benefit Analyses as tools to support the identified project choices, defining the minimum number of users necessary to balance the investment/maintenance costs of the new itineraries and the economic, social, and environmental benefits induced (Gazzola et al., 2018). Differently, Zhu (2022) approached the problem through a multi-objective mixed-integer linear programming model. The goal is to maximise the accessibility of cyclists to the points of interest (POIs), minimise the total travel time, maximise the level of service, and minimise the number of intersections.

Factors used or identified by the behaviours or preferences of (tourist) cyclists in the literature are manifold. The most in-depth contribution derives from (Bakogiannis et al., 2020), which have highlighted the most comprehensive set of factors that influence cycle tourism. They were characteristics of the path network, following the natural environment and, finally, the built environment. The social context turned out to be of little importance. Among related sub-factors, the following emerged as of primary importance through the AHP: the medium slope of the path (<6%), the quality of the path surface, the presence of infrastructure/cycle paths, interchange such as public transport. Many of them have been confirmed by the literature; for instance, preferences for dedicated paths segregated from traffic (Deenihan and Caulfield, 2015; Winters et al., 2011), the interchange (Lumsdon et al., 2004; Gazzola et al., 2018), the presence of elements of the natural environment (Ritchie, 1998), accessibility to POIs (Lumsdon et al., 2004; Gazzola et al., 2018), distances maximums of 20-30 km or average journeys of about 3 hours (Lumsdon et al., 2004).

However, no study evaluates intervention priorities of planned cycling itineraries according to decision-making and objective methodologies. Therefore, this study fills this gap by applying an integrated method among several planned cycling itineraries in a GIS environment. The originality does not consist in methodological innovation itself, but in the cycle touristic topic so far neglected in literature and in adopting both intrinsic or context factors of paths. Because many conflicting criteria (e.g., public administrator preferences, technical and economic feasibility) and possible alternatives can occur, this study frames this method as a multi-criterion decision problem (MCDM). Specifically, at first, the Analytical Hierarchy Process (AHP) is used to calculate the weights of factors derived from the literature; subsequently, the ELimination Et Choix Traduisant la REalitè I (ELECTRE I) method is applied to provide a priority ranking of cycling itineraries among the planned ones, calculating indices of concordance and discordance between pairs of alternatives. Finally, the integrated method is applied to the Franciacorta area (Italy), a national and international tourist importance territory encompassing 22 municipalities in the Lombardy region. The results can be a useful tool to support public administrators to rationalise and prioritise cycle-tourist itineraries according to a multidisciplinary approach between transport planning and urban planning.

The remaining paper is organised as follows. Section 2 explains the 4-phase method AHP-ELECTRE. Section 3 presents the main results of the method applied to the case study of Franciacorta. Lastly, Section 4 concludes the contribution by providing some limits and suggestions for future development.

2. Methodology

The methodology for evaluating project priorities consists of an integrated 4-phase approach. In the first phase, the prevailing design criteria to plan suitable cycle-tourist itineraries are defined by reviewing the literature. In the second phase, the cycle-tourist itineraries are defined. This phase characterises the action of the designer-planner and the participatory co-design with public administrations concerned in the area (Carra et al., 2018).

The third phase concerns the multi-criteria analysis that summarises the decisions, choices, or preferences of the subjects involved. The subject are "experts" that can be technicians, public decision-makers and/or expert users. Due to the heterogeneity of experts, the objective pursued, and the possibility of distorted opinions (e.g., inconsistent values), the AHP was applied as done in other contexts (e.g., Carrara et al., 2021; Carra et al., in press). It can break up the problem by elements of a different nature (i.e., qualitative and quantitative, objective and subjective), structure elements in a hierarchical way concerning the objective, and it can process the judgments according to a normalised priority scale (i.e., values) that take into account the reciprocity (or likelihood), homogeneity and independence of judgments (Saaty, 1994). The AHP is implemented to measure the relative relevance of specific design criteria for cycle-tourist itineraries and context factors that could affect itineraries themselves. It is solved by understanding how much one criterion is more important than another in identifying implementation priorities of cycle-tourist itineraries (i.e., priority vector). Scores of each comparison derive from the judgment of experts (on a specific criterion) based on their experience and opinion. The outcome is a matrix (Table 1) that determines the vector of absolute percentage weights calculation through pairwise comparisons resulting from experts' numerical judgment (j_j/j_n) between, e.g., the criterion *Cj* and *Cn*, respectively. This is done using a numerical/linguistic evaluation scale of the relative importance of criteria (Wind and Saaty, 1980).

Table 1. Generic example of pairwise comparisons matrix.

	C_1	C_2	…	C_j	…	C_n
C_1	1	j_1/j_2	…	j_1/j_j	…	j_1/j_n
C_2	j_2/j_1	1	…	j_2/j_j	…	j_2/j_n
…	…	…	…	…	…	…
C_j	J_j/j_1	J_j/j_2	…	1	…	J_j/j_n
…	…	…	…	…	…	…
C_n	j_n/j_1	j_n/j_2	…	j_n/j_j	…	1

Next, the consistency is assessed, i.e., whether experts' judgments are consistent through the definition of the Consistency Ratio (CR < 0.1) given by the ratio between the Consistency Index (CI) and the Random Index (RI). The first is obtained from the comparison matrix equal to the average CI of a high number of matrices of the same order (n) generated randomly. The second is the average CI values, calculated by a group of experts and evaluated concerning a large number of square, reciprocal, positive and random matrices. As a result, the application of AHP determines the weight of each criterion to be applied in the following phase of the ELECTRE I method.

The fourth step applies the ELECTRE I preference aggregation method, which enables building binary update relationships, i.e., it sorts by multiple criteria the best alternative or priorities among alternatives among a set of possible solutions. Therefore, it draws up a comparison of alternatives (Figueira et al., 2016). ELECTRE I begins with the building of a decision matrix expressed in terms of respondence between the criterion and alternative. Next, the matrix is converted into a utility matrix through utility functions (Table 2). In this study, utility functions are assumed to be linear. Each utility function (U_{ij}) must be determined for each alternative (O_i) and considering each criterion (C_j). The maximum (1) and minimum (0) values depend on whether a given value maximises or minimises the objective, i.e., whether the criterion considered represents a Cost or a Benefit in the choice. Consequently, the value will be equal to 1 for lower cost and maximum benefit values. Therefore, it represents the most favourable utility function among alternatives for a given criterion. Intermediate values can be defined by a linear function.

Table 2. Utility matrix (a simple example).

	C_1	C_2	…	C_j	…	C_n
	w_1	w_2	…	w_j	…	w_n
O_1	U_{11}	U_{12}	…	U_{1j}	…	U_{1n}
O_2	U_{21}	U_{22}	…	U_{2j}	…	U_{2n}
…	…	…	…	…	…	…
O_i	U_{i1}	U_{i2}	…	U_{ij}	…	U_{in}
…	…	…	…	…	…	…
O_n	U_{n1}	U_{n2}	…	U_{nj}	…	U_{nn}

Next, the method builds one or more outranking relations, which can fully compare each possible pair of alternatives or options (Table 3). The concordance index (Ic) and the discordance index (Id) are evaluated for each of them. The first is intended as the sum of weights associated with corresponding criteria (w_j), normalised and derived from the AHP, which form the coalition of criteria for which the alternative (X) is preferable to (Y). The discordance index represents the maximum value of the greater difference in utility for each criterion (R_{xy}) in favour of the alternative Y over the X.

Table 3. Index of concordance and discordance in pairs.

(1)		(2)	(3)	**(4)**	(5)	(6)	(7)	(8)	**(9)**
		Concordance			**Discordance**				
Pairs of alternatives		**C_j for $U_x > U_y$**	**w_j related to (2)**	**Concordance index**	**C_j for $U_x < U_y$**	**ΔU_{yx}**	**$\Delta C_{j(U_{max} - U_{min})}$**	**R_{xy}**	**Discordance index**
X	**Y**								
O_1	O_2	$C_1 \ldots C_j$	w_j	**$Ic_{12} = \Sigma w_j$**	$C_2 \ldots C_j$	ΔU_{21}	ΔC_{12}	$R_{12} = \Delta U_{21} / \Delta C_{12}$	**$Id_{12} = \max(R_{12})$**
O_1	O_3	$C_1 \ldots C_j$	w_j	**$Ic_{13} = \Sigma w_j$**	$C_2 \ldots C_j$	ΔU_{31}	ΔC_{13}	$R_{13} = \Delta U_{31} / \Delta C_{13}$	**$Id_{13} = \max(R_{13})$**
…	…	…	…	**…**	…	…	…	…	**…**
O_n	O_n	$C_n \ldots C_j$	w_j	**$Ic_{nn} = \Sigma w_j$**	$C_n \ldots C_j$	ΔU_{nn}	ΔC_{nn}	$R_{nn} = \Delta U_{21} / \Delta C_{nn}$	**$Id_{nn} = \max(R_{nn})$**

The selection of the priority alternatives rankings consists of exploiting the joint outranking relationship of (Ic) and (Id). For each X-Y pair, X is the preferable alternative to Y if $Ic_{(x,y)}$ is close to unity (1) and if $Id_{(x,y)}$ is close to zero. To perform the choice, it is necessary to set a pair of limit values for the two indices, which enables discarding all those pairs of alternatives that do not fall within the interval. Next, it is possible to approach the most favourable remaining alternatives by constructing an arrow preference pattern. The interval will be reduced as preferences are not clarified. Additionally, applying the global concordance ($\widehat{Ic}$), and discordance ($\widehat{Id}$) index method to each alternative is possible to avoid the relatively arbitrary choice of limit values.

$$\widehat{Ic} = \sum_k Ic_{xy,k} - \sum_k Ic_{yx,k} \qquad \text{with } x \neq y \tag{1}$$

$$\widehat{Id} = \sum_k Id_{xy,k} - \sum_k Id_{yx,k} \qquad \text{with } x \neq y \tag{2}$$

Alternatives with a negative $\widehat{Ic}$ and a positive $\widehat{Id}$ are excluded from the calculation. In the case is not enough to identify the most favourable alternative, it is necessary to adopt other evaluation methods, such as the weighted sum method, which is not discussed in this study.

3. The Franciacorta case study

The overall four-phase method presented in Section 2 was tested in the case study of Franciacorta wide area, located in the North of Italy. It includes 22 municipalities in the province of Brescia, in the Lombardy region, with around 194.000 inhabitants. It is characterised by a territory of environmental, historical, and cultural relevance, strongly anthropised. Its main vocation is productive activities mainly linked to the wine sector. The landscape is characterised by vast crops characterised by vineyards, and numerous technological and transport infrastructures such as the railway routes that connect Brescia to Milan and Brescia with Camonica Valley.

Recently, regional planning has been oriented towards greater attention to the existing naturalistic and landscape assets and the enhancement of the historical and cultural values of the territory. The approval of the *Piano Territoriale Regionale d'Area della Franciacorta* (PTRA, i.e., Regional plan of Franciacorta wide-area) in 2017 defined clear planning guidelines oriented to sustainability principles and finds the usability of the territory one of the cornerstones of local development. The project "Sustainable mobility in Franciacorta. Wide area cycle itineraries" fits into this framework and has as its primary objective the configuration of planning tools to support the implementation of the sustainable mobility objectives set by the PTRA. The focus is paid to non-systematic cycling mobility with a tourist vocation. Therefore, the study is configured as an intermediate pre-feasibility planning and design tool that incorporates and develops the Third strategic objective of the PTRA: "Supporting an integrated system of accessibility and sustainable mobility". The action focuses on itineraries between all 22 involved municipalities, creating a network that connects the inhabited centres both with the main infrastructures of collective mobility and with the elements that characterise the territory both from the cultural and gastronomic points of view. Therefore, the study operates according to the systematisation of the existing paths, investigating the characteristics of each stretch and identifying several strategic actions aimed at completing and strengthening the existing cycle network through the definition of priority interventions. In this way, the project pursues a triple objective: (i) to develop more sustainable territorial and local transport; (ii) modernise the tourist offer through the enhancement of cycle mobility infrastructures by promoting a type of sustainable tourism; (iii) improve the usability and cycle-tourist accessibility. Therefore, the method has been used to define a priority ranking of cycling tourist paths among possible alternatives.

3.1. Phase 1 and 2: Dataset and GIS modelling

In phase 1, a set of criteria has been defined based on the revision of the relevant literature, i.e., average slope, estimated cost of realization, length, municipality crossed, points of interest (within 1 km), stretches with paths dedicated, train stations and priority bus stops (within 1 km), unpaved stretches. These criteria were the starting point for the next modelling and design phase.

In phase 2, a dataset was developed in which the criteria selected in phase 1 were mapped. It took place in a GIS environment and enabled to define a database of the characteristics of the existing itineraries (Fig. 1b). It was the starting point for co-design activities with the municipal technicians of the Franciacorta. The project scenario resulted in several actions to strengthen the existing network by creating a system of paths that crosses the Franciacorta area, connects municipalities and related points of interest (POI), i.e., historic-cultural, landscape-environmental, enogastronomic, and recreational (Fig. 1c).

Consequently, four itineraries were designed (Fig. 1a) according to preferences of local administrators: (A) Brescia-Paratico; (B) Palazzolo-Sulzano; (C) Gussago-Palazzolo; (D) Rovato-Capriolo.

3.2. Phase 3: AHP

Phase 3 aimed to establish a priority order of criteria that characterised cycle-tourist itineraries; therefore, the criteria selected in phase 1 were evaluated using the AHP method partially. A web survey was carried out to define weights associated with each criterion, in which experts in soft mobility and cycling tourism themes were involved (i.e., technicians, public decision-makers and expert users).

(a) (b) (c)

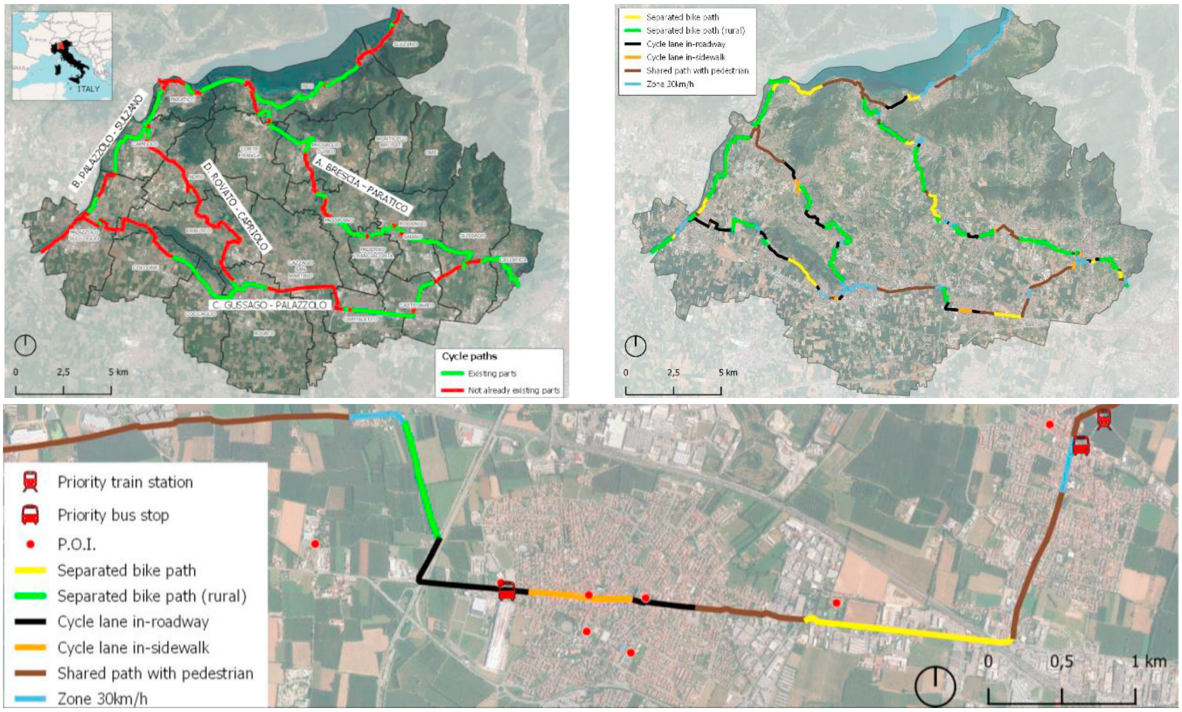

Fig. 1. (a) The 4 itineraries categorised in existing (green) and not (red) ones; (b) The 4 itineraries categorised by planned bikeways types; (c) Detail of itineraries C categorised by bikeways types with POIs and priority bus stops and stations.

Weights can be associated with the characteristics of each path, enabling to establish a strong basis for evaluating the itineraries themselves. Therefore, phase 3 is preparatory to the subsequent assessment of cycle-tourist itineraries. Table 4 shows the resulting average weight of criteria and represents the criteria order of relevance themselves according to experts' judgment (#14). Consequently, experts first preferred the "Points of interest within 1 km" and "Average slope" criteria.

Table 4. Average weights of criteria (AHP analysis).

Criteria	Cost or Benefit	Aggregate average weight	Standard deviation
Average slope [%] ($\overline{w}_1$)	C	0.159	0.108
Municipality crossed [#] ($\overline{w}_2$)	B	0.100	0.078
Stretches with paths dedicated [%] ($\overline{w}_3$)	B	0.099	0.059
Unpaved stretches [#] ($\overline{w}_4$)	C	0.085	0.059
Length [m] ($\overline{w}_5$)	B	0.068	0.034
Points of interest within 1 km [#] ($\overline{w}_6$)	B	0.258	0.115
Train stations and priority bus stops within 1 km [#] ($\overline{w}_7$)	B	0.116	0.076
Estimated cost of realization [€] ($\overline{w}_8$)	C	0.116	0.063

3.3. Phase 4: ELECTRE I

Phase 4 evaluated itineraries applying the ELECTRE I method and linked the previously performed GIS modelling and AHP analysis. According to a utility matrix, each planned itinerary has been systematised and weighed based on its characteristics and compared with the other itineraries (Table 5). Next, the pairs of alternatives comparison have determined indices of concordance and discordance as described in Table 3, and it has been set up a pair of limit values ($Ic_{xy} > 0.55$; $Id_{xy} < 0.55$) for both indices to discard the worst alternatives (Table 6). Therefore, they resulted in four pairs of alternatives valid (A-B; C-A; C-B; C-D). For instance, according to results in Table 6, Alternative A wins in comparison with B because its Ic is larger than 0.55 and Id is lower or equal than 0.5.

Table 5. Decision and utility matrix.

Itineraries	$\overline{w}_1$	$\overline{w}_2$	$\overline{w}_3$	$\overline{w}_4$	$\overline{w}_5$	$\overline{w}_6$	$\overline{w}_7$	$\overline{w}_8$
A	2.57%	9	31.25%	45.26 %	31,857	37	8	1.987.001€
B	3.22%	5	46.84%	32.33 %	31,128	32	12	1.898.996€
C	1.40%	10	47.16%	10.89 %	27,575	48	10	2.242.234€
D	3.19%	4	25.11%	46.39 %	13,811	51	4	2.564.866€
				Utility matrix				
A	0.36	0.83	0.28	0.40	1.00	0.26	0.50	0.87
B	0.00	0.17	0.33	0.03	0.96	0.00	1.00	1.00
C	1.00	1.00	1.00	1.00	0.76	0.84	0.75	0.48
D	0.02	0.00	0.00	0.00	0.00	1.00	0.00	0.00

Table 6. Index of concordance and discordance in pairs.

Pairs of alternatives	Ic	Pairs valid for $Ic_{xy} > 0.55$	Id	Pairs valid for $Id_{xy} < 0.55$
A-B	0.700	valid	0.500	valid
A-C	0.135	null	0.722	valid
A-D	0.742	valid	0.737	null
B-A	0.300	null	0.667	null
B-C	0.269	null	1.000	null
B-D	0.583	valid	1.000	null
C-A	0.847	valid	0.383	valid
C-B	0.731	valid	0.515	valid
C-D	0.742	valid	0.158	valid
D-A	0.258	null	1.000	null
D-B	0.417	valid	1.000	null
D-C	0.258	null	1.000	null

Using the arrow method to schematise the preference relationships, with the tip facing the preferred alternative, resulted in the preference of itinerary C over D, B and A, and the preference of itinerary A over B and D. However, it is unattainable to make a priority ranking since the preference between B and D, and A and D itineraries is unknown. Consequently, the global concordance and discordance indices have been set to finalise the ranking (Table 7).

Table 7. Itineraries rankings.

B   **D**
↑   ↖   ↑
A   ←   **C**

Itineraries	$\widehat{Ic}_n$	$\widehat{Id}_n$	Priorities ranking
A	0.173	-0.092	**2**
B	1.599	3.682	**4**
C	2.712	-1.665	**1**
D	1.517	1.105	**3**

The results showed how the itinerary C presents the "best" alternative to be considered a priority over the others, following the itinerary A, D and B, respectively.

4. Conclusion

The study applies a decision-making methodology to evaluating intervention priorities of planned cycling-tourist itineraries for the first time. The 4-phase method is derived from intrinsic characteristics of paths and context factors in which the paths are inserted. Therefore, it could be a useful approach for technicians and public administrations to support decision-making in terms of economic and sustainability relevance, developing an integrated cycling network and promoting cycling tourism, linking territories of a wide area and satisfying both reasons of feasibility for public decision-makers and users' needs. Therefore, the methodology is based on a multidisciplinary approach that integrates urban and transport planning, oriented to the cyclist's safety and preferences and the enhancement of territorial peculiarities.

Despite these results, the study presents some limitations of simplification to solve with future development. First, the adopted method could not only provide the prioritisation of itineraries but also modelling design alternatives to multiple trunks of the single path for the entire network of the considered territory. Therefore, decision analysis could become more stratified. Second, many more context factors could be considered due to they could describe punctually the quality of the cyclist experience and tourist attractiveness, e.g., the relationship between the itinerary and the natural environment (panoramic views and tangent points to lakes, rivers, wooded areas, vineyards, Natura 2000 sites, landscapes of particular relevance) the built environment (accommodation points, historic centres, industrial areas), or additional features of the cycle-tourist path (Bakogiannis et al., 2020). In this perspective, the method could be improved to correlate the characteristics of the cycle-tourist paths with the land use of adjacent areas to the paths themselves. Finally, the assessment could include new variables related to e-Powered Micro Personal Mobility Vehicles (Lin et al., 2021; Boglietti et al., 2021).

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