

Analysis and evaluation of abandoned railways aimed at greenway conversion: A methodological application in the Sicilian landscape using multi-criteria analysis and geographical information system

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Abstract

Nowadays, in many countries around the world, abandoned railways are considered as important resources that can be recovered and converted into greenways, thanks to their specific adaptability to this function. With its about 1000 km of dismantled lines, Sicily is the Italian region where the abandonment of railways is more evident. Nevertheless, to the present day, only about 20 km have been converted in greenways. As a recovery action requires large investments, it is necessary to determine a priority list based on the actual suitability of a track to be converted. Therefore, the aim of this paper was to define and apply a methodology, based on multi-criteria analysis associated with geographical information system (GIS), for the assessment of different suitability degrees of an abandoned railway to be converted in greenway for agro-touristic and cultural use of the land. The work was developed on two abandoned railway lines, sited in the province of Syracuse, embedded in landscapes of great value thanks to the existence of natural areas and cultural heritage. The applied method attributes great importance to the quality of the landscape that is considered in the same way as the intrinsic characteristics of the track. Several indicators were weighed and spatially mapped to describe the local resources at the margin of the track and the characteristics of the stretches of the two lines. The GIS analysis allowed obtaining various intermediate maps containing the necessary information for drawing the ultimate maps, which showed the suitability of each line to be converted in greenway. The results showed that the suitability level depends on the specific characteristics of the railroad and its marginal values, as well as on the quality of the landscape and the develop-

ment opportunities that it offers.

The creation of greenways can thus become a support to make easier the integration between the landscape and the growing demands of land, economic and tourist development, while maintaining intact the rural land and favoring its connection with the urban centers. The study, although referred to specific territorial areas, is generally valid from a methodological point of view and can be applied in other contexts.

Introduction

In recent decades, the oldest railway lines, which are no longer efficient and slower than road transport, tend to be abandoned. In most cases, these railways are in a state of decay and disrepair. Several countries around the world have focused on the conversion of such railways to greenways. Indeed, the characteristics of the railroad tracks fit perfectly with greenway requirements, especially if the definition given by the Italian Greenways Association (AIG) is taken into account: *a system of linear connected territories which are protected, managed and developed in order to obtain recreational, ecological and historical-cultural benefits*. It should be emphasized that the *linear* extension is prevalent on the *transversal* dimension, which, in some locations, can be limited to the only viable carriageway. In this sense, but not only, the railroad tracks are suitable to be converted in greenways. Other characteristics that suggest this kind of conversion are (Rovelli *et al.*, 2004):

- Separation from the road network: a greenway obtained from a railway line develops on its own site and, therefore, guarantees a high level of safety for users due to the rare intersections with roads for motorized vehicles. Furthermore, it offers a path that is far away from atmospheric and acoustic pollution.
- Public ownership or control: railways are built to play a role of *public utility*, which persists even after the lines are dismantled. Therefore, they could be more easily subjected to appropriate legislative safeguard measures.
- Low slope of the track: railways have steady and modest slopes (generally below 35%) which make them appropriate to create ideal pathways for *soft mobility*, intended for different types of users: pedestrians of all ages, cyclists, people with reduced mobility, but also skaters, horseback riders, *etc.*
- Planimetric characteristics: railways generally have long straights and wide-radius curves. This feature makes it possible to create easy and safe paths, which allows wide visibility.
- Connection among villages and cities: this feature allows to improve the mobility system by connecting people with the resources of the territory and with the *centers of life* of urban settlements, both in cities and in rural areas.
- Richly varying landscape: railway lines cross-different types of environment (urban, suburban, rural), passing through various types of landscape: residential, agrarian, forest, archaeo-

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logical and industrial. This feature offers users not only a very varied visual experience, but also the opportunity to know and *understand* the territory they are crossing. It is so possible to get in touch with an intact, spontaneous and unique heritage, characterized by great wealth of natural and landscape resources.

- Railway buildings: abandoned railway lines have a valuable, often abandoned architectural heritage consisting of bridges, galleries, viaducts, stations, maintenance houses, which can be recovered, protected and, in some cases, reused as rest areas, refreshment points, overnight stays and technical services.

Therefore, the recovery of abandoned railways as greenways allows the preservation of the integrity of old railway tracks together with their buildings and all any other elements, which are part of the cultural heritage of a territory and testifies its history and development (Toccolini *et al.*, 2004; Oppido, 2014).

Toccolini (2004) and Senes (2004) pointed out that in 1916, the United States of America had the largest rail network in the world, with over 430,000 km of railway lines. In the XX century, political and economic changes, together with the development of new means of transport, led to the disposal of over 240,000 km of railroads. The same authors report that the trend of disposal was about 5000 km/year. In the U.S.A. the first experiences of recovering abandoned railways as greenways were conducted in the mid-1960s (the first line was the Illinois Prairie Path, 88 km long, that was inaugurated in 1966). A strong impulse came with the constitution, in 1986, of the Rails to Trails Conservancy (RTC), which provides support and assistance to the promoters of these kind of projects. When RTC was founded, no more than 90 railroads were recovered throughout the whole territory of the U.S.A. In 2003, this number grown up to about 1200 railroads, covering about 20,000 km (Senes, 2004). A web page is available (<http://www.abandonedrails.com>) featuring the descriptions of 1542 railway lines that were abandoned over the last 40 years, across the whole territory of the U.S.A. The website is dedicated to the preservation of the history of each of these former railroad lines and the companies that operated them.

Among the other experiences conducted outside Europe, in Australia only 1437 km of abandoned railways, out of a total of about 7700 km, have been recovered and converted into multi-use green paths with the support of Rail Trails Australia, a non-profit organization which works for the development and promotion of a rail trail network Australia-wide (<http://www.railtrails.org.au>). In New Zealand, the most relevant example is the Otago Central Rail Trail that, originally, was a railway used to transport minerals from the central regions to the coast. After its abandonment, it was adapted and provided with all the necessary equipment to be enjoyed by tourists, mountain-bike or trekking lovers (<https://www.lifeintravel.it/tag/ferrovie-in-bici.html>).

In the 80's and 90's of the last century, the idea of recovering the old abandoned railways as greenways reached Europe. Significant experiences include the *Vias Verdes* in Spain, the *Réseau Autonome des Voies Lentes* (RAVeL) project in Belgium, the *Sustrans Program* (Sustainable Transport) in England and the latest Portuguese *Ecopistas*. The British railway paths, the Spanish *vías verdes* and the French and Belgian *chemin du rail* are multi-functional public greenways obtained by the recovering of abandoned railroads (Senes *et al.*, 2004; Oppido, 2014). Belgium showed to be especially sensitive to this issue, so that since the mid-1990s over 250 km of abandoned railways were converted in *chemins du rail*. Also the Spanish experience was particularly relevant, as from 1993 to date more than 2200 km of abandoned railway lines have been converted into greenways, together with sev-

eral railway buildings which were restored to provide services to the users of *Vias Verdes*. However, the most important aspect of this program is the intensive work in organizing events for greenway promotion, such as international conferences, seminars and theme days, through the involvement of many governmental authorities, associations and citizens (Aycart, 2004).

At European level, in 2002 the EU funded the REVER MED project with the aim of planning a *Green European Network* for the Mediterranean regions of Portugal, Spain, France and Italy, reserved for non-motorized users and that include also greenways resulting from the conversion of abandoned railways (Rovelli *et al.*, 2006).

Other examples, less extensive but of great qualitative and social impact, are some of the recovery actions in urban areas such as the Promenade Plantée in Paris and High Line in New York, two public parks built on a raised historical railroad.

The European Greenways Association drew attention to the role of greenways for the protection and promotion of abandoned railway heritage in Europe: *Egwa advocates the transformation of disused railway lines into greenways as the most appropriate way to ensure that Europe's railway heritage is preserved and maintained, and at the same time generates local economic opportunities. Egwa seeks to help more organisations get involved with greenway development and, at the same time, makes a special appeal to government administrations and railway companies - the main owners of these infrastructures - to embrace the movement, offering its full collaboration for that purpose* (European Greenways Association, 2012).

In Italy, the first achievements were only recently realized after many years of studies, researches and conferences on the theme, mainly promoted by AIG. AIG also drew up an inventory of the abandoned railway heritage throughout the country, finding that about 8000 km of railroads could be reused (Senes, 2004). The abandoned railways are specifically concentrated in some areas, particularly in Sicily and South Tyrol (Toccolini, 2004). Nevertheless, the shortage of funding sources and the lack of an adequate legislation for the acquisition of railway track areas were the main causes, which limited the recovery actions, compared to other countries (Senes, 2004). Indeed, the recovery of an abandoned railway is an isolated event, often carried out following the commitment of individual stakeholders or on the basis of occasional financial availability. Until today, no substantial trend reversal has been observed, despite the activism of the AIG to promote knowledge about the consistency of this heritage and, above all, the methodological approaches for the analysis and valorization of the abandoned railways developed over time by various researchers (Little, 1990; Senes, 2004; Rovelli *et al.*, 2006).

As mentioned above, with its about 1000 km of dismantled lines, Sicily is the Italian region where the abandonment of railways is more evident. The Sicilian Region acknowledged both the wideness of the available heritage and the importance of cycle/pedestrian paths as an opportunity for sustainable socio-economic development. Therefore, it issued various laws and regulations in this field from 1998 to 2005. Specifically, the most important act was the *Plan of non-motorized mobility in Sicily*, adopted on 6 June 2005 and conceived as an integral part of the Regional Transport Plan. The *Plan* was elaborated with the aim of *creating a regional network of alternative mobility with low or no environmental impact (soft mobility), with the priority use of abandoned railway lines and other minor or secondary roads*. The itineraries identified by the *Plan* were designed with the primary goal of recovering almost all abandoned railways. Further paths running on main roads or on secondary roads (the so called *Regie trazzere*)

were added with the main purpose of interconnecting individual trails or reaching and enjoying areas of special value (Regione Sicilia, 2005).

Nevertheless, to the present day, only about 20 km of abandoned railways have been converted in greenways due to the shortage of funding. Additionally, the ineffective implementation of the Plan was also determined by the absence of a priority list of intervention, established on the basis of the suitability of each line to be converted in greenway.

Therefore, this work aims to define and apply a methodology, based on Multi-criteria analysis associated with geographical information system (GIS), for the assessment of different suitability degrees of an abandoned railway to be converted in greenway for agro-touristic and cultural use of the land. Indeed, the study shows how the different degree of line suitability to be reused as greenways depends on the specific features of the railroad and of the resources at the margin of the track (in the following referred to as *margin values*), as well as the quality of the landscape and the development opportunities that it offers (Riguccio *et al.*, 2016).

Two abandoned railway lines were selected in the territory of the former province of Syracuse. The choice was supported by two reasons:

- The municipalities of Noto and Pachino recently issued a call for university research groups to draw up projects to apply European funding, with the aim to recover the Noto-Pachino line, which is one of the line chosen in this study. The call underlined how the valorization of abandoned railways could play a crucial role in promoting the agricultural, cultural and environmental resources through the territory and, therefore, showed undoubted interest in the recovery of the specific line.
- The results of a previous study by the same authors (Quattrone *et al.*, 2017) on the whole territory of Syracuse province, with the aim to identify infrastructure systems capable of supporting a greenways network that can contribute to the promotion of areas of particular value (Figure 1).

The conversion of the two lines in greenways can ease the integration between the landscape and the growing demands of land, economic and tourist development, while maintaining intact the rural land and favoring its connection with the urban centers (Taylor, 2015).

In the next section the areas under study, the materials used and the method applied are described. The explanation of the method is subdivided into three paragraphs, which address the application rules of the multi-criteria analysis for the specific problem, the role of the field analysis, and the use of GIS associated with multi-criteria analysis.

The *Results* section is also divided into three paragraphs, which follows the structure of the description of the method, and report the results of multi-criteria analysis, field analysis, and GIS application. Finally, in the *Discussion and conclusions* section the results are discussed and compared with those ones obtained in literature, and some conclusions are drawn on the strength of the research from the point of view of the methodological approach and with regard to the specificity of the matter.

Materials and methods

The areas under study

Two abandoned railway lines were considered, together with

a respective 1000 m wide buffer per side (Figure 1): the Syracuse-Vizzini (line A), which is 97 km long in EW direction, and the Noto-Pachino (line B), which is 27 km long in NS direction.

The Noto-Pachino was a standard-gauge railway opened in 1935 and closed in 1985. It was a non-electrified single-track line. It was known as the *wine railroad* due to the predominant function of transporting local wines to the North. The line is of great cultural, environmental and touristic interest, with important archaeological sites (Eloro), natural reserves (Vendicari), renowned baroque cities (first of all Noto included in UNESCO's World Heritage List) and sea locations (Marzamemi).

The Syracuse-Vizzini was a narrow-gauge railway, built between 1915 and 1923 and closed between 1949 and 1956. It connected the coast with some cities of the hinterland of Ragusa province and run along the bank of the River Anapo for much of its length, crossing sites of remarkable landscape qualities. Even along this line there are well known archaeological and environmental locations (the prehistoric site of Pantalica, Cavagrande, Anapo Valley).

Materials

The territorial analysis of the areas 14 and 17 of the Territorial Landscape Plan of the Sicilian region (PTPR), which coincide with the territory of the former Province of Syracuse, was carried out using the thematic shape files of the Local Landscape Plan (PPA), developed in accordance with the Code of Cultural Heritage and Landscape (Legislative Decree N. 42 of 22 January 2004 and subsequent amendments and additions). These files were provided by the Superintendence of Cultural and Environmental Heritage of Syracuse. The information included in the files were updated and enriched by means of both direct surveys and data obtained from the Web portal and the Regional Territorial Information System (SITR) of the Sicilian region. In addition, the following documents were considered: PTPR guidelines; Rural Development Plan 2007-2013 of the Sicilian region (PSR); Regional Operational Program 2000-2006 of the Sicilian region (POR); guidelines of the Sicilian Ecological Network 2005; list of the restrictions on cultural and

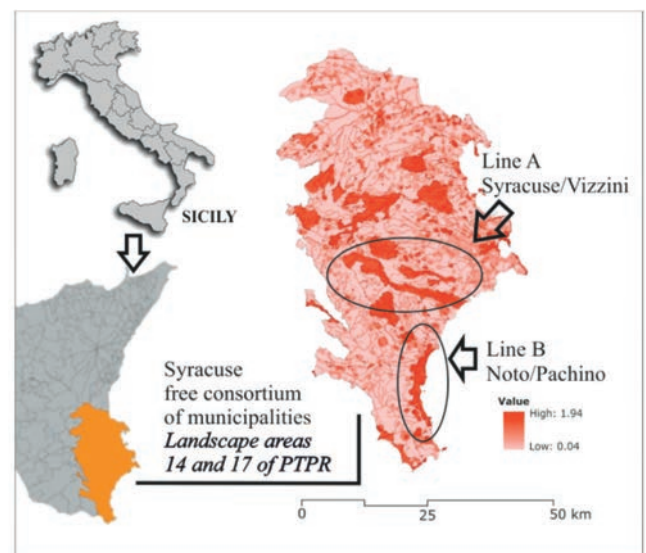


Figure 1. Location of study area on the land suitability map for the development of greenway networks.

landscape heritage available on the website of Department of Cultural Heritage and Sicilian Identity; guidelines of the Operational Program European Regional Development Fund (P.O. F.E.S.R. 2007/2013), Intervention Line 3.3.2.4 *Implementation of a regional strategic plan for soft and/or non-motorized mobility*. Furthermore, the most recent satellite images of Google Earth (2016) were considered, together with their database of the available tourist and commercial services.

The map data were processed with ArcMap 9.2 and ArcGis 9 software, whereas the numerical processing was developed with EXCEL 2010. Analysis data-sheets of the main buildings along the two railway lines were also drawn up.

Method

Multi-criteria analysis

The previous study by Quattrone *et al.* (2017), carried out in the territory of Syracuse (areas 14 and 17 of the PTPR), was aimed to identify the infrastructures suitable to be used as greenways, in order to support tourism and cultural activities in the rural area analyzed. The results of that study were summarized in the suitability map of both infrastructures and major areas of interest, for the development of the greenway network (Figure 1). This map shows that the areas with the highest suitability degree develop along two axes represented by the two railway lines examined in this study. Thus, starting from the results of the previous work, this research focuses on the intrinsic characteristics of the railway tracks and of their immediate surroundings. While using the same methodological approach (multi-criteria analysis associated with GIS), the scale of analysis is different and the results relate to the assessment of the suitability of specific stretches of the two railway lines to be converted in greenways. Therefore, consistently with the results of the previous study, the *goal* of the multi-criteria analysis of this research was to evaluate the suitability of a stretch of an abandoned railway to be converted for slow tourism use. This

choice is also justified by the territorial and socio-economic characteristics, as well as by the richness of natural and historic-cultural resources (Taylor, 2015).

The structure of the multi-criteria analysis consists of three hierarchical levels (including level 0) (Figure 2).

Consistently with Saaty's (1990) assertion, the hierarchical tree, built for multi-criteria analysis ... *is not the traditional decision tree. Each level may represent a different cut at the problem*. The first level (S_i systems) refers to the requirements needed to assess the suitability of a stretch, while the indicators of the second level ($S_{i,n}$) describe, for each requirement, the performance of the stretch ($S_{1,n}$ and $S_{2,n}$) and of its surroundings ($S_{3,n}$).

The indicators (level 2) referred to the three systems of level 1 - characteristics (S_1), conditions of use (S_2), margin values (S_3) - were subjected to pairwise comparison in relation to the *goal* (Toccolini *et al.*, 2004).

The system *characteristics* (S_1) include the indicators that refer to the intrinsic characteristics of the track. They are: recognizability ($S_{1,1}$), pavement type ($S_{1,2}$), width ($S_{1,3}$), slope ($S_{1,4}$).

The system *conditions of use* (S_2) includes the following indicators: danger ($S_{2,1}$), accessibility ($S_{2,2}$), practicability ($S_{2,3}$). Indeed, intersections with carriageways, unavailability of private property stretches, level of difficulty due to tight curves are among the factors that should be considered.

The system *margin values* (S_3) concerns the existence of cultural, commercial, environmental and landscape resources as well as of road links that allow reaching the railway, inside the 1000 m wide buffer per side of each track (Caliandro *et al.*, 2014). It includes the following indicators: panoramic position ($S_{3,1}$), existence of services ($S_{3,2}$), existence of cultural and environmental goods ($S_{3,3}$), existence of transport infrastructures ($S_{3,4}$), existence of historical railway buildings and structures ($S_{3,5}$) (Table 1).

In the hierarchical analysis, all the three systems (S_1 , S_2 , S_3) are equally important (Toccolini *et al.*, 2004), therefore a pairwise comparison was not necessary. Indeed, a pairwise comparison at

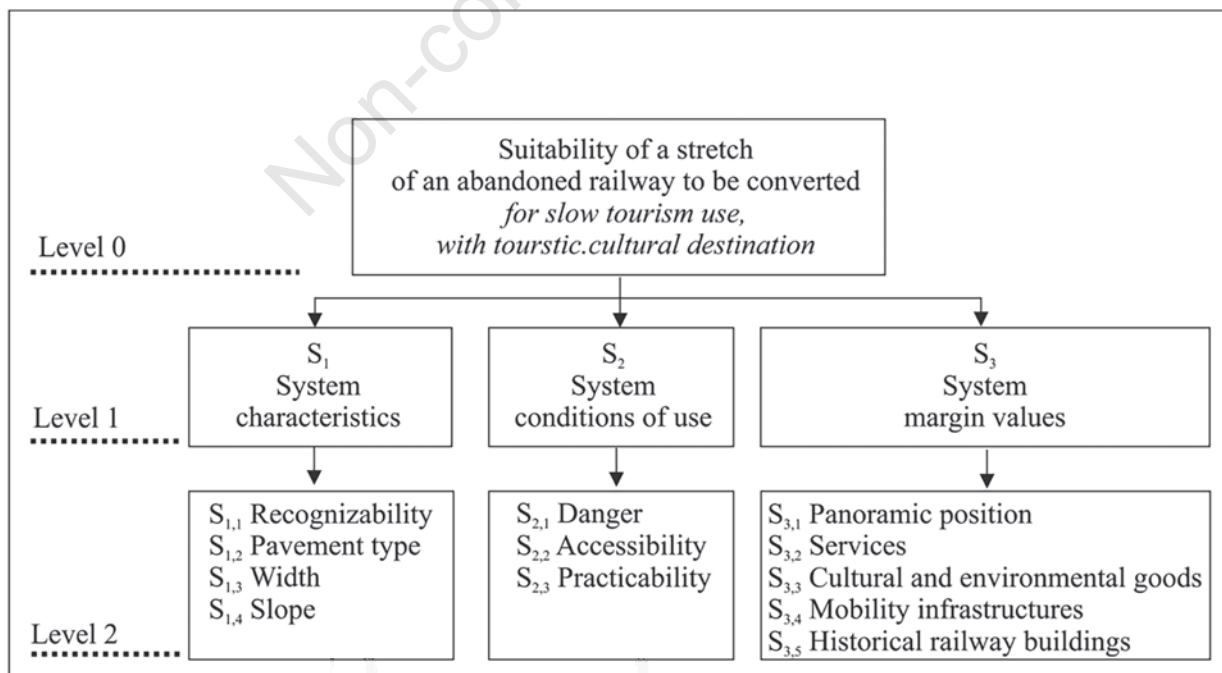


Figure 2. Hierarchical tree used in the multi-criteria analysis.

this level (level 1) would give a weight vector with the same values for each system. Therefore, multiplying the weights of the next level (level 2) by vectors with equal values would not cause any change in the priorities of the indicators.

On the contrary, pairwise comparison was carried out for the $S_{i,n}$ indicators of each S_i system. Specifically, the weights were assigned using Saaty's scale (1990): 1 - Equal importance, 3 - Moderate importance of one over another, 5 - Essential or strong importance, 7 - Very strong importance, 9 - Extreme importance.

The weights were assessed by a group of experts consisting of two professors specialized in landscape analysis and planning as well as in techniques and methods for rural infrastructure development, and two landscape architects specialized in designing public green areas.

Each indicator groups elements that, though distinct for their specific nature, have a homogeneous character, as they represent *performance* and *attractiveness*, which are absolutely required for cultural tourism enjoyment of a greenway. Therefore, the pairwise comparison between the indicators was carried out in terms of their performance. For example, as regards the indicators of the system S_1 , the question was: how much more important is the column indicator than the line indicator for identifying the suitability of a stretch to be converted in greenway?

It should be pointed out that the hierarchical problem, as it was structured, did not intend to measure and express the cultural and environmental value of the landscapes crossed by a greenway, nor it was related to the assessment of the suitability of the margin values to be converted for other uses, which would require a more detailed hierarchy of the multi-criteria problem.

Therefore, the final values of the weights obtained with the pairwise comparison indicate how much the presence or the characteristic of each indicator affects in percentages the suitability of a line to be converted in greenway, so that they are a meaningful measure of general performance.

Field analysis

A detailed analysis of the two lines was carried out, aimed at the acquisition of the existing intrinsic characteristics and the resources within each buffer. This allowed to explicit and classify (Table 2) the elements of S_1 and S_2 systems that were referred to homogeneous railroad stretches. Each stretch was obtained assuming the subdivision proposed by Condorelli and Simon (2004) based on intersections with public roads or on the presence of stations or maintenance houses (Table 3). As an example, Figure 3 reports a data-sheet used for acquiring the characteristics of a railroad stretch. The elements of S_3 system were detailed in the 1000 m buffer per side, according to their specific type.

GIS mapping

The last part of the methodology concerned the transfer of the evaluation obtained with the multi-criteria analysis into the GIS environment. This process was carried out in subsequent phases. Firstly, data were made consistent with GIS environment, digitized and transferred into a GIS setting. Then, the data were elaborated in a GIS setting. Specifically, the weights were associated to the corresponding indicators of the database, the rasterization of the weighted indicators was implemented. Rasterization was performed using a cell size of 500x500 m, because the punctual and linear indicators were represented by their respective minimum size buffers corresponding to the circular area included in each cell. Finally, the function *Raster calculator* was applied for the overlay of the weighted layers and the creation of the weighted maps.

Preliminarily, the classifications of the indicators of S_1 and S_2 systems were associated with each stretch, and the margin values (cultural, commercial, environmental and landscape resources, mobility infrastructures) of S_3 system were mapped. Then, the mapped indicators were associated with the weights obtained with multi-criteria analysis.

As regards S_1 and S_2 systems, the stretches with the following classifications were excluded from the suitability analysis

Table 1. Description of the indicators of each system.

System	Indicators	Description
S_1 Characteristics	$S_{1,1}$ Recognizability	Disappearance, permanence or persistence of the railway track
	$S_{1,2}$ Pavement type	Asphalted or unpaved pavement
	$S_{1,3}$ Width	Adequate width of the track
	$S_{1,4}$ Slope	High, moderate or low slope
S_2 Conditions of use	$S_{2,1}$ Danger	Intersections with carriageways and/or fast roads
	$S_{2,2}$ Accessibility	Publicly or privately owned stretches
	$S_{2,3}$ Practicability	Easyness of stretch practicability
S_3 Margin values	$S_{3,1}$ Panoramic position	Possibility to enjoy and perceive the landscape and the panorama
	$S_{3,2}$ Services	Accommodations and refreshment points
	$S_{3,3}$ Cultural and environmental goods	Existence of: Historic centers of different age and typology with different roles in territorial centrality, archeological sites, valuable settlements and artifacts, museums addressed to the preservation and enjoyment of historical/cultural heritage, natural resources (reserves, protected areas, SCI/SPA zones), architectural elements and isolated goods connoting the rural landscape consisting of a variety of civil, religious, military and productive artifacts that are highly diversified by historical origin and by constructive features
	$S_{3,4}$ Mobility infrastructures	Existence of mobility infrastructures linked or adjacent to the railway stretch, which allow the achievement of the track itself and of the cultural and environmental goods identified above
	$S_{3,5}$ Historical railway buildings	Existence of a railway architectural heritage (stations, maintenance houses, bridges, galleries)

(Linehan *et al.*, 1995): S_{2,1} *high danger*; S_{1,4} *high slope*; S_{2,3} *difficult practicability*; S_{2,2} *limited accessibility*. Concerning the S_{1,3} (*width*) and S_{1,2} (*pavement type*) indicators, all the stretches with a width ≥ 2.00 m and an existing or recognizable track were included. As for S_{1,1} indicator (*recognizability*), those stretches that disappeared or become private were also included, in the hypothesis of a possible recovery or of an alternative path.

All the components of S₃ system that were found during field surveys were included and mapped. S_{3,1} indicator (*panoramic position*) obtained a low rating from the multi-criteria analysis, therefore it was considered not essential to evaluate a railroad recovery proposal. Consequently, the same weight was assigned to all the stretches of the two lines.

Finally, the *weighed* maps of the three systems and the suitability map of the stretches for the proposed use were obtained.

Results

Multi-criteria analysis

The hierarchical analysis started by performing a pairwise comparison among the indicators (S_{1,1}, S_{1,2}, S_{1,3},...S_{3,5}) of the three systems (S₁, S₂, S₃) with respect to the *goal*. The indicators, as described above, represent the decision-making variables of the

problem. The three systems take the same and highest importance for identifying the suitability of the railroads to be converted, considering their both intrinsic and extrinsic characteristics as fundamental and equally important to achieve the ultimate goal.

The *matrices of pairwise comparisons* of the indicators of the three systems were built using the *Saaty Semantic Scale* (1 to 9). The comparison respect to the goal of the indicators of each row with the indicator of each column allowed evaluating which component is more important than the other within each system. The geometric mean, the vector of the weighs, the eigenvalue, the consistency index, the random consistency index and, finally, the consistency ratio (CR) were calculated. As the CR value was always < 0.1 , the matrices were consistent (Table 4).

In S₁ system, the highest value was assigned to S_{1,4} indicator, since it appears to be a key element to ensure greenway access to all users.

In S₂ system, the highest value was assigned to S_{2,1} and S_{2,3} indicators, which concern the safety and comfort/easiness of the trail.

In S₃ system the most important indicators were S_{3,2}, S_{3,3}, S_{3,4}, and S_{3,5}. They concern the existence and accessibility of commercial services, accommodation facilities, cultural and environmental goods, historical railway buildings and structures. Indeed, the existence of commercial, natural, historical and cultural resources, able to become points of touristic attraction and to offer services, are of great importance in view of a recovery for cultural tourism use (Riguccio *et al.*, 2015a). Table 5 shows the values of the indicators

Table 2. Classification of the indicators of each system.

System	Indicators	Classification	Description
S ₁ Characteristics	S _{1,1} Recognizability	Disappeared	The track was dismantled and the seat was incorporated into the new urban context (the road network changed, the pavement was asphalted, new buildings were built, <i>etc.</i>)
		Permanence	There is evidence not easily recognizable, but identifiable thanks to some existing signs
	S _{1,2} Pavement type	Persistence	The existence of the railway is easy to find
		Asphalted	Rails and railroad ties were removed and the seat was asphalted
		Unpaved	Rails and railroad ties were removed and the seat was left unpaved
	S _{1,3} Width	With track	Rails and railroad ties are still existing
S _{1,4} Slope	Low	No classification was required due to the constant width of the railways	
S ₂ Conditions of use	S _{2,1} Danger	High	Safety for users could be difficult to achieve due to the high number of intersections with road infrastructures or the lacking of protective barriers
		Medium	It is possible to take actions aimed at raising the safety level of a stretch with road intersections and/or without protective barriers
		Low	No dangerous situation is present (absence of intersection with road network and existence of protective barriers)
	S _{2,2} Accessibility	Limited	Privately owned
		Accessible with limitations	The stretch can be enjoyed only in specific periods or at certain hours of the day
	S _{2,3} Practicability	Accessible	Publicly owned
Easy		Low or moderate slope and asphalted pavement	
S ₃ Margin values	S _{3,1} Panoramic position S _{3,2} Services S _{3,3} Cultural and environmental goods S _{3,4} Mobility infrastructure S _{3,5} Historical railway buildings and structures	Medium	Moderate slope and unpaved floor in good maintenance conditions
		Difficult	Moderate or steep slope and unpaved floor in bad maintenance conditions
			All the elements were considered which intersect the railways or are located within the 1000 m buffer per side. Each element was classified following the specific typology

in descending order.

The results show that the highest values, and therefore the most important elements to check recovery suitability, are those features that ensure safety, practicability and easiness of travelling which are related to intersections with the road network, linearity of the track and slope (Diti *et al.*, 2015).

Given the specific aim to be reached (touristic and cultural), the next features for importance are the presence of bridges, galleries and railway buildings located along the track, as well as the existence, inside the buffer, of natural, archaeological, historical and commercial resources, of museums and isolated goods, together with an infrastructure network which assures their availability



LINE A - SYRACUSE/VIZZINI		S ₂ - SYSTEM CONDITIONS OF USE		
STRETCH N.	PHOTO	DANGER	ACCESSIBILITY	PRACTICABILITY
3		Medium – for pedestrians and cyclists The stretch has 11 intersections, mainly sited in close proximity to the road network of Florida and Solarino. Some intersections are sited in proximity of provincial roads.	Limited In some segments the stretch is not accessible; the stretch falls within privately owned lands.	Easy The slope of this stretch is moderate, so it is easily viable.
4		Low – for pedestrians and cyclists The stretch is physically separated from the road network, that intersects in only 4 points. One intersection is grade separated with a bridge over the River Anapo, another is with an unpaved access road of a farm holiday, and the other two are with low-traffic provincial roads.	Accessible The stretch is fully accessible.	Easy The slope of this stretch is moderate, so it is easily viable.

Figure 3. Part of the analysis data-sheet concerning the *conditions of use system* (S₂) for the line A.

Table 3. Description of the stretches of the two railway lines: A) Syracuse/Vizzini, B) Noto/Pachino.

Stretch No.	Localization	Length (km)
Line A: Syracuse/Vizzini		
1	From the old station of Syracusae, Ermocrate avenue n.2, to traversa Palma	3.00
2	From traversa Palma to traversa Muragliamele	9.00
3	From traversa Muragliamele to SP 28 Solarino (Syracuse)	8.00
4	From SP 28 Solarino to the entrance of the Oriented Natural Reserve (ONR) Pantalica, Valle dell'Anapo, Torrente Cavagrande - Sortino (Syracuse)	11.00
5	From ONR Pantalica, Valle dell'Anapo, Torrente Cavagrande Sortino to Cassaro (Syracuse)	13.00
6	From SP 45 Cassaro to SS 124 Palazzolo Acreide (Syracuse)	9.00
7	From SS 124 Palazzolo Acreide to SP 23 Palazzolo Acreide	7.00
Line B: Noto/Pachino		
1	From the station of Noto (Syracuse) to SP 19, SP 35, SP 34 Calabernardo (Syracuse)	4.00
2	From SP 59 Calabernardo to Lido of Noto (Syracuse)	2.00
3	From SP 59 Lido of Noto to SP 19 (Syracuse)	2.00
4	From SP 19 to Oriented Natural Reserve ONR Wildlife Oasis of Vendicari	14.00
5	From Contrada San Lorenzo (Syracuse) to Sebastiano Fortuna avenue, Pachino (Syracuse)	3.00
6	From Contrada Lettieria, Pachino to Pietro Nenni street, Pachino	2.00

from the railroad (De Montis *et al.*, 2016).

The sub-indicators related to the recognizability, accessibility and panoramic position appear to be less important. The result about recognizability can be explained considering that the original characteristics of a no recognizable stretch of an abandoned railway can be reported by means of map indications and specific signs. In this case, a partial recovery of the track or a deviation from the original path can be usefully evaluated. The planning of an alternative path can be a valid solution also for those not accessible private stretches, for which an eminent domain is not viable. Finally, the panoramic position, although it is an important feature, does not appear to be a key element in designing the recovery of an abandoned railway.

Field analysis

Line A

The *characteristics* of the line (S_1 system) vary mainly according to the orography of the site. All stretches are recognizable ($S_{1,1}$) except for the n.1, at the urban level. Stretch n.2 is only recognizable thanks to the presence of some railway buildings, whereas stretch n.3 disappears within the Floridaia and Solarino urban centers and reappears in their peripheral areas. All the other stretches (n.4 to n.7) are perfectly recognizable as they are part of pedestrian paths within the valleys of Anapo and Cavagrande. The pavement ($S_{1,2}$) is asphalted in urban areas and untarmacked in all the other parts. The width ($S_{1,3}$) is constant in all recognizable stretches. As regards the slope ($S_{1,4}$), the tracts near the coast are mainly flat, while most of the inner tracts have a moderate gradient with the exception of stretch n.7 which has a steep slope.

The *conditions of use* (S_2) are generally appropriate for the reconversion into a greenway. Most of the stretches are quite safe ($S_{2,1}$) for slow mobility except for those ones that cross the urban areas. Accessibility ($S_{2,2}$) is maximum in stretches 2, 4, 6 and 7. The accessibility of stretch 5 is partly limited due to its location within the Oriented Nature Reserve (ONR) of *Pantalica, Valle dell'Anapo, Torrente Cavagrande*. The accessibility of other stretches is completely limited by either the presence of urban activities or because the plots of land are privately owned. Stretches 1 to 5 are all easily practicable ($S_{2,3}$) due to the regularity of the track and the low slope, whereas stretches 6 and 7, located at higher altitudes, are difficult to ride due to the uneven pavement

and the steep gradient.

The *margin values* (S_3) make the line of very great interest for tourist and cultural purposes. Inside the buffer, close to the track, there are some panoramic tracts ($S_{3,1}$) near Floridaia and Sortino. An important panoramic tract is located within the ONR of *Pantalica, Valle dell'Anapo, Torrente Cavagrande*. Two other panoramic areas intersect the railway track near Palazzolo Acreide - Buscemi.

There is a substantial presence of services ($S_{3,2}$) homogeneously dislocated along the axis of the track, consisting of commercial activities related to restoration and overnight stays. It is discreet the presence of farm holidays and teaching farms. The existence of cultural and environmental goods ($S_{3,3}$) is numerical significant. Specifically, 39 isolated goods were identified inside the buffer, different in typology and condition, which could be restored and intended for new uses. There are also archaeological sites of great interest such as Pantalica, historical centers, museums and the above mentioned ONR of *Pantalica, Valle dell'Anapo, Torrente Cavagrande*, which play a key role as tourist attractions.

Transport infrastructures ($S_{3,4}$) of various types, ensure the accessibility to the sites crossed by the abandoned railway as well as to the near commercial, tourist and environmental resources. Close proximity to highway and SS 114 and SS 124 state roads is remarkable, while fast roads are fundamental to assure mobility within the area. Finally, the presence of 12 stations, 3 train stops and 8 maintenance houses was detected along the former Syracuse-Vizzini railway ($S_{3,5}$). These buildings are located in three different provinces: Syracuse, Ragusa and Catania. Only a part of them are privately owned. Most are in very poor conditions, but can be recovered. Some of the buildings inside the ONR of *Pantalica, Valle dell'Anapo, Torrente Cavagrande* were restored, but are currently unused.

Line B

The line has homogeneous *characteristics* (S_1) in almost all stretches. The railroad has still its track ($S_{1,2}$) and a constant width ($S_{1,3}$) for almost its entire length, therefore it is easily recognizable ($S_{1,1}$), even if often covered by spontaneous vegetation. The wooden ties were dismantled only near the few intersection points with the carriageways where the grade-level crossing was covered with asphalt. The maximum slope ($S_{1,4}$) is 14% in stretch 2. The minimum radius of curvature is 300 m.

Table 4. Results of the hierarchical analysis.

System	Indicators	GM	W	K	CI	RI	CR
S ₁ Characteristics	S _{1,1} Recognizability	0.76	0.18	1.06			
	S _{1,2} Pavement type	0.84	0.20	0.98			
	S _{1,3} Width	0.84	0.20	0.98			
	S _{1,4} Slope	1.87	0.43	1.01			
					0.01	0.9	0.01
S ₂ Conditions of use	S _{2,1} Danger	1.44	0.44	1.03			
	S _{2,2} Accessibility	0.55	0.17	1.02			
	S _{2,3} Practicability	1.26	0.39	0.97			
					0.01	0.58	0.02
S ₃ Margin values	S _{3,1} Panoramic position	0.51	0.10	1.08			
	S _{3,2} Services	1.25	0.24	1.03			
	S _{3,3} Cultural and environmental goods	1.25	0.24	1.03			
	S _{3,4} Mobility infrastructures	1.00	0.19	0.95			
	S _{3,5} Railway buildings	1.25	0.24	1.03			
					0.03	1.12	0.03

GM, geometric mean; W, vector of the weights; K, Eigenvalue; CI, consistency index; RI, random consistency index; CR, consistency ratio.

The present *conditions of use* (S_2) exclude a high danger ($S_{2,1}$) of the path although there are 36 connections/intersections with the roadway network. However, most of the intersections are grade-separated ones, so that both infrastructures can safely coexist. The line is accessible ($S_{2,2}$) in almost all stretches: only a few short parts of stretch 2 and some access points were privatized. Due to the moderate slope and the good condition of the pavement, the line is easily practicable ($S_{2,3}$).

Also for this line, the *margin values* (S_3) make the path of great interest for tourist and cultural purposes. The results obtained by the analyses show that there are only few panoramic tracts ($S_{3,1}$) near the track. However, the extraordinary value of the landscape in some areas of the surroundings ensures a high quality perception. There are a large number of services ($S_{3,2}$) related to commercial activities of catering and overnight stay. Several accommodation facilities, particularly active in summer, welcome tourists heading for Noto and ONR *Vendicari*.

Cultural and environmental goods ($S_{3,3}$) consist of 17 isolated goods of different typology and condition, which are suitable to be restored and intended for new uses. There are also archaeological sites, historical centers, museums and natural reserves that play a key role in tourism promotion.

The existence of transport infrastructure ($S_{3,4}$) of various types (mainly provincial roads) ensures the accessibility to the sites crossed by the abandoned railway as well as to the near commercial, tourist and environmental resources. Finally, there are 9 stations and 7 maintenance house along the former Noto - Pachino track ($S_{3,5}$). Part of them is intended for residential use. Most of these buildings are in poor condition, but they are all still recogniz-

able and potentially suitable for recovery and reuse.

GIS mapping

The first phase of GIS implementation involved the digitalization and harmonization of acquired data for the two abandoned lines. The classifications of the indicators of S_1 and S_2 systems were mapped by associating them with the respective stretches (Figures 4 and 5), so graphically represent the results of the field

Table 5. Priority of the indicators.

Indicators	Weight
$S_{2,1}$ Danger	0.44
$S_{1,4}$ Slope	0.43
$S_{2,3}$ Practicability	0.39
$S_{3,2}$ Services	0.24
$S_{3,3}$ Cultural and environmental goods	0.24
$S_{3,5}$ Railway buildings	0.24
$S_{1,2}$ Pavement type	0.20
$S_{1,3}$ Width	0.20
$S_{3,4}$ Mobility infrastructures	0.19
$S_{1,1}$ Recognizability	0.18
$S_{2,2}$ Accessibility	0.17
$S_{3,1}$ Panoramic position	0.10

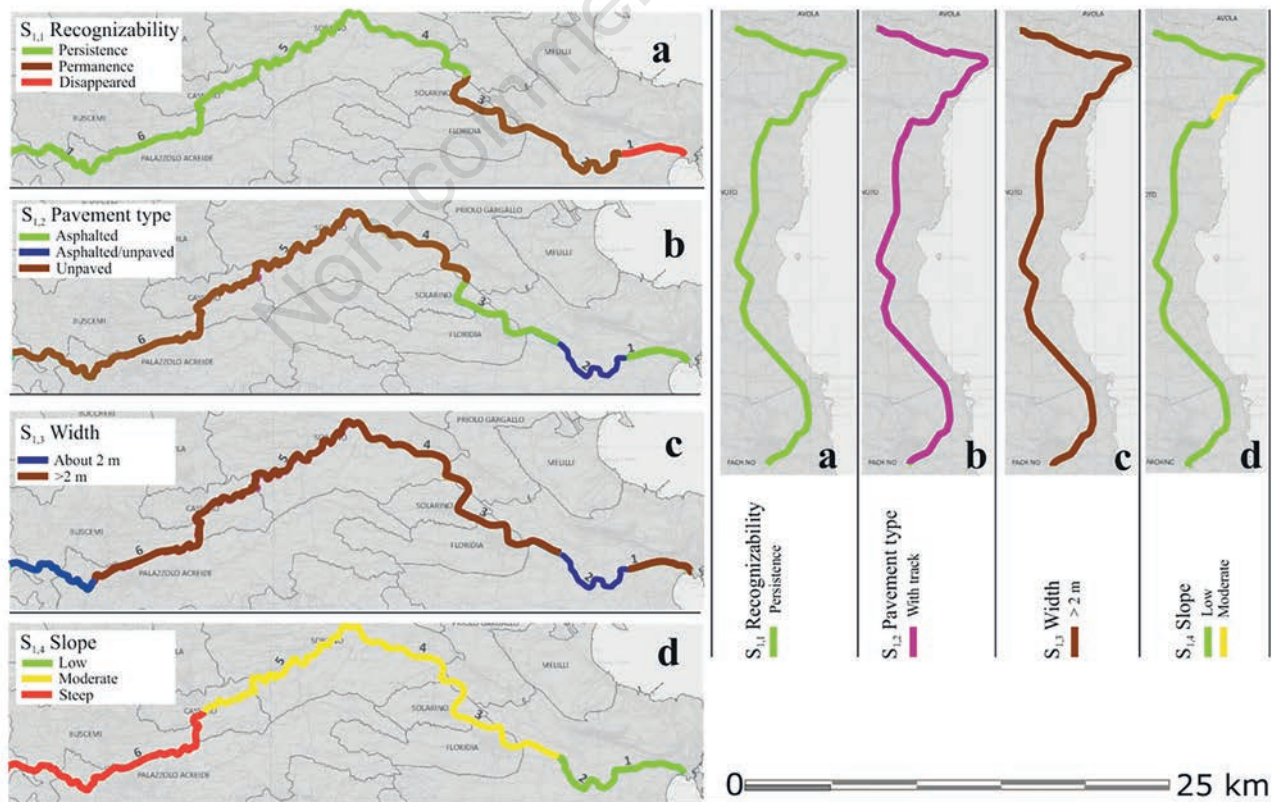


Figure 4. Classification of the indicators of the system characteristics (S_1): a) recognizability; b) pavement type; c) width; d) slope.

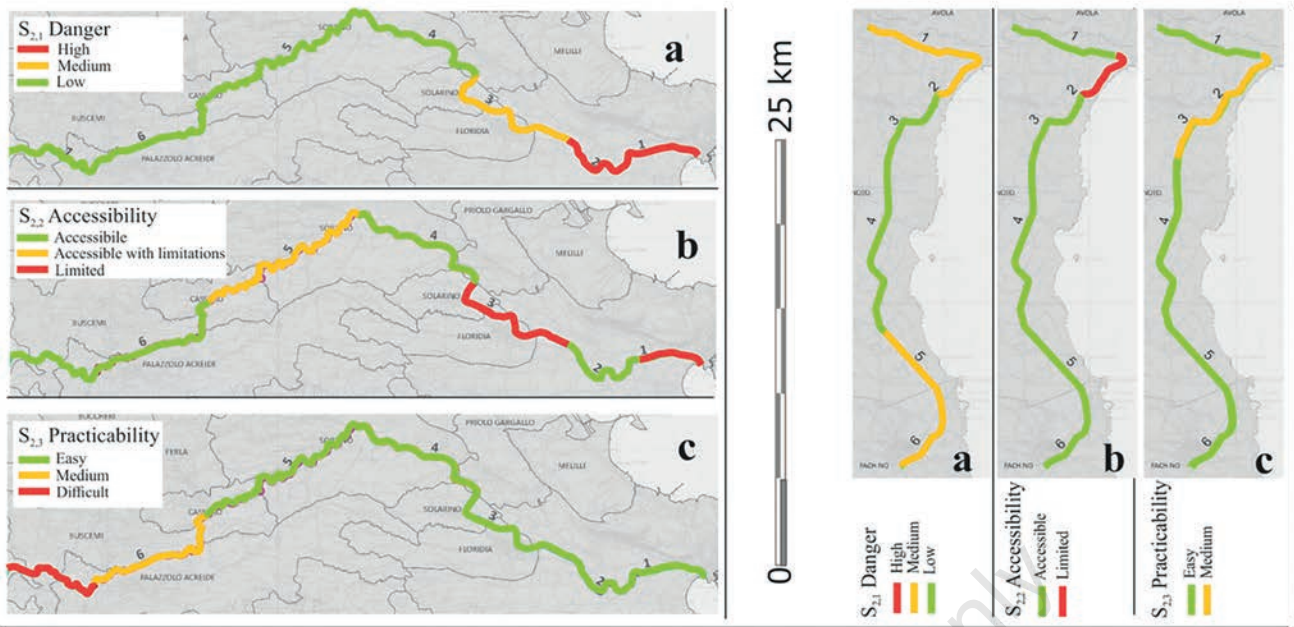


Figure 5. Classification of the indicators of the system *conditions of use* (S_2): a) danger; b) accessibility; c) praticability.

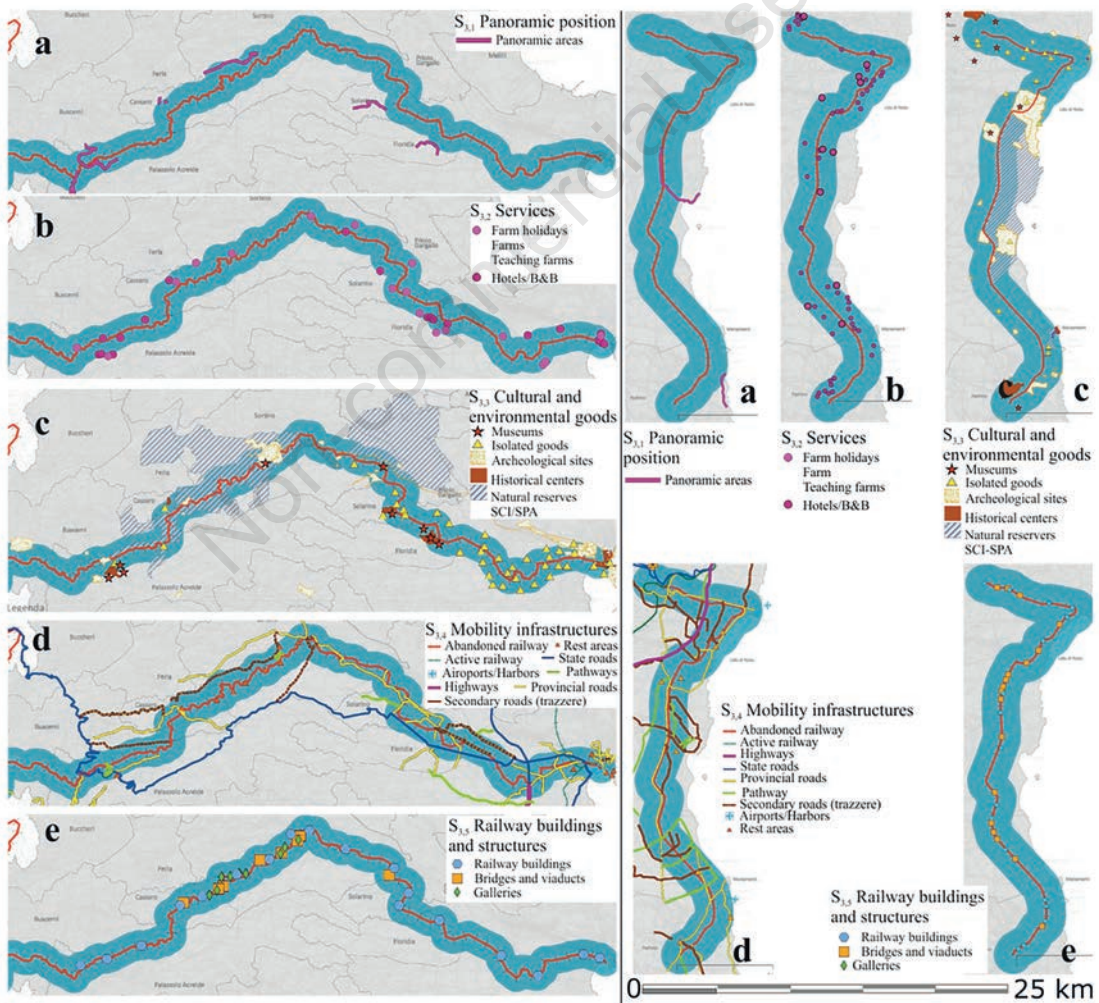


Figure 6. Classification of the indicators of the system margin values (S_3): a) panoramic position, b) services, c) cultural and environmental goods, d) mobility infrastructures, e) railway buildings and structures.

analysis described in the previous paragraph.

As regards the S_3 system, all point resources within the buffer were inserted in the GIS environment as they are, whereas linear and spatial resources were inserted also considering that parts that cross the boundary of the buffer. The classification of the indicator was associated with the corresponding geometry (point, line, polygon). The mapped results described in the previous paragraph are shown in Figure 6.

The last part of the application of the method concerned the transfer in the GIS environment of the results obtained with the multi-criteria analysis.

As regards the *Line A*, the results concerning the *characteristics* system (S_1) show that the extreme stretches (1, 2 and 7) are poorly suitable for recovery, as the sum of the weights are close to the minimum value of 0.18. Indeed, stretches 1 and 2 are characterized by maximum danger, while stretch 7 has steep slope, therefore the weights of the respective indicators were not associated with these tracts. The results of the *conditions of use* system (S_2)

show that also stretch 3 is unsuitable to be recovered as greenway due to its limited accessibility (Figure 7). On the contrary, the high values (close to 1.01) obtained in the *margin values* system (S_3) makes the entire track suitable for conversion. Maximum values are found in the stretches inside protected areas full of services, cultural goods, historical railway buildings, isolated goods and adequate infrastructure network (Figure 7).

Therefore, given the previous results, *Line A - Syracuse/Vizzini* is suitable to be recovered as greenway in the traits within the Nature Reserve (Figure 7).

Line B is completely suitable to recovery in relation to the *characteristics* system (S_1) since no tract presents any limitation, while regarding the *conditions of use* (S_2) some drawbacks are found in stretches 1, 5 and 6 due to the danger caused by the existence of intersections and the poor accessibility caused by the presence of privately owned land (Figure 7). Furthermore, the line is entirely suitable for conversion in relation to the *margin values* (S_3), as the sum of the weights assumes maximum values for

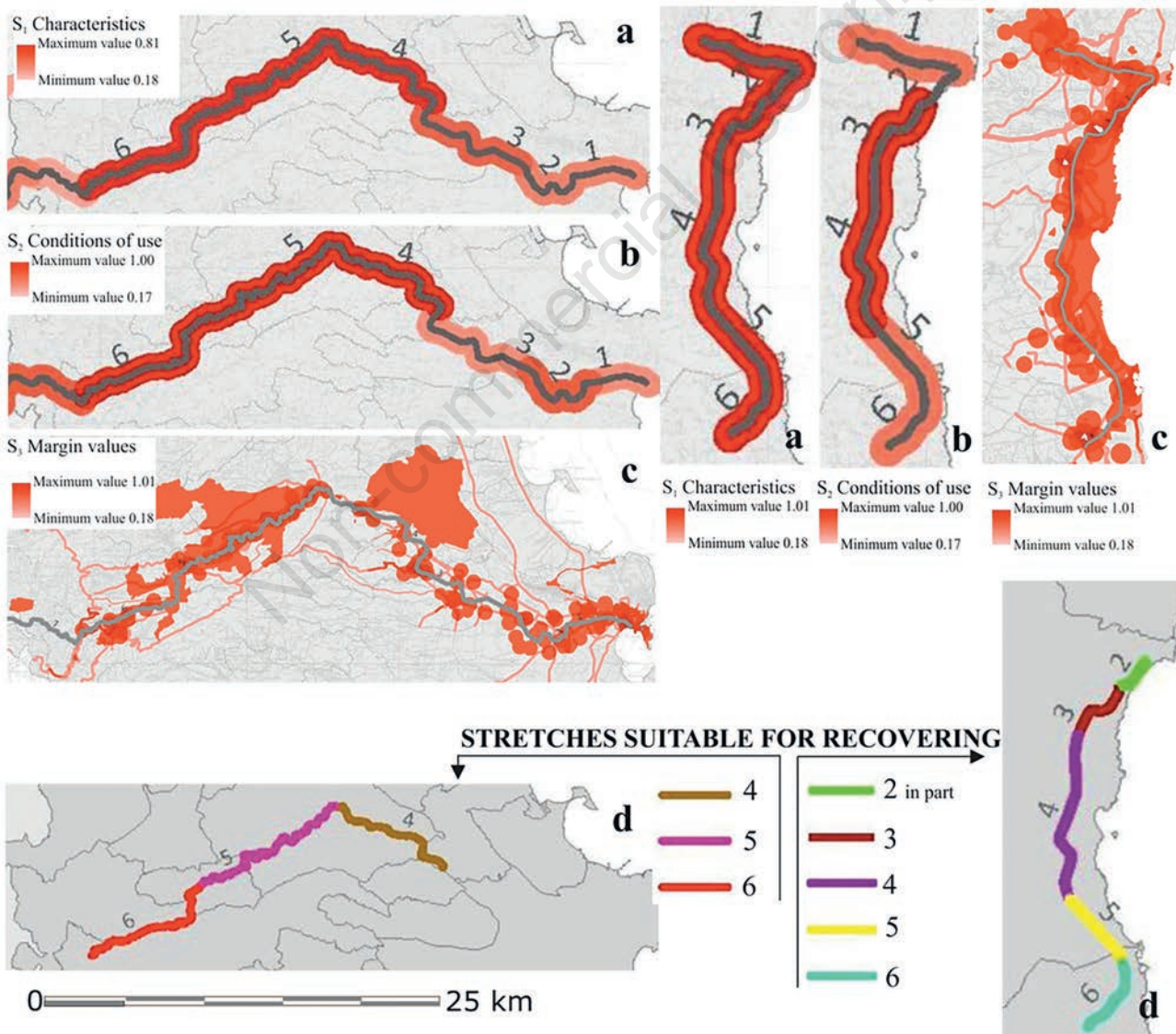


Figure 7. Suitability map of the two lines and identification of the stretches suitable for the conversion.

almost all the track (Figure 7).

Therefore, Line B - Noto/Pachino is suitable to be recovered as greenway in the traits from the former station Noto Marina to the Pachino terminal, included the tract inside the ONR *Vendicari* (Figure 7).

Discussion and conclusions

In order to evaluate the suitability of a stretch of an abandoned railway to be converted into greenway for the tourist and cultural enjoyment of rural areas, the combined use of multi-criteria analysis and GIS was adopted, according to various scientific papers (Geneletti and Van Duren, 2008; Giordano and Setti Riedel, 2008; Comino *et al.*, 2014; Riguccio *et al.*, 2015b, 2017), which showed its great versatility and widespread use in spatial planning.

This methodology was recently applied to address various aspects related to the building of greenways and to the recovery of abandoned railways. Giordano and Setti Riedel (2008) carried out a research aimed to the optimal placement of a greenway along the banks of a river in Brazil in such a way to preserve its hydrological function. Eizaguirre-Iribar *et al.* (2017) assessed the accessibility of an abandoned railway from urban and rural centers in order to evaluate its conversion for uses different from a greenway. Ferretti and Degiovanni (2017) studied different recovering options for abandoned railways with respect to heterogeneous environmental and socio-economic impacts. They reported interesting results on the clear preference of the stakeholders for the conversion in greenways, together with the reasons why they considered this option as the best alternative. Di Ruocco *et al.* (2017) made an interesting proposal for an integrated recovery of an abandoned railway track crossing an archaeological site near Paestum (Italy).

It is evident that, although several in-depth studies were carried out concerning the relationship between abandoned railways and greenways, it does not seem to be studies concerning methodological applications for evaluating the suitability of specific stretches of abandoned railway to be reused as greenways. Literature, however, shows a clear propensity to recovery actions for sustainable uses, which are those allowed by greenways.

Specifically, this research was able to highlight the railway stretches that best fit to be recovered as greenways for tourism and cultural promotion of the territory. Significant part of the two lines is suitable for this purpose. Specifically, 33.00 km of the line A and 22.50 km of the line B, respectively the 34% and 83% of their whole length, are recoverable.

An important activity for the development of the research was field analysis. Specifically, it enabled the recognition and mapping of over 65% of the indicators considered in this study (recognizability, pavement type, width, slope, danger, practicability, panoramic position, existence of historic railway building) with the ability to assign the prevailing conditions of each indicator for each stretch of abandoned railway line. This procedure involved a considerable expense of human energies, however the unique alternative to this method could be the use of aerial photography. Furthermore, direct survey enabled to build a database, mainly related to historic railway buildings, containing notes on the maintenance conditions and completed with photographs (data not used in this research). The other indicators (accessibility, services, cultural and environmental goods, mobility infrastructures) were mapped from existing shape files.

The proposed methodology can provide useful support to planning decision-making processes for the analysis, evaluation and

design of an abandoned railway recovery, aimed to suggest new perspectives and new uses.

This research is a contribution to lay the foundations for supporting recovery processes of those abandoned railways suitable to be intended for other uses. The hope is that in the near future, environmental corridors can be created, consisting of a public infrastructure network for slow mobility able to connect natural areas and points of historical and artistic interest, so promoting a conscious and responsible users' enjoyment (Fichera *et al.*, 2015; Marcheggiani *et al.*, 2011).

In conclusion, the application of the proposed methodology to the whole Sicily, where the abandonment of railways is more evident, would make it possible to identify many tracks to be recovered that could constitute a network able to *systemize* the whole territory with all the other non-motorized mobility networks (cycle paths, pedestrian paths, *regie trazzere*, trails) and the related activities and services (Toccolini *et al.*, 2006). Thus, each track could take the role of a synergistic agent for the development of territorial components and gain a strategic importance in planning and rehabilitation of environment and landscape (Caschili *et al.*, 2014).

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