A Co-design and Co-evaluation Model for the Reconversion of Dismissed Railways to Greenways: The Case of Misterbianco

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Abstract. The conversion of dismissed railway infrastructure into greenways has emerged as a sustainable strategy for enhancing mobility, fostering social interaction, and promoting environmental resilience. This study focuses on the transformation of a segment of the former Circumetnea railway in Misterbianco, a key urban center in the Metropolitan City of Catania. Using a participatory co-design and Social Multi-Criteria Evaluation (SMCE) approach, the research aimed to integrate community needs into the planning and design process.

Through stakeholder engagement, focus groups, and co-evaluation workshops, the study identified mobility patterns, safety concerns, and recreational preferences among Misterbianco's residents. Key findings indicate that the greenway must prioritize accessibility, security, and social value by incorporating dedicated cycling and walking paths, enhanced lighting, and bike-sharing facilities. The SMCE framework allowed for an objective assessment of design alternatives, balancing technical feasibility with community expectations.

The results underscore the importance of participatory planning in infrastructure projects, ensuring that redevelopment efforts align with local needs. The Misterbianco case serves as a model for similar railway-to-greenway conversions, demonstrating how co-evaluation methodologies can optimize functionality, social cohesion, and environmental sustainability. Future research should assess long-term usage patterns and economic impacts to refine planning strategies for green mobility networks.

Keywords: dismissed railways · greenways · SMCE · co-evaluation

1 Introduction

The emergence of railways in 19th-century Europe revolutionized transportation, facilitating economic growth, urban expansion, and cultural exchange [1]. The 1825 launch of the Stockton & Darlington Railway in England showcased the potential of steam locomotives, prompting rapid railway expansion across Europe. Nations like Belgium, France, and Italy invested heavily in railway networks, linking cities, industrial hubs, and ports. This infrastructure enhanced trade, encouraged migration, and required synchronized timekeeping, contributing to standardized time zones. Railways became a symbol of progress, central to the industrial revolution and urban modernization [2].

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By the 20th century, the rise of automobiles and aviation reshaped transportation. Affordable cars, like the Ford Model T, provided individual mobility, while air travel facilitated rapid long-distance connections. Governments prioritized road and airport expansion, diminishing the role of railways in passenger transport [3]. This transition exacerbated urban congestion, pollution, and carbon emissions. Recognizing rail efficiency and sustainability, recent efforts have focused on reintegrating rail into modern mobility systems, particularly through high-speed networks and green transit solutions [4].

Mid-century railway closures disrupted regional transport networks. In the UK, the Beeching cuts of the 1960s led to the closure of over 4,000 miles of railways and 2,000 stations, isolating rural communities [5]. Italy abandoned over 7,000 km of railway, due to economic inefficiency. Across Europe, over 50,000 km of railway tracks have been decommissioned, resulting in economic stagnation, social isolation, and declining accessibility in affected regions [6].

The abandonment of railway infrastructure represents significant economic and environmental loss. The high costs of railway construction and maintenance - including land acquisition, track development, and station building - have gone to waste. Many structures of historical and cultural value have deteriorated rather than being repurposed. The environmental impact is equally severe: without rail options, dependence on high-emission road and air travel has intensified, contributing to climate change and habitat disruption. Instead of becoming green spaces, unused railway corridors have turned into neglected wastelands [7].

The social consequences of railway closures are profound. Many communities have lost access to essential services, education, and employment opportunities, widening disparities between urban and rural areas and displaying damaged heritage [8]. Without intervention, these trends risk entrenching long-term socio-economic inequalities [9].

A potential solution lies in transforming dismissed railways into greenways – linear routes designed for cycling, walking, and ecological conservation. [10] Greenways reconnect fragmented regions and play a key role in the regeneration of territories [11]. Moreover, unused railways often cross marginal areas with an overall complex heritage context [12]. Marginal and inner areas are a critical theme [13]: on the one hand, they are in a state of lack of resources and objective difficulties [14], but their peculiar condition offers possibilities for experimenting with new redevelopment horizons [15]. Their revitalization can improve resilience [16], benefit the local economy and real estate market [17], and align with sustainability goals by promoting green mobility and active lifestyles. This shift reflects a broader urban mobility paradigm, emphasizing reduced car dependency and enhanced public spaces [18]. It should also be considered that shared infrastructures bring social valuation in their design and use [19].

However, effective greenway planning requires community participation and adaptive design strategies, in addition to evaluating its costs and benefits [20, 21], and project feasibility and economic optimization [22]. Successful projects must balance connectivity with local lifestyle integration, ensuring that infrastructure aligns with user needs. A co-design and co-evaluation approach is crucial, engaging stakeholders in decision-making and functional assessment. This will produce a new generation of expanded urban areas, more internally integrated [23].

This paper explores a structured methodology for greenway development, tested through a case study on the dismissed Circumetnea railway in Sicily. A multi-criteria co-design and co-evaluation process was conducted in collaboration with three municipalities, generating data-driven design strategies for specific greenway segments.

The paper is structured as follows:

- Section 2 outlines the concept of greenways and methodologies for co-evaluation.
- Section 3 presents the Circumetnea railway case study, detailing historical evolution and territorial impact, then describes the methodological application, with the co-design and co-evaluation process, analyzing stakeholder engagement and design outputs.
- Section 4 provides conclusions, emphasizing the applicability of participatory models in greenway planning.

2 Materials and Methods

2.1 Greenways

Greenways have been defined in various ways over time, reflecting their evolving functions and applications. Horte and Eisemann describe them as "linear public parks and places that facilitate active travel and recreation in urban areas" [24], emphasizing their role in urban planning and sustainable mobility. Earlier, Little defined a greenway as a "linear open space established along either a natural corridor, such as a riverfront, stream valley, or ridgeline, or overland along a railroad right-of-way converted to recreational use, a canal, scenic road, or other route" [25]. The connection between dismissed railways and greenways dates back to the 1980s with the establishment of the Rails-to-Trails Conservancy, a pioneering initiative that repurposed abandoned rail corridors into multi-use trails. These rail-to-trail conversions have since been implemented in many countries, providing cycling and walking paths that link urban and rural areas, fostering local economic development through increased tourism and business opportunities. Similar initiatives in Germany and France have revitalized disused rail networks, repurposing them for regional transport and active mobility, reducing traffic congestion and urban sprawl [26].

Greenways can be categorized into five primary types based on their function and location [27]:

- Waterfront and riverside greenways – Developed along rivers, lakes, or coastlines, these serve both ecological and recreational purposes.
- Rail-to-trail greenways – Created by repurposing dismissed railway corridors, these provide active mobility routes while preserving historic infrastructure.
- Natural trails – Found in forests, rural areas, and protected landscapes, these trails are primarily leisure-oriented rather than for daily commuting.
- Active Travel Corridors (ATCs) – Explicitly designed for non-motorized transportation, these are integrated with transit hubs and public transport systems.
- Multitype greenways – Combining two or more categories, these maximize accessibility, connectivity, and ecological benefits.

This research focuses on the rail-to-trail and multitype greenways, as they are most relevant to the transformation of the dismissed Circumetnea railway. Rail-to-trail projects directly address the issue of railway abandonment, while multitype greenways offer greater functional diversity, accommodating both active mobility and recreational use [28].

Several successful rail-to-trail conversions demonstrate the social, economic, and environmental benefits of such projects:

- Rail Trail Cycleway (Western Sydney, Australia) – A 16.5-km path created in 2000, designed to promote physical activity in adults aged 18 to 55 [29];
- The 606 (Chicago, USA) – A 2.7-mile (4.35 km) elevated trail repurposed from the Bloomingdale railway line, connecting diverse neighborhoods and supporting urban regeneration [30];
- High Bridge Trail State Park (Virginia, USA) – Originally a railway bridge built in 1854, this was converted into a multi-use trail after its decommissioning, preserving historic infrastructure while promoting recreational use.

Beyond their physical categorization, greenways serve two main purposes [31]:

- Active Mobility (AM) – Facilitating daily commuting and transport via walking and cycling.
- Physical Activity (PA) – Supporting recreational exercise such as jogging and leisure cycling.

Although both functions involve similar infrastructural elements, they differ in user behavior and design requirements. Studies show that PA users typically travel up to 4.2 km, while AM users are conventionally limited to 3 km, though some empirical evidence suggests a threshold of 3.2 km [32].

To maximize functionality, greenway design must consider specific user needs. Research has identified key perceptual and physical factors that influence jogging-friendly environments, which can be applied to both PA and AM-oriented greenways.

For physical activity-focused (PA) greenways, effective design strategies include [33]:

- Minimizing intersections and road crossings to ensure uninterrupted movement.
- Providing essential amenities such as benches, hydration stations, and lighting.
- Using soft but durable surfaces like asphalt or specialized running tracks.
- Integrating natural elements (greenery, water features) while maintaining adequate openness.
- Enhancing cultural identity by incorporating local design elements.

For active mobility (AM) greenways, the literature identifies key infrastructural, environmental, and behavioral considerations [34]:

- Infrastructural characteristics:
  - Flat or gently sloped paths encourage frequent use.
  - Wide, well-paved surfaces (asphalt or compacted gravel) accommodate both pedestrians and cyclists.

  - Clearly marked lanes reduce user conflicts and improve safety.

- Environmental and aesthetic factors:

  - Trees and vegetation provide shade and wind protection, making greenways usable in all seasons.
  - Proximity to forests, riversides, or historic landmarks enhances psychological well-being, encouraging longer use.

- Accessibility and connectivity:

  - Greenways should link to public transport (bus stops, train stations, bike-sharing points).
  - Multiple access points ensure usability across different neighborhoods.
  - Behavioral and safety aspects:
  - Solar-powered lighting and emergency call stations improve security, making greenways safer for evening and early morning use.
  - Avoiding intersections with car traffic enhances safety for children, elderly pedestrians, and casual cyclists.

This classification framework provides the basis for analyzing how rail-to-trail greenways, such as the one planned for the Circumetnea railway in Misterbianco, can be designed and optimized. The next section will delve into the historical context and territorial characteristics of the Circumetnea railway, highlighting the factors that have shaped its conversion into a greenway.

2.2 Social Multi-criteria Evaluation (SMCE)

Social Multi-Criteria Evaluation (SMCE) [35] has gained prominence in decision-making processes that involve multiple stakeholders, competing interests, and complex socio-ecological dynamics. Unlike traditional frameworks that prioritize economic or technical factors, SMCE integrates social values, participatory mechanisms, and deliberative processes to improve the legitimacy and effectiveness of policy decisions [36]. It extends Multi-Criteria Decision Analysis (MCDA) by placing greater emphasis on social engagement and conflict resolution, with respect to traditional multi-criteria analyses and comparative evaluations [37]. Proposed by Munda [38], SMCE addresses the limitations of cost-benefit analysis and conventional multi-criteria methods in handling social equity and incommensurable values. Its key features include the integration of quantitative and qualitative evaluation criteria, consideration of stakeholder preferences, the use of non-compensatory aggregation techniques (e.g., ELECTRE [39], NAIADE [40]) to avoid trade-offs that could disregard minority viewpoints, and a focus on sustainability-oriented decision-making [41], particularly in environmental, urban, and rural planning. Preliminary evaluation is indeed relevant to produce a suitable place-based design [42]. In addition to the resolution of decisional conflicts, one key aspect of this typology of decision-making procedures is to accentuate the perception of the economic-civic

value of space for inhabitants and users [43]. SMCE has been applied in territorial planning, environmental governance, energy policy, and urban regeneration. In the Basque Country, Spain, Garmendia and Gamboa used SMCE to assess management strategies for the Urdaibai Estuary [44], a UNESCO Biosphere Reserve. The process included stakeholder identification through a snowball method, representation of environmental NGOs, fisheries, tourism operators, and public authorities, and the selection of evaluation criteria such as ecological sustainability, economic viability, and social acceptance. A Multi-Criteria Impact Matrix quantified trade-off, while non-compensatory aggregation techniques (PROMETHEE and NAIADE) ranked alternatives. A deliberative workshop allowed stakeholders to assign weights to different criteria and conduct a sensitivity analysis. This approach ensured that conservation priorities were not overruled by economic interests. Similarly, an SMCE process in Mutriku, Basque Country, helped balance competing land-use demands, revealing conflicts between economic efficiency and environmental sustainability [45].

SMCE has also been used in urban regeneration, where social sustainability – equity, inclusivity, and cultural preservation – must be considered alongside economic and physical transformation, also as an alternative to traditional value-based estimations [46]. A study in Northern Italy applied SMCE to evaluate six social housing strategies, combining stakeholder analysis, economic feasibility assessments, and social cohesion indicators [47]. Using NAIADE, researchers found that high-density social housing, while technically efficient, disrupted community networks. Instead, mixed-use, incremental development models received greater support, highlighting the importance of integrating community perspectives into urban planning.

Co-design and co-evaluation play a fundamental role in SMCE by ensuring that infrastructure projects align with community needs. These participatory approaches allow designers to refine proposals based on real user feedback while fostering transparency and trust. In greenway planning, SMCE supports the evaluation of design alternatives, helping balance transportation efficiency, environmental conservation, and social inclusivity [48].

Several multi-criteria evaluation methodologies are commonly used within SMCE. NAIADE (Novel Approach to Imprecise Assessment and Decision Environments) applies pairwise comparisons to balance technical and social criteria, often used in urban and environmental planning [40]. ELECTRE (Elimination and Choice Translating Reality) ranks alternatives based on threshold-based comparisons, making it suitable for land-use and infrastructure planning. [49] PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations) orders alternatives according to stakeholder preferences and is widely applied in conservation planning [50]. The Multi-Criteria Impact Matrix (MCIM) allows direct trade-off comparisons and is used in participatory governance [51]. Fuzzy Multi-Criteria Decision-Making (Fuzzy-MCDM) incorporates uncertainty and subjective stakeholder preferences, making it useful in climate adaptation and water resource management [52]. Each method offers specific advantages depending on project goals, stakeholder complexity, and data availability.

3 Case Study Application: The Circumetnea Dismissed Railway

3.1 The Context: History of Circumetnea and Misterbianco

The Ferrovia Circumetnea (FCE) is a historic narrow-gauge railway that encircles Mount Etna, connecting Catania to Riposto along a 110 km route that passes through various towns in the province of Catania [53]. The railway was constructed in phases, with the Catania-Adernò (now Adrano) section opening in 1895, followed by an extension to Bronte in 1897, and completion to Riposto in 1898, enabling connectivity between the Etnean hinterland, the national railway network, and Ionian coast ports.

Throughout the early 20th century, the Circumetnea railway became a crucial freight and passenger transport system, supporting local industries and connecting rural settlements to urban centers. However, after World War II, declining freight traffic, driven by the rise of road transport, significantly impacted railway operations. In response, modernization efforts in the 1950s and 1960s introduced diesel railcars to replace steam locomotives, but competition from automobiles and buses continued to weaken rail-based mobility [54].

Since the 1990s, FCE has focused on passenger transport revitalization and integration with the Catania Metro, which launched in 1999 with an initial segment between Borgo and Porto stations. Over the years, the metro system expanded, replacing certain Circumetnea sections with underground routes and modernized infrastructure. Today, the Ferrovia Circumetnea remains an essential mobility corridor, serving both local commuters and tourists, offering scenic rail journeys through Etna's volcanic landscape and historic settlements.

The Circumetnea railway has undergone numerous route modifications, reflecting shifts in mobility demand and urban expansion. A major transformation occurred in 1999, when the Catania Metro absorbed portions of the surface railway, leading to the decommissioning of the original Catania Porto–Catania Borgo section. The former railway terminus near the port was demolished, and the Galatea metro station replaced a key surface segment. Additionally, sections connecting Catania Borgo to Nesima were abandoned in 2017, as the metro expanded underground, further reducing the Circumetnea's surface presence [55].

The most recent and impactful decommissioning occurred in 2024, with the closure of the Catania Borgo–Paternò railway segment to accommodate new underground metro construction. This decision, which ended over a century of railway service along this stretch, generated significant public debate, as it marked the removal of a historic transportation link. While these modernization efforts have enhanced public transport efficiency, they have also resulted in the loss of original railway corridors, raising questions about alternative uses for abandoned infrastructure.

One of the most relevant transformations concerns the Misterbianco area, a key urban center along the dismissed railway route. The repurposing of the former railway track into a greenway has been proposed as a sustainable urban strategy, integrating non-motorized transport and public space improvements into local planning. This approach is guided by two key objectives: first, to understand how the greenway can meet the mobility and recreational needs of the local community; second, to explore design strategies that maximize usability, safety, and environmental benefits.

To achieve these goals, a co-design and Social Multi-Criteria Evaluation (SMCE) approach was implemented, involving Misterbianco's residents, stakeholders, and planners. The participatory process allowed for a detailed assessment of local needs and expectations, ensuring that the greenway transformation aligns with mobility patterns, environmental considerations, and social dynamics. The next sections will outline the specific methodology adopted, the results of the evaluation, and the final design proposals for the greenway in Misterbianco.

Misterbianco is a municipality in the Metropolitan City of Catania, located 6 km west of Catania. It has a population of approximately 49,000 and covers 37 square kilometers. Originally destroyed by the 1669 Etna eruption, it was rebuilt in the Milicia area. While historically agricultural, Misterbianco has expanded into industrial and commercial sectors, with major landmarks such as the Scavi Archeologici di Campanarazzu, Cattedrale Santa Maria delle Grazie, and Centro Sicilia shopping mall. Its residential growth has been influenced by its proximity to Catania and favored by the employment of national and local incentives [56], making it an important suburban hub.

3.2 Co-design and Co-evaluation Methodology

A co-design and co-evaluation methodology was implemented in Misterbianco from January to June 2024 to plan the conversion of a dismissed railway into a greenway. The process included:

1. Institutional analysis, identifying key stakeholders.
2. Focus groups, gathering community insights.
3. Definition of design perimeters and concepts.
4. Co-design workshops, developing alternatives.
5. Co-evaluation workshops, selecting the best option.
6. Presentation of results to the public.

This participatory approach ensured that the greenway design aligned with local needs, supporting sustainable mobility, recreation, and connectivity. Moreover, this approach falls into the design methodologies based on multi-criteria evaluations [57]. Design-oriented evaluation is being increasingly used, especially for projects involving sustainability [58]. The following sections will describe the methodology and findings in detail.

The first phase involved identifying stakeholders and representatives of different social groups in Misterbianco through web-based searches and place-based investigations. The goal was to engage diverse community actors without filtering by purpose. The analysis identified:

- 4 volunteering associations;
- 1 cultural foundation;
- 10 sports associations;
- 1 theatrical association;
- 15 religious groups;
- 1 tourist association;
- 2 local TV networks;

- 52 food businesses;
- 38 shops.

This mapping ensured broad community representation, forming the basis for co-design and co-evaluation activities in the greenway planning process.

A focus group is a qualitative research method used to gather insights from a diverse group of participants about a specific topic. Guided by a moderator, discussions encourage participants to share opinions, preferences, and expectations, revealing perspectives that may not emerge in structured surveys or individual interviews. In this study, the focus group aimed to identify the primary needs and expected uses of the greenway, along with its role in local mobility and recreational activities.

In Misterbianco, eight participants were selected, ensuring equal gender representation and coverage of all age groups. The survey items in Table 1 were used to guide discussions, beginning with individual opinions before including general perceptions and mobility habits. They followed a funnel approach, in which wider discussions were opened after starting from individual standpoints.

Table 1. Focus Group questions

Code	Questions	Alternatives
FG1	What is your main connection to the area?	Resident/Business owner/Commuter/Worker
FG2	Which is your age group?	18–25/26–40/41–65/66+
FG3	What should be the main purpose of the greenway?	Transportation/Physical activity/Social gathering/Recreational space/Other
FG4	What activity would you engage in on the greenway?	Walking/Running/jogging/Cycling/Socializing/Attending community events/Other
FG5	Which destination would you likely reach through the greenway?	Open question
FG6	What would encourage you to use the greenway more frequently?	Safety measures/Seating areas/Clear signage/Community events/Public transport integration
FG7	What is your bicycle usage preference?	Own bike/Prefer bike-sharing/No bike and would not use bike-sharing/No bike but would use bike-sharing

Table 2 provides an outline of the provenience and institutional relationships of the members of the focus group.

Table 2. Focus Group participants

Participant	Age Group	Connection to the Area	Institutional Affiliation (if any)
P1	18–25	Resident	Local sports association
P2	18–25	Worker	No formal affiliation
P3	26–40	Resident	Business owner (food sector)
P4	26–40	Commuter	Member of a local volunteering group
P5	41–65	Resident	Religious group representative
P6	41–65	Business Owner	Local commerce association
P7	66+	Resident	Cultural foundation member
P8	66+	Resident	No formal affiliation

The following elements emerged:

- several inhabitants of the city work in the industrial area north-west of Piano Tavola and could presumably use the greenway for daily commuting, considering the short extra-urban distance;
- several inhabitants regularly visit the natural area of Oasi di Ponte Barca for recreational purposes, though it is located at 20 km, and this function could be performed at a closer distance if there were equipped green areas in the city's proximity;
- inhabitants frequently go to Catania (5 km from Misterbianco) for various purposes, as it represents a major center;
- inhabitants would be generally more inclined to use the greenway for cycling rather than for jogging, due to the presence of several sports facilities within the city;
- inhabitants perceive a general lack of community events;
- in Misterbianco, it is not common to have private bicycles due to frequent thefts, and this led to the recent closure of two bike shops;
- the introduction of a bike-sharing service would be perceived positively by the population.

Thus, it results that the segment of the greenway within Misterbianco's scope will extend 5 km westward to the industrial area near Piano Tavola and 8 km eastward to Catania, improving connectivity and recreational accessibility. The design prioritizes cycling safety, green areas, interchange stations, a bike-sharing service, and recreational spaces to promote both mobility and social engagement.

In March 2024, a co-design workshop was held, engaging residents and stakeholders in defining the aesthetic and functional aspects of the greenway. Participants provided input on materials, lighting, seating, vegetation, and trail layout, ensuring the design aligns with community expectations. Three alternative road plan models were developed, each adjusting elements such as surface texture, pathway width, and landscaping features to balance safety and usability. The resulting concepts had the following characteristics:

– the first one (Concept 1) appears as a mobility-oriented corridor designed to facilitate efficient cycling and walking connections between Misterbianco and key destinations.

It presents direct, uninterrupted routes with a bidirectional asphalt bike lane and a separate pedestrian path, ensuring smooth, high-speed commuting. A low vegetative buffer provides minimal separation between cyclists and pedestrians, optimizing space efficiency. Street lighting is strategically positioned for safety, and bike parking facilities are integrated at key junctions to enhance multimodal transport connectivity;
- the second one (Concept 2) emphasizes recreational and ecological functions, providing an alternative to the Oasi di Ponte Barca by offering accessible natural spaces closer to Misterbianco. The design incorporates a meandering soft-surfaced pedestrian trail and a permeable paved cycling path, promoting low-impact, leisure-oriented movement. The surrounding environment is characterized by dense vegetation, native tree canopies, and biodiversity-enhancing green buffers, fostering ecological restoration and climate resilience. Seating areas, drinking fountains, and educational signage are distributed along the route, encouraging interaction with the natural surroundings;
- the third concept (Concept 3) represents a hybrid model, balancing mobility, social engagement, and multi-functional public space. This alternative incorporates a dedicated bike lane, a pedestrian promenade, and a multimodal hub, supporting both cycling and alternative transport options such as bike-sharing. The inclusion of small plazas, seating areas, and shaded gathering spaces fosters informal social interactions, while public art, murals, and interactive installations enhance the sense of place. The design also features a flexible-use area, adaptable for community events, pop-up markets, or educational activities. Smart lighting poles with motion sensors ensure safety while minimizing energy consumption. This alternative differs from the others by serving as a socially vibrant corridor, not only facilitating movement but also creating public spaces for engagement and cultural activation.

Following the three concepts developed in the Co-Design Workshop, 3 projects were developed, identified as "The Commuter Greenway", "The Urban Nature Greenway" and "The Community Mobility Greenway". The Commuter Greenway is designed for daily travel, featuring high-speed bike lanes, secure parking, and well-lit paths, ensuring safety for early and late commuters. It connects Misterbianco to the industrial area and Catania, integrating with public transport. The Urban Nature Greenway focuses on recreation and environmental benefits, with green spaces, pedestrian-friendly trails, biodiversity areas, and event spaces for markets and performances. It enhances local access to nature. The Community Mobility Greenway combines bike-sharing stations, smart infrastructure, multimodal hubs, and social spaces, offering a balanced approach to mobility, safety, sustainability, and community engagement, making it the most versatile option.

In the Co-Evaluation Workshop, held in May 2024, participants assessed three preliminary design proposals using Social Multi-Criteria Evaluation (SMCE) supported by the ELECTRE II method, functional for ranking design alternatives in a multi-group perspective. Table 3 reports the weights given to the criteria, chosen by the workshop participants.

The ELECTRE II method was applied to rank three greenway design alternatives – The Commuter Greenway, The Urban Nature Greenway, and The Community Mobility Greenway – based on multiple stakeholder perspectives. The evaluation used five criteria: Accessibility & Connectivity (0.30), Safety & Security (0.25), Environmental Sustainability (0.15), Social & Recreational Value (0.20), and Economic Impact & Feasibility

Table 3. SMCE Criteria and Weights

Criteria	Weight
Accessibility & Connectivity	0.30
Safety & Security	0.25
Environmental Sustainability	0.15
Social & Recreational Value	0.20
Economic Impact & Maintenance Feasibility	0.10

(0.10), with adjusted weight distributions for three groups: commuters, local residents, and policymakers. A decision matrix was built, rating each alternative from 1 to 10. The Commuter Greenway excelled in accessibility but was weaker in environmental and social aspects. The Urban Nature Greenway performed best in sustainability and recreation but was less suitable for commuting. The Community Mobility Greenway achieved balanced scores across all criteria. In the following, the implementation of the ELECTRE II methodology is outlined.

The first step was to compute the Concordance Index. For each pair (A_i, A_j), it is equal to:

$$C(A_i, A_j) = \sum_{k \in G(A_i, A_j)} W_k \tag{1}$$

where $G(A_i, A_j)$ is the set of criteria where $A_i \geq A_j$.

For example, $C(A_1, A_2)$ included Accessibility & Connectivity (0.30) and Economic Feasibility (0.10), totaling 0.40. Repeating this for all pairwise comparisons, the concordance matrix is reported in Table 4.

Table 4. Concordance matrix for the ELECTRE II methodology, calculated for the three design alternatives of the greenway's Misterbianco scope.

C(Ai, Aj)	A1 (Commuter)	A2 (Urban Nature)	A3 (Community Mobility)
A1→	–	0.40	0.55
A2→	0.60	–	0.45
A3→	0.45	0.55	–

Then, the discordance index was calculated as:

$$D(A_i, A_j) = max_{k \in B(A_i, A_j)} \frac{|a_{ik} - a_{jk}|}{max_k |a_{ik} - a_{jk}|} \tag{2}$$

where $B(A_i, A_j)$ is the set of criteria where $A_i < A_j$.

Table 5. Discordance matrix for the ELECTRE II methodology, calculated for the three design alternatives of the greenway's Misterbianco scope.

D(Ai, Aj)	A1 (Commuter)	A2 (Urban Nature)	A3 (Community Mobility)
A1→	–	1.00	0.75
A2→	0.80	–	0.65
A3→	0.60	0.70	–

For instance, $D(A_1, A_2) = 1.00$ due to a significant difference in Environmental Sustainability (A1 = 5, A2 = 9). The final discordance matrix is reported in Table 5.

Finally, outranking relations were established. Using thresholds $\lambda_c = 0.50$, $\lambda_d = 0.75$, an alternative A_i outranks A_j if:

$$C(A_i, A_j) \geq \lambda_c \; AND \; D(A_i, A_j) \leq \lambda_d \tag{3}$$

Applying descending and ascending distillation, A3: The Community Mobility Greenway emerged as the top-ranked option, balancing mobility, security, sustainability, and social engagement. The Commuter Greenway ranked second due to its mobility advantages but weaker environmental and social performance. The Urban Nature Greenway ranked last due to low transportation benefits despite high sustainability scores. This ranking suggests that a mobility-integrated greenway best suits Misterbianco's needs.

4 Conclusions

This study demonstrates the effectiveness of integrating Social Multi-Criteria Evaluation (SMCE) and participatory co-design in greenway planning, ensuring alignment between technical feasibility and local preferences. While greenways are often perceived as a standardized intervention, this research highlights how community engagement reveals differentiated stakeholder responses to various design alternatives. The participatory process, which included focus groups and co-design workshops, identified three conceptually distinct alternatives - the Commuter Greenway, the Urban Nature Greenway, and the Community Mobility Greenway - each addressing specific mobility, recreational, and social needs.

The application of ELECTRE II allowed for a structured ranking of these alternatives based on accessibility, safety, environmental sustainability, social value, and economic feasibility. The results indicate that the Community Mobility Greenway emerged as the most balanced solution, offering bike-sharing, multimodal integration, and community-oriented spaces, which best address the diverse mobility patterns and social needs of Misterbianco's population. The Commuter Greenway ranked second, primarily excelling in connectivity and transport efficiency but receiving lower scores in environmental and social aspects. The Urban Nature Greenway, while valued for its ecological and recreational benefits, ranked lowest due to its limited accessibility for daily mobility.

These findings underscore the context-dependent nature of greenway interventions, challenging the assumption that a single model can universally satisfy diverse urban

populations. Instead, this study confirms that different community groups prioritize distinct functional aspects, reinforcing the need for adaptive, participatory approaches in greenway planning. The Misterbianco case exemplifies how co-evaluation methodologies can enhance infrastructure usability, social cohesion, and sustainability. Future research should explore long-term behavioral shifts, economic impacts, and the effectiveness of participatory strategies in green mobility planning, ensuring that greenways remain responsive to evolving community needs. Moreover, precise indicators could be integrated with the bottom-up participatory approach to improve design quality [59].

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References

1. Hornung, E., Ostler, M.: Railroads and growth in prussia. J. Eur. Econ. Assoc. **13**(4), 699–736 (2015)
2. Veenendaal, A.J.: European Railways 1825–2001: An Overview. Research Memorandum GD-54, Groningen Growth and Development Centre (2002)
3. Launius, R.: Planes, trains, and automobiles - Choosing transportation modes in the twentieth century. 38th Aerospace Sciences Meeting and Exhibit (2000)
4. Zhang, X., Li, H., Li, Y.: The impacts of high-speed railway on environmental sustainability. Hum. Soc. Sci. Commun. **10**, 21 (2023)
5. Gibbons, S., Heblich, S., Pinchbeck, E.W.: The spatial impacts of a massive rail disinvestment program: the Beeching Axe. J. Urban Econ. **143**, 103691 (2024)
6. Bianchi, A., De Medici, S.: A sustainable adaptive reuse management model for disused railway cultural heritage to boost local and regional competitiveness. Sustainability **15**(6), 5127 (2023)
7. Jasper, S.: Abandoned infrastructures and nonhuman life. Society & Space (2020)
8. Torrieri, F., Oppio, A., Rossitti, M.: Damage assessment for architectural heritage: the Cavallerizza Reale complex in Turin. Valori e Valutazioni **30**, 71–84 (2022)
9. Taylor, Z.: Railway closures to passenger traffic in Poland and their social consequences. J. Transp. Geogr. **14**(2), 135–151 (2005)
10. Acampa, G., Grasso, M., Pino, A.: An MCA proposal with ANP and veto thresholds to support decision-making in former railway track regeneration initiatives. In: Gervasi, O., Murgante, B., Misra, S., et al. (eds.) Computational Science and Its Applications – ICCSA 2024, LNCS, vol. 14300, pp. 376–385. Springer, Cham (2024)
11. Stanganelli, M., Torrieri, F., Gerundo, C., Rossitti, M.: A strategic performance-based planning methodology to promote the regeneration of fragile territories. Lect. Notes Civil Eng. **146**, 149–157 (2021)
12. Rossitti, M., Torrieri, F.: Action research for the conservation of architectural heritage in marginal areas: the role of evaluation. Valori e Valutazioni **30**, 3–42 (2022)
13. Rossitti, M., Torrieri, F.: The THEMA tool to support heritage-based development strategies for marginal areas: evidence from an Italian inner area in Campania Region. Region **9**(2), 109–129 (2022)
14. Acampa, G., Pino, A.: Village repopulation: analysis of extra-economic indicators to evaluate and valorise social generativity in ecovillages. In: Gervasi, O., Murgante, B., Misra, S., et al. (eds.) Networks, Markets, and People: Proceedings of the 2024 International Conference on Computational Science and Its Applications – ICCSA 2024, LNCS, vol. 14300, pp. 376–385. Springer, Cham (2024)

15. Acampa, G., Pino, A.: Filling the old with new life. Application of original indicators for evaluating ecovillages as village repopulation initiatives. Aestimum **85**, 73–86 (2024)
16. Rossitti, M., Torrieri, F.: Circular economy as 'catalyst' for resilience in inner areas. Sustain. Mediterran. Construct. **5**, 64–67 (2021)
17. Oppio, A., Torrieri, F., Dell'Oca, E.: Land value in urban development agreements: methodological perspectives and operational recommendations. Valori e Valutazioni **21**, 87–96 (2018)
18. Acampa, G., Pino, A., Alberti, F.: The URGET VADEMECUM 2030–2050 project: applying threshold theory to sustainable urban mobility. In: Gervasi, O., Murgante, B., Misra, S., et al. (eds.) Computational Science and Its Applications – ICCSA 2024, LNCS, vol. 14300, pp. 233–245. Springer, Cham (2024)
19. Miccoli, S., Finucci, F., Murro, R.: Shared infrastructures: Technique and method for an inclusive social valuation. In: Transport Infrastructure and Systems, pp. 759–768. CRC Press (2017)
20. Del Giudice, V., Passeri, A., Torrieri, F., De Paola, P.: Risk analysis within feasibility studies: an application to cost-benefit analysis for the construction of a new road. Appl. Mech. Mater. **651–653**, 1249–1254 (2014)
21. Acampa, G., Finucci, F., Grasso, M., Magarò, A.: Preliminary approach for the cost-benefit analysis in the building envelope: study and comparison of actions. In: Calabrò, F., Della Spina, L., Bevilacqua, C. (eds.) New Metropolitan Perspectives – NMP 2022, LNCS, vol. 100, pp. 786–794. Springer, Cham (2022)
22. Acampa, G., Pino, A.: Optimal computing budget allocation for urban regeneration: an unprecedented match between economic/extra-economic evaluations and urban planning. In: Gervasi, O., Murgante, B., Misra, S., et al. (eds.) Computational Science and Its Applications – ICCSA 2023 Workshops, LNCS, vol. 14300, pp. 69–79. Springer, Cham (2023)
23. Miccoli, S., Fabrizio, F., Murro, R.: A new generation of urban areas. Feasibility elements. In: Advances in Energy Science and Equipment Engineering, pp. 1146–1149. Taylor & Francis Group (2015)
24. Horte, S.A., Eisemann, E.: Urban greenways: a systematic review and typology. Land **9**(2), 40 (2020)
25. Little, C.E.: Greenways for america. Johns Hopkins University Press (1990)
26. Bartoschek, A.: The unexploited potential of converting rail tracks to greenways. Sustainability **12**(3), 881 (2020)
27. Turner, T.: Greenways, blueways, skyways and other ways to a better London. Landsc. Urban Plan. **33**, 269–282 (1995)
28. Zuniga-Teran, A.A., Orr, B.J., Gimblett, R.H., et al.: Influences on greenways usage for active transportation: a systematic review. Sustainability **15**(13), 10695 (2023)
29. Merom, D., Bauman, A., Vita, P., Close, G.: An environmental intervention to promote walking and cycling - the impact of a newly constructed Rail Trail in Western Sydney. Prev. Med. **36**(2), 235–242 (2003)
30. Gobster, P.H., Rigolon, A.: Up on The 606: understanding the use of a new elevated pedestrian and bicycle trail in Chicago. Transport. Res. Rec.: J. Transport. Res. Board **2644**(1), 83–91 (2003)
31. Chen, X., Wang, S., Liu, X., Wang, X., Huang, Z.: Greenway interventions and physical activity levels: a systematic review and meta-analysis. Int. J. Environ. Res. Public Health **21**(2), 567 (2024)
32. Zhao, J., Zhang, T., Zhao, P., et al.: Exploring restrictions to use of community greenways for physical activity in china: a mixed-methods study. Int. J. Environ. Res. Public Health **20**(14), 6210 (2023)

33. Deng, Y., Liang, J., Chen, Q.: Greenway interventions effectively enhance physical activity levels - A systematic review with meta-analysis. Front. Public Health **11**, 1268502 (2023)
34. Hunter, R.F., et al.: Investigating the physical activity, health, wellbeing, social and environmental impact of a greenway in a deprived community: a longitudinal study. Int. J. Behav. Nutr. Phys. Act. **18**, 155 (2021)
35. Munda, G.: A conflict analysis approach for illuminating distributional issues in sustainability policy. Eur. J. Oper. Res. **194**(1), 307–322 (2009)
36. Saarikoski, H., Mustajoki, J., Barton, D.N., et al.: Multi-criteria decision analysis and environmental decision making. Environ. Sci. Policy **55**, 87–98 (2016)
37. Nicolella, M., Landolfi, R., Pino, A., Scognamillo, C.: Comparative evaluations of sustainability, durability and resilience of external envelopes for environmentally efficient buildings. IOP Conf. Series: Earth Environ. Sci. **296**(1), 012023 (2019)
38. Munda, G.: Social multi-criteria evaluation: Methodological foundations and operational consequences. Eur. J. Oper. Res. **158**(3), 662–677 (2004)
39. Battisti, F.: ELECTRE III for strategic environmental assessment: a "phantom" approach. Sustainability **14**(10), 6221 (2022)
40. Munda, G.: A NAIADE based approach for sustainability benchmarking. Int. J. Environ. Technol. Manage. **6**(1/2), 65–78 (2006)
41. Battisti, F.: SDGs and ESG criteria in housing: defining local evaluation criteria and indicators for verifying project sustainability using florence metropolitan area as a case study. Sustainability **15**(12), 9372 (2023)
42. Finucci, F., Masanotti, A.G., Mazzoni, D.: Preliminary evaluation approaches in the urban regeneration of Corviale in Rome. Lect. Notes Networks Syst. **1186**, 128–141 (2024)
43. Battisti, F., Pisano, C.: Common property in Italy. Unresolved issues and an appraisal approach: towards a definition of environmental-economic civic value. Land **11**(11), 1927 (2022)
44. Garmendia, E., Gamboa, G.: Weighting social preferences in participatory multi-criteria evaluations: a case study on sustainable natural resource management. Ecol. Econ. **84**, 110–120 (2012)
45. Etxano, I., Villalba-Eguiluz, U.: Conflicting values in rural planning: a multifunctionality approach to conflicts in the Basque Country. Sustainability **10**(5), 1431 (2018)
46. Fattinnanzi, E., Acampa, G., Battisti, F., Campo, O., Forte, F.: Applying the depreciated replacement cost method when assessing the market value of public property lacking comparables and income data. Sustainability **12**(21), 8993 (2020)
47. Bottero, M., Datola, G.: Addressing social sustainability in urban regeneration processes: an application of the social multi-criteria evaluation. Sustainability **12**(18), 7579 (2020)
48. Yildirim, V., Yildiz, N.D.: Multi-criteria decision making methods for urban greenway: the case of Aksaray, Turkey. Int. J. Eng. Geosci. **4**(3), 131–138 (2019)
49. Roy, B.: The outranking approach and the foundations of ELECTRE methods. Theor. Decis. **31**(1), 49–73 (1991)
50. Brans, J.P., Vincke, P.: A preference ranking organisation method: the PROMETHEE method for MCDM. Manage. Sci. **31**(6), 647–656 (1985)
51. Kiker, G.A., Bridges, T.S., Varghese, A., Seager, T.P., Linkov, I.: Application of multicriteria decision analysis in environmental decision making. Integr. Environ. Assess. Manag. **1**(2), 95–108 (2005)
52. Zimmermann, H.J.: Fuzzy set theory - and its applications. Springer, Boston (2001)
53. Cinelli, I., Anfuso, G., Privitera, S., Pranzini, E.: An overview on railway impacts on coastal environment and beach tourism in sicily (Italy). Sustainability **13**(13), 7068 (2021)
54. Petino, G., Wilson, J., Knudsen, D.C.: Slow tourism in the ETNA meso region: discovering the rural space with the circumetnea railway. Almatour.: J. Tour. Cult. Territor. Develop. **9**(17) (2018)

55. Pigorini, A., Sciotti, A., Corbo, A., Quarzicci, G., Romualdi, A.: The new major railway lines in Southern Italy: planning and design approaches towards sustainable solutions. In: Expanding Underground - Knowledge and Passion to Make a Positive Impact on the World, pp. 852–860. CRC Press (2023)
56. Battisti, F., Campo, O.: The assessment of density bonus in building renovation interventions. The Case of the City of Florence in Italy. Land **10**(12), 1391 (2021)
57. Baratta, A.F.L., Finucci, F., Magarò, A.: Generative design process: multi-criteria evaluation and multidisciplinary approach. TECHNE – J. Technol. Architect. Environ. 304–314 (2021)
58. Borsos, Á., Finucci, F., Gyergyák, J., Masanotti, A.G.: Evaluation in green building design for conversion projects: case studies and comparative approaches. E3S Web Conf. **436**, 01008 (2023)
59. Baratta, A.F.L., Mariani, M., Mazzoni, D.: The National Innovative Program for Housing Quality (PINQuA). Strategies and Indicators for Design Quality. Lecture Notes in Computer Science (LNCS), vol. 14104, pp. 635–646 (2023)