A methodological proposal for the analysis of disused railway lines as territorial structuring elements: The case study of the Vasco-Navarro Railway.

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Abstract

The thousands of kilometres of disused railway lines that make up a fascinating body of heritage have been the subject of studies by several authors over recent decades. Several interventions for their reuse and reconversion have been carried out. However, there is a mismatch between theoretical and practical achievements. This research claims that an analysis of the railway lines under discussion should develop a comprehensive vision in order to establish common criteria for their preservation and for future interventions. As such, the objective of this paper is to create a methodological proposal for the analysis of disused railway lines as complex systems, thus demonstrating their potential as part of situated proposals for sustainable development. Accordingly, a Comprehensive Analysis Method (CAM) is created based on three theoretical and methodological underpinnings: disused railways as heritage systems; former linear infrastructures as non-motorised axes; and a balance between transport and other land uses around former railway nodes. The conclusions make reference to the potential of disused railways as territorial structuring systems, including both the potential of the linear infrastructure and the potential of the railway nodes, in order to encompass repurposing beyond the current greenways while continuing to promote the preservation of railway heritage. Both general strategies and specific action points have been identified for the repurposing of disused railway infrastructure. The proposed methodology has been applied in the case study of the Vasco-Navarro Railway, identifying strategic points in the infrastructure and areas where specific strategies can be implemented.

1. Introduction

Significant construction of railway infrastructure occurred in the 19th century, while in the 20th century many lines fell into disuse. (Appleton & Appleton, 1970; Sarmento, 2002; Schwieterman, 2001). In the present century, the future of these disused railways is under question. The thousands of kilometres of disused railway lines that make up a railway heritage of great interest have been the subject of studies by several authors over the last few decades (Ferrari, 2010; Ferretti & Degioanni, 2017; Tarchini, 2010). The literature generally emphasises the enormous potential of this infrastructure as part of a move towards local sustainable development, (Di Roucco et al. 2017; Llano-Castresana et al. 2013, Ottomano, et al. 2016) in terms of mobility, land use and also with respect to architectural heritage and cultural landscapes.

With reference to mobility, railways have been converted into paths designed for different transit systems. There are cases in which trails are transformed into motorised transit infrastructure, as for example, light rail lines, tramways, busways or limited access roads (Duckett, 2013; Hill, 2007; Vigrass & Smith, 2005). However, cases in which the disused railway line becomes infrastructure for non-motorized transit are more common in the literature. Most authors point out the potential of the paths to pedestrian or cycling mobility due to technical features (soft slope and turning radius). As such, greenways are the best known examples of railway reconversions (Quattrone, 2018). Although these were initially linked to the park systems movement (Fábos & Ryan, 2004), they were also planned to provide access to open areas and to link urban and rural areas (President's Commission on Americans Outdoors, 1987; Walmsley, 1995). In this regard, railway based greenways or rail-trails have become increasingly popular. Disused railway infrastructures can also facilitate everyday trips, (Eizaguirre-Iribar et al., 2016) as greenways can be used as alternative infrastructures for commuting (Fábos, 1995). Accordingly, accessibility must be considered in this context, since it is one of the main factors of the urban spatial form (Lynch, 1981). Locations with good accessibility had a higher development chance and at higher density (Hansen, 1959).

Linked to this, ideal land-use and transport systems have been proposed for city planning (Wegener & Fürst, 1999), where the balance between transports and land uses provides one of the conditions for assessing sustainability (Reusser et al., 2008). Transport oriented developments and, especially, Transit Oriented Developments (TOD) have been proposed in this context. A TOD is understood as “a mix of moderately dense pedestrian-friendly development around transit stations” (Cervero, 2009), and, hence, TODs are presented as dual nature elements (Bertolini & Spit, 1998; Bertolini, 1999). Public transport stations act as nodes in a transport network intended to move people from one destination to another, while simultaneously establishing the area around the node as a place where activities occur and destination in itself. The reconversion of disused railway lines may constitute an opportunity to improve the mobility related to both public and non-motorised transports, as suggested by Froggatt (2017) in his doctoral thesis. Such reconversions combine two aspects relevant to sustainable development. On the one hand, longitudinal flows can be implemented using sustainable transport modes. On the other hand, a hierarchy around nodes can be created, where a balance between transports and land uses is advantageous to the achievement of more sustainable development.

With respect to heritage, architectural elements and cultural landscapes linked to disused railway infrastructure have been discussed from two perspectives. Some authors emphasise the inherent heritage value (Burman & Stratton, 2014; Gerencia de Protección de Bienes Histórico-Ferroviarios y Trenes Históricos, 2016) while others emphasise the potential for local development (Ferrari, 2010; Galindo & Sabaté, 2009), generally linked to tourism (Taylor, 2015; Willard & Beeton, 2012).

Nevertheless, when it comes to assessing the potential of railway heritage for development proposals, few studies have understood it as a system capable of creating territorial relationships. This mismatch between theoretical and practical achievements has been identified by Porcal (2011) and has been taken into consideration in this research with the aim of contributing to the development a comprehensive vision in order to establish common criteria for the preservation or future repurposing of this infrastructure. Accordingly, the objective of this paper is to develop a methodological proposal for the analysis of disused railway lines as complex systems (Eizaguirre-Iribar et al., 2015), thus demonstrating their potential for situated sustainable development.

A Comprehensive Analysis Method (CAM) based on the aforementioned theoretical foundations is presented in this article. In addition, the results obtained from the application of the CAM to the case study of Vasco-Navarro Railway are described. The

Vasco-Navarro is one of the principal disused railway lines in Basque Country and Navarre (Northern Spain). It has great potential as both an asset in terms of land use planning, due to the strategic importance of its route, and for the heritage value of its architectonic elements. The Vasco-Navarro is analysed as part of a larger territorial system where different modes of motorised transport have been prioritised and settled, while there is a significant lack of infrastructure dedicated to non-motorised transport on a territorial scale. For this reason, the use of the railway infrastructure is limited to non-motorised mobility. Furthermore, active transport creates a small scale structuration of the territory that is out of the large scale structuration created by highways and high speed railways (Eizaguirre-Iribar et al., 2016). There are also health, economic and social benefits derived from active transport (Litman,2012; Macmillan et al. ,2014; Sælensminde, 2004; Sallis et al., 2016) which contribute to the advancement of local sustainability promoted in this analysis. Finally, the method described here could be applied to other disused railway systems located in both urban and rural territories, and even to other territorial systems composed of a territorial infrastructure containing several connected nodes.

2. Case study: the Vasco-Navarro Railway

The Vasco-Navarro Railway is the longest disused railway (139 km) of the Basque-Navarre territory. Although the first section of the Vasco-Navarro Railway was opened in 1887, the entire route was not completed until 1927. The line was in operation for another 40 years and finally closed in 1967. In the recent years, most of the route kilometres have been turned into greenways or bicycle lanes. It crosses three different administrative regions and diverse territories or landscapes, from cities to rural towns or protected natural areas. The north side of the infrastructure goes through narrow valleys and mid-sized towns whereas the west side goes principally through plain terrains and rural areas. Moreover, it is the disused railway with the highest number of railway nodes of the Basque-Navarre territory, from which almost 12000 m^2 are still preserved distributed in 33 existing nodes.

Railways and disused railways of the Basque-Navarre territory have been widely studied considering the historical aspects of both the whole network (Olaizola & Vaillant, 2011; Ormaechea, 1999; Salmerón & Olaizola, 1990) or a specific line (Olaizola, 2002). Those historical aspects include general creation, development or closure history and specific issues, such as electrification, rolling stock or economic and social issues. The current state of the disused railways has also been included in some of the specific studies and reconversion or protection proposals. Furthermore, the influence that the creation of these railways had on the territory has been studied, by focusing on the industrialisation process (González, 1999), economic development (Macías, 1994) or urban and population development (González et al., 2012). Conversely, the influence that the closure of these lines had in the territory or the relations that they can nowadays create in the territory have not been studied yet. That is why the methodology proposed below is of particular interest.

3. Definition of the methodology: A Comprehensive Analysis Method (CAM)

3.1. Theoretical and methodological approaches

The principal theoretical and methodological approach used for the design of a Comprehensive Analysis Method (CAM) is based on the understanding of disused railway lines as territorial heritage systems, since a railway station is not only a heritage element that can reactivate its environment but is also part of a territorial system that combines infrastructure and its surrounding environment.

Railway heritage has been framed as a complex system by Aguilar (2008), who argues that it includes a wide range of elements. Tarchini (2010) further developed this conception for the reintegration of the railway areas at a territorial and local level. In this regard, and taking into consideration the concept of a system in which relations between the different elements are considered in addition to the elements themselves (Von Bertalanffy, 1993), it is important to define both the components and the relations that can be created in this type of systems in order to develop a comprehensive analysis of disused railway lines. Accordingly, the concept of Disused Railway System (DRS) was defined (Eizaguirre-Iribar et al., 2015), from which the principal areas of analysis have been derived. On the one hand, the elements or components that are part of the system are considered, i.e. the line and the nodes. On the other hand, the relations between these elements and the surrounding territory are studied. Hence, an analysis of relationships between line and territory, and an analysis of nodes and territory are proposed. These are the four are the main areas of analysis of the CAM (fig. 1).

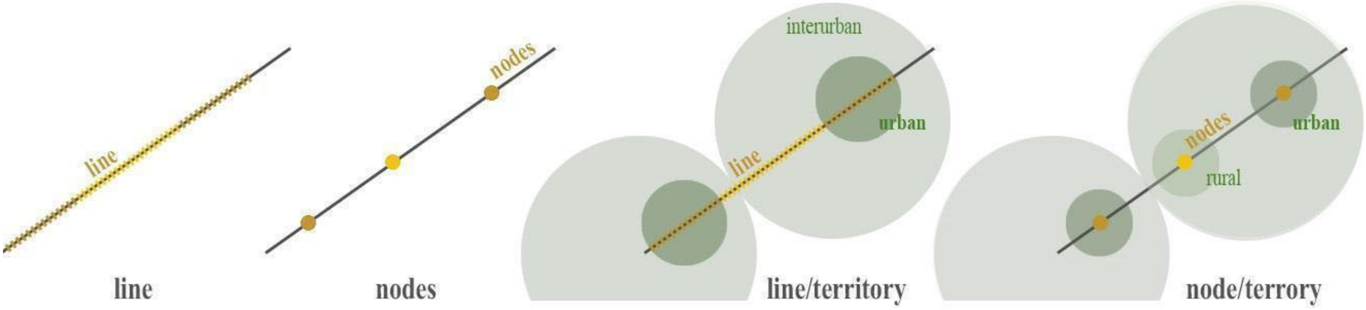


Figure 1. Areas of analysis for the Comprehensive Analysis Method (CAM)

In addition to the concept of a system, two other issues are considered in the four areas of analysis. One is the opportunities offered by disused infrastructure as axis for non-motorised transport in contemporary society in the context of a shift towards sustainable development (Coutts, 2008; Millward et al., 2013). The accessibility relations between the infrastructure and the territory are considered for that purpose. Secondly, an analysis of relations between railway nodes and territory is developed based on transit oriented development proposals (Nigro et al., 2019; Vale, 2015; Vale 2018). Once again prioritising sustainability, these proposals are conditioned by a need to balance transports and land uses.

Three different ideas that influence the methodological proposal are defined in the theoretical and methodological framework. An understanding of disused railways as heritage systems, and the consequent definition of distinct areas of analysis, influence the method throughout the paper. The other two ideas are related to specific analysis areas: structuring non-motorised axes in the relations between line and territory; and transports and land uses in the relations between line and territory and the relations between nodes and territory (fig. 2). Hence, these three theoretical and methodological concepts are the basis for the creation of a Comprehensive Analysis Method (CAM) for the study of Disused Railway Systems (DRS). By means of a CAM, taking into consideration four areas of analysis, the potential of a DRS as a territorial structuring element is studied.

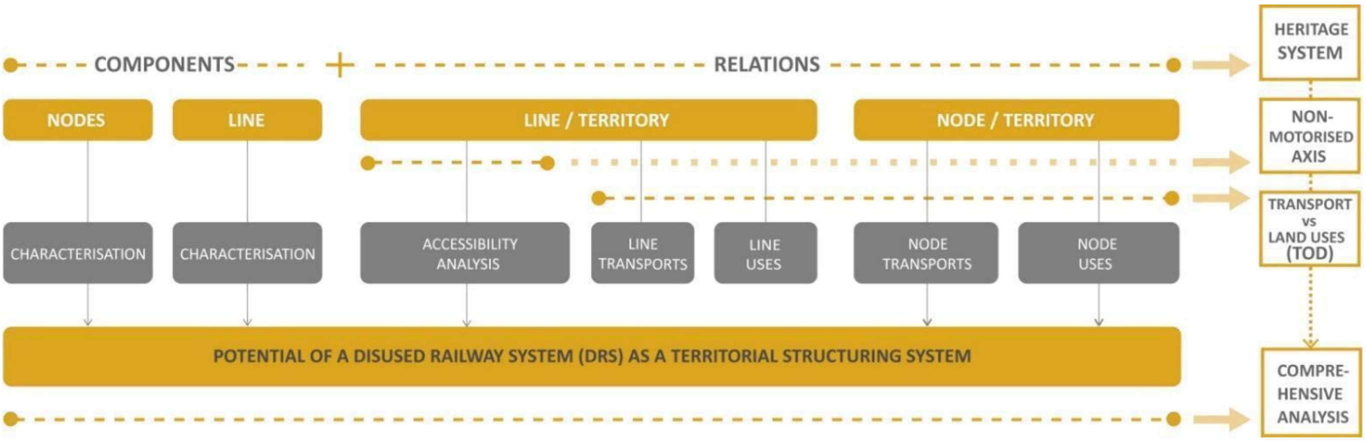


Figure 2. Theoretical approach of the Comprehensive Analysis Method (CAM)

The Comprehensive Analysis Method (CAM) is structured so as to take into account different theoretical and methodological approaches. The first step in the method focuses on understanding the individual elements, from their origins to the present, placing an emphasis on the importance of DRSs as heritage. The second and third steps include the study of opportunities presented by disused railway systems with respect to sustainable development. This includes the potential of the linear infrastructure as a non-motorised transport axis, and the potential of each node in its surroundings. Hence, different areas of analysis and methods are used to define the CAM. Each approach responds to different elements and relationships and together they produce the overall results relevant to a particular DRS. These results refer to the potential of a DRS as a territorial structuring system, including both the potential of the linear infrastructure and the potential of the nodes, in order to cover new uses beyond the current greenways, while also promoting the preservation of railway heritage. In this regard, general strategies or guidelines and specific action points can be defined for the reconversion of disused railways.

3.2. Areas of Analysis and methodological proposals for a Comprehensive Analysis Method (CAM)

The CAM has been divided in four principal areas of analysis that include the elements that are part of the system and the external relations between the elements and the surrounding territory: line, nodes, line/territory relations and node/territory relations.

Different methodologies adapted to specific elements are proposed for each stage of analysis. However, prior to commencing the analysis, data related to railway components (lines and nodes) and their surrounding territory must be compiled. The creation of a GIS based inventory is proposed for this purpose. These kinds of inventories are easy to update and hence it is possible to add or change information during or after the research process.

3.2.1. Lines

The line (the linear infrastructure and specifically related elements) is understood as the main element of a railway system. It generates flows along a linear infrastructure, creating longitudinal relations at a territorial level. As part of the CAM, an analysis of the infrastructure at different historical moments is proposed: the historical period in which the railway was in use, and the present in which it is not used as a railway system. In this way, the two most important stages are considered: the historical state and the current state (fig. 4).

An analysis of the railway route is proposed as a way of understanding the territorial links created by the railway. Furthermore, the different technical features (slope, turns, etc.) must be taken into consideration, since they remain unchanged and they can promote the usage of the infrastructure. A study of the current level of preservation and features (use, interaction with surrounding areas, types of pavement and the existence of bypasses) for different sections of the line is also essential in defining proposals for each section.

Secondly, a study of different constructed elements that permit those favourable features or auxiliary buildings is proposed. This study documents the construction materials used, overall dimensions and the distribution of constructed elements along the line. The latter is quite regular in the case of the service buildings such as electrical substations and worker's housing, but also varies according the terrain in the case of structures such as bridges or tunnels. The level of preservation of these secondary elements influences the current and future functionality of the linear infrastructure, and also the heritage value of the system itself.

3.2.2. Nodes

A railway node, including railway station areas and stopping areas and made up either simple shelters or sets of buildings, is also understood as an important element of a railway system. These generate connections between railway infrastructure and territory, creating crosscutting relations at an urban level.

In the case of nodes, two phases of analysis are carried out (fig. 4). First of all, the identification and classification of nodes is proposed in order to understand territorial structures and hierarchies created by railway systems. Furthermore, the buildings that are part of these nodes are analysed both as functional elements of the railway and as meaningful or eloquent elements. Subsequently, the analysis of the current state of these elements is proposed, identifying missing or degraded elements and cataloguing existing ones. The level of preservation and current usage and ownership is determined, as this conditions possible developments of the whole system. Furthermore, limitations and opportunities imposed by legislation are identified, which includes the heritage protection status of the elements.

3.2.3. Line/Territory relations

An analysis of relationships between line and territory aims to demonstrate that disused railway lines have potential as non-motorised infrastructures that operate on urban and interurban scales to promote more sustainable development. In this regard, an accessibility analysis focusing on the possibilities offered in an area by disused railway systems for daily use, in addition to leisure or tourism uses, is proposed. Methodological aspects of a non-motorised multilevel accessibility analysis using location based measures have been already proposed by the author for this purpose (Eizaguirre-Iribar et al., 2016). The proposed scales of analysis and the resultant approaches encompass the areas around the railway infrastructure (fig. 4) and facilitate an analysis of non-motorised accessibility in a disused railway infrastructure and its environment. Each of the three approaches described below produce results applicable at different scales, and a combination of all three facilitates an analysis whole line areas. Subsequently, is possible to understand the potential of disused railway infrastructure as non-motorised axes and demonstrate its capability to organise territory in response to various needs simultaneously, thus offering solutions for more sustainable transportation.

- **Accessibility Level 1 (AL1):** A regional approach to the accessibility of cities and towns along the disused infrastructure. Accessibility at regional level (AL1) shows the potential of disused railway infrastructure as non-motorised axis of active transport, defining areas where uses beyond greenways are viable. To this end, accessibility from a given point of origin to different destinations (from a town or city to other towns or cities that are connected to the infrastructure) is measured by taking into account population at destination. PgRouting in QGIS (kdijkstra) is proposed for the creation of the distance matrix. Based on potential accessibility defined by Hansen (1959), different total network distances are established, limiting travel impedance and reducing the end of the line effect that occurs in linear infrastructures in order to identify the most accessible cores (1).

$$P = P_i + \sum_{j=1}^{n} P_j \text{ when } \sum_{j=1}^{n} I_{ij} \leq x \tag{1}$$

Where P represents accessibility for each origin i to j destinations, P_i is the population at origin i, P_j is the population at the destination j, I_{ij} is the travel impedance (in this case, travel distance) between each origin–destination pair and x represents the established total network distance. Different territorial areas or zones that depict territorial and urban realities can be identified comparing level of accessibility of cities or towns using different population ranges.

- **Accessibility Level 2 (AL2):** An interurban approach addressing the accessibility of the areas near the line. Accessibility at an interurban level (AL2) shows the potential of disused lines as non-motorised axes for different transport modes and journeys. The number of cities or towns from which a given point in the infrastructure can be accessed in a specific time (45 minutes) is measured in order to define the level of non-motorised accessibility of each section. PgRouting in QGIS (driving distance) is used to assess simple network distance measures. Moreover, strategic opportunity points and areas can be identified by comparing levels of accessibility of different sections. These points can act as possible nodes along non-motorised infrastructure.

- **Accessibility Level 3 (AL3):** An urban approach addressing accessibility in urban areas. Accessibility at an urban level (AL3) defines land use and activity areas that are included in the accessibility or service area of a line or a node and, hence, could be the origins or destinations of journeys at different levels. Taking into account all transport infrastructure and urban networks in addition to disused railway infrastructure, sites that can be accessed from a point on the line or a specific node in a maximum time of 10 minutes by non-motorised transport are defined using distance accessibility measures (isochrones) developed in QGIS (PgRouting, alphashape). Furthermore, accessibility areas can be classified into four groups by comparing the relationship between the node service or accessibility area and its surrounding urban area: an urban core is larger than the accessibility area of a node (city); an urban core is similar to the accessibility area of a node (town); and urban core is smaller than the accessibility area of a node and is reachable from within the walking round-trip influence area (rural town); and an urban core is smaller than the accessibility area of a node and is not reachable from the walking round-trip influence area (rural areas).

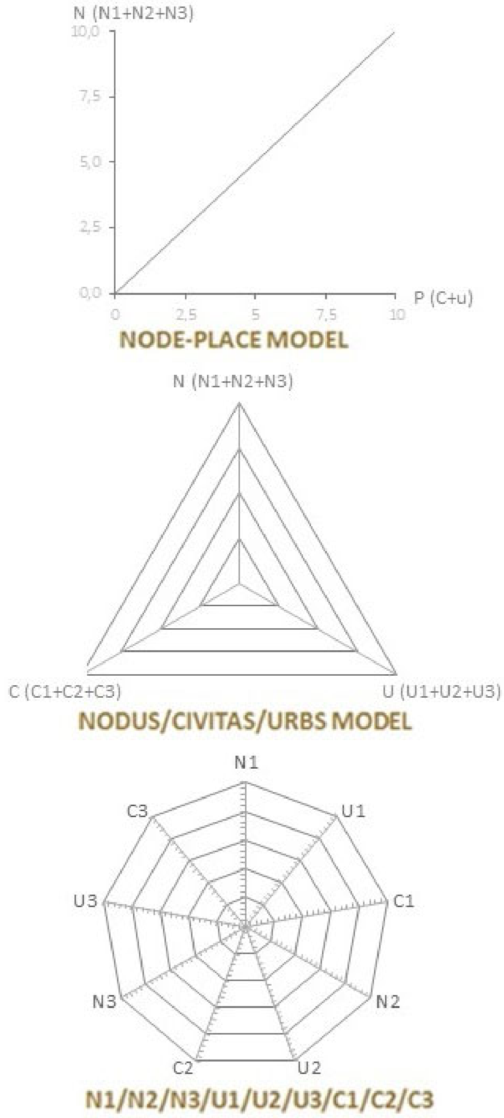
At interurban and urban levels, different time and, in consequence, distance limits are proposed in accordance with Marchetti's Principle (Marchetti, 1994) and the average journey-to-work time (30 min) across a wide range of cities (Kenworthy & Laube, 1999). Furthermore, different speeds are given for different modes of transport (walking/cycling) and areas of analysis (urban/interurban).

Accessibility analysis at different levels and with different limits and non-motorised transport modes facilitates the study of different sections of a disused railway line located in a diverse territory, measuring accessibility in urban and rural areas and obtaining results for each section of the line and each core that the line passes through. In this regard, this multilevel approach permits the analysis of territories which include different land uses and spatial patterns along the linear infrastructure.

3.2.4. Node/Territory relations

An analysis of relationships between nodes and territory aims to show the potential that former railway nodes and surrounding new nodes have for development based on active transport and hence, for more sustainable development. To this end, a systematic cataloguing of different transport systems and land uses located around each railway node and the study of the balance between them is proposed. This approach facilitates an understanding of each former railway node as a node in a network and as a place in a city. Subsequently, these can be proposed as nodes in future non-motorised transport axes. The models developed and selected here (fig. 4) can be applied in the development of proposals for DRSs located in varied territories.

- **Node/Place Model (N/P)**: The transport systems and land uses around each railway node are studied and diagrams with two axes are created (Bertolini, 1999).
- **Nodus/Civitas/Urbs Model (N/C/U)**: Transport systems, activities and morphological features around each railway node are studied and diagrams with three axes are created (Moreno, 2013).
- **Multiaxial Model (N1/N2/N3/C1/C2/C3/U1/U2/U3)**: The transport systems, activities and morphological features around each railway node are studied, taking into consideration both urban and rural areas, and diagrams with nine axes are created (Eizaguirre-Iribar, 2019).



VARIABLES AND INDICATORS OF THE MODELS

VARIABLES			INDICATORS	
NODE	NODUS	N1	N_{11}	Nº of rail stops
			N_{12}	Nº of rail directions serverd
			N_{13}	Nº of bus stops
			N_{14}	Nº of bus directions served
			N_{15}	Nº of tram stops
			N_{16}	Nº of tram directions served
		N2	N_{21}	Distance from the closest motorway access
			N_{22}	Distance from the closest secondary road
			N_{23}	Parking capacity
		N3	N_{31}	Cycling path lenth
			N_{32}	Pilgrimage routes in the area
			N_{33}	GR routes in the area
PLACE	URBS	U1	U_{11}	Distance to the town centre
			U_{12}	Population density
			U_{13}	Urban land-uses
		U1	U_{21}	Number of residents in the area
		U2	U_{31}	Forest cover
			U_{32}	Agricultural land-uses
	CIVITAS	C1	C_{11}	Nº of wokers in industry
			C_{12}	Nº of wokers in services
			C_{13}	Nº of student in education
			C_{14}	Open areas
			C_{15}	Degree of multifunctionality
		C2	C_{21}	Elements of interest
			C_{22}	Heritage elements
		C3	C_{31}	Protected natural areas
			C_{32}	Linking corridors
			C_{33}	Agricultural land
			C_{34}	Degree of multifunctionality

Figure 3. Different transport and land use models proposed for the analysis of disused railway node areas (left) and variables and indicators of the models (right).

These models enable an analysis of transport and land uses, and a study of their balance, taking into consideration both urban and rural areas. Hence, the diagrams of the three models complement one another, where the results refer to the potential of node areas in a non-motorised axes and possible future directions that could be taken in each node area (fig. 3 left). First of all, the two axes analysis (N/P) defines the balance between transport (node) and land uses (place) showing the potential for physical human interaction (levels of transport supply) and the degree of current realisation of this potential (activity level) (Bertolini, 1999). This balance is essential for the creation of developments based on active transport. Similarly, the three axes analysis(N/C/U) defines the balance between transport systems (nodus), activities (civitas) and morphological features (urbs). Hence, human activities and physical features of the area itself are distinguished through the place variable. This is because morphological features also represent the potential for human interaction in the future. Finally, the nine axes analysis (N1/N2/N3/C1/C2/C3/U1/U2/U3) characterises the transport systems, activities and morphological features of varied territories. Although the (N, C and U) variables are repeated from the three axis analysis, three criteria (1, 2 and 3) are distinguished to identify urban and rural features. Criterion 1 refers to the urban approach of the node area, while criterion 3 corresponds to rural issues. Criterion 2 includes the indicators related to either urban or rural areas. Therefore, the diagram created identifies features that must be modified or created to encourage a particular development and the comparison between them enables a classification and grouping of node areas. This grouping refers to nodes that could follow the similar guidelines in the future.

Although different models have been proposed, the methodological approach and, especially, the indicators used, are the same for each of them. This facilitates comparison between different models in addition to making the process easier. Accordingly, the overall methodological process is defined as follows:

- Definition of nodes and their catchment areas: The main nodes of a DRS are the former railway stations and other railway buildings of the system itself. However, there are other points in the system that can act as new nodes in the future, since the connection points between line and territory are unlimited in a disused system. Accordingly, the analysis of the transport and land uses around a DRS and an accessibility analysis of areas around the line are proposed for the identification of possible new nodes. Once a railways original nodes and potentially useful new nodes are identified, an assessment of their influence or catchment areas can be achieved by means of an accessibility analysis at an urban level (AL3) and connected to different modes of non-motorised transport.

- Definition of variables and indicators: Taking into consideration proposals by other authors (Bertolini, 1999; Reusser et al., 2008; Chorus and Bertolini, 2011; Moreno, 2013; Vale, 2015), indicators related to the variables N, C and U and criteria 1, 2 and 3 of the three models are proposed. Urban or rural activities and their combinations are measured in C1 and C3, while elements and areas of special interest are measured in C2 (fig. 3 right). Urban and rural morphology are also measured based on different land uses and densities in U1 and U3, and population is measured in U2. Finally, rail, bus and tram accessibility are measured as public transports in N1, car accessibility in N2 and non-motorised transports in N3.

- Analysis of nodes. Multi-criteria Decision Analysis: The use of Multi-Criteria Decision Analysis (MCDA) is proposed in order to address complex problems. For this purpose, firstly, all the criteria are structured and weighted according to their relative importance using the Analytic Hierarchy Process (AHP), originally developed by Saaty (1980). Pairwise comparison matrixes are used to evaluate the relative importance of indicators and to calculate average weightings, while consistency analysis is carried out to assess the consistency of the initial rating. Afterwards, values for each defined node area referring to each indicator are measured and first results for each variable and model are obtained. Using these results, three diagrams for each node area can be created in order to show their potential and the balance between different variables. A ranking of the different node areas can also be created. Finally, a sensitivity analysis is proposed in order to determine the variability of the parameters and assess the suitability of previously established weightings. If these are not suitable, the process starts again and AHP is reviewed and edited.

- Comparison and classification of node areas: A comparison of results is proposed in the three models in order to classify node areas and create different groups that represent development typologies, from cities to non-developed areas. A single diagram can be used for comparisons in the node/place model (each node is a point in a two-axes diagram), but not in the other two models. Therefore, the use of different zones or groups established in the accessibility analyses is proposed: Territorial zones obtained in the regional accessibility approach (AL1) and groups of accessibility or service areas established according to accessibility at an urban level (AL3). This facilitates the classification of node areas with similar features.

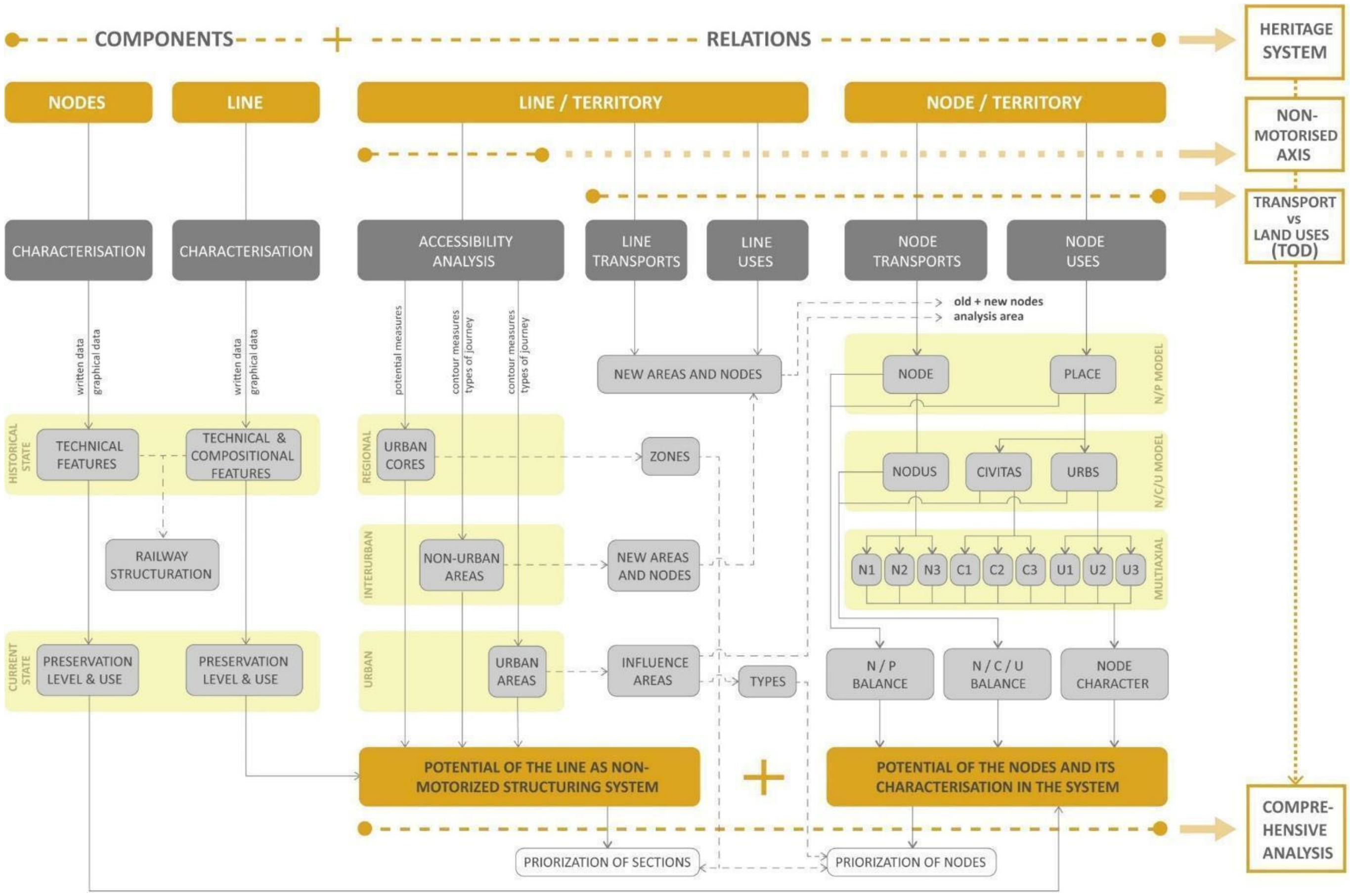


Figure 4. Detailed representation of the Comprehensive Analysis Method (CAM)

3.3. Results of the Comprehensive Analysis Method (CAM)

Although the different areas of analysis to be taken into consideration have been presented and developed separately, the results in each area are interrelated. The potential of relationships between a railway system and territory will not be realised if the current state of the elements themselves is not considered (fig. 5 left). Accordingly, the results obtained from the line/territory analysis will present limitations and opportunities that depend on the features and level of preservation of the linear infrastructure itself. That is to say, two sections of the linear infrastructure with high accessibility levels will have different opportunities if one of them is in a good state of conservation and has suitable territorial integration, and the other has disappeared or is useless. This is also the case with nodes that are part of the railway system. Furthermore, taking into consideration the methodological proposal for each analysis area, there are analyses specific to each type of relationship including accessibility analyses of line/territory relations and transport and land use analyses for node/territory relations. Furthermore, there are also other analysis not expressly limited to a specific area of analysis. For instance, transport and land use analysis around linear infrastructure is related to line/territory studies, but the results are necessary for the node/territory studies. The extra information obtained in accessibility analyses is also reintegrated. Accordingly, in addition to an evolution of results from the top down, a process from the left to right is created in the relations that are identified in the system, which are represented in figure five, the detailed representation of a comprehensive methodology (fig. 5 left).

Consequently, the detailed representation of the CAM (fig. 4) illustrates steps in the comprehensive methodology for the analysis of the elements and relations in a DRS, but it also shows the links and interrelations that exist between the different areas of analysis. The studies of the railway elements are located on the left. They contribute to the definition of the potential of each type of element in the territory, but they also facilitate understanding and documentation of the heritage elements in the system. Moreover, relationships between linear infrastructure and territory are studied in the central area of the figure. The accessibility analyses show the potential that linear infrastructure has as a non-motorised transport axis, while the transport and land use study, together with the extra information obtained in the accessibility analyses, defines the existing and possible nodes and their catchment areas for the node/territory analysis. Finally, the relations between the nodes and the territory are depicted on the right, showing the potential of the former railway buildings as nodes along in non-motorised infrastructure.

Taking all this into consideration, the potential of a point or section of a DRS will include the potential of the linear infrastructure of the defined area and the potential of the nodes located there. Accordingly, reconversion proposals for a DRS as a non-motorised axis and territorial structuring element will be related to that potential. Furthermore, different sections or points can be prioritised by taking into account the line or nodes, or by considering both in general. In the case of the line, strategic points can be identified in different zones. In the case of the nodes, significant points can be defined in different zones and type of settlements. Consequently, the following graphic which illustrates the general results (fig. 5 right) can be created for a section of a DRS by means the proposed Comprehensive Analysis Method (CAM) described in this article. In the middle of the graphic, the current state of the infrastructure is represented showing the type of routes and their interaction with the surrounding areas and the existing types of pavement, while the current state of the nodes includes their current level of presentation and use. In the bottom part, the line/territory relations are compiled, taking into consideration the three levels of analysis and indicating the identified zones, type of cores and connections along the linear infrastructure. In the upper part, node/territory relations are represented by means of the classification created for the different node areas.

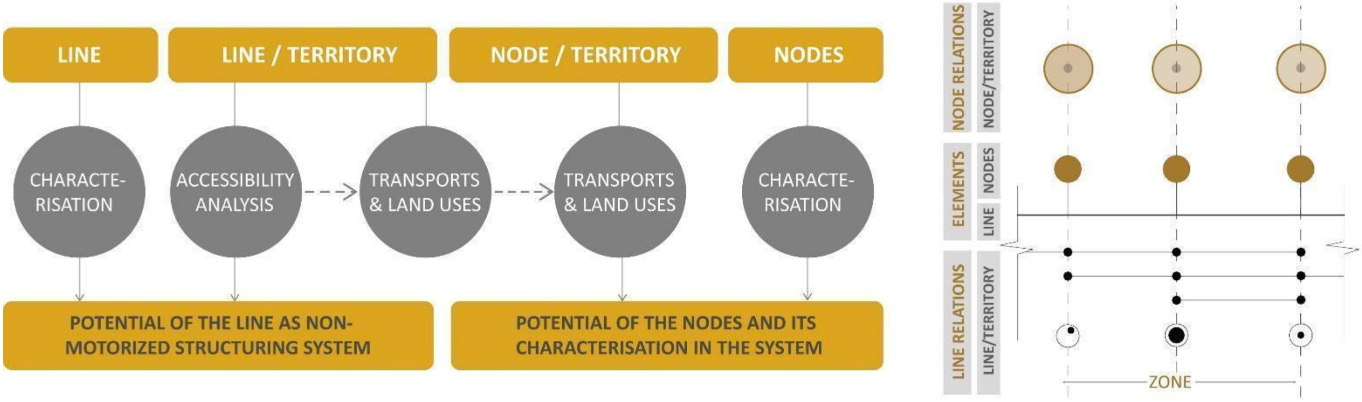


Figure 5. Graphic representation of the Comprehensive Analysis Method (left) and general scheme of results (right)

4. Application and results of the Comprehensive Analysis Method (CAM) in the case of the Vasco-Navarro Railway

By applying the CAM to the Vasco-Navarro Railway, a general scheme including the most important data is obtained. Although the general results of each area of analysis are compiled in the general scheme, results of a specific section or the whole railway system can be also inferred, i.e. differences between areas that have similar results in some of the previous areas of analysis can be identified. Hence, these results represent a general characterisation of the DRS, which is essential for both future reconversion proposals targeting different sections or areas of the system, and the creation of general guidelines related to the whole territorial system. The main results generated by the application of a CAM to the Vasco-Navarro Railway System and some guidelines that take these results into consideration are presented in the following paragraphs.

According to the analysis of relations between line and territory five territorial zones are identified (fig 6) in the case of the Vasco-Navarro Railway, measuring accessibility at a regional level (AL1). Moreover, the CAM shows the differences between urban and rural settlements in different zones. Zone 1 (northern towns) comprises the major towns, where urban cores are similar in size to the accessibility areas of the nodes. By contrast, the small town of Leintz-Gatzaga is the only core in Zone 2 (the mountain pass of Arlaban). In Zone 3 (zone of influence of Vitoria-Gasteiz) and Zone 5 (zone of influence of Lizarra), there are several small settlements where the cores are smaller than the node accessibility areas. Finally, there are no major cities or towns in Zone 4, where all cores are smaller than the accessibility areas of the railway nodes. However, there are two cores (Maeztu and Kanpezu) that create an internal structuration of their surrounding areas. Their influence areas coincide with the influence areas of Vitoria-Gasteiz and Lizarra, so two strategic points between zones are created: Erentxun and Antzin. Erentxun can be also defined as a strategic point between the DRS and the external transport systems, and hence, it can be also defined as a future strategic area at territorial scale. There are disused heritage elements as well as tourism and leisure facilities in the surrounding area of Antzin. Furthermore, at both strategic points, the disused infrastructure has been converted into a greenway and the former railway node areas are strategic rural towns, where there are strong morphological features and certain rural activities, but few urban activities or heritage and elements of interest.

Moreover, nine types of node areas or development typologies, ranging from cities to non-developed areas, have been identified along the linear infrastructure by means of analysis of the relations between nodes and the territory (fig 6). The different typologies of node areas are not regularly distributed along the line, since groups that have more urban features are mainly located in the north, while groups with predominantly rural and natural characteristic are located in the south.

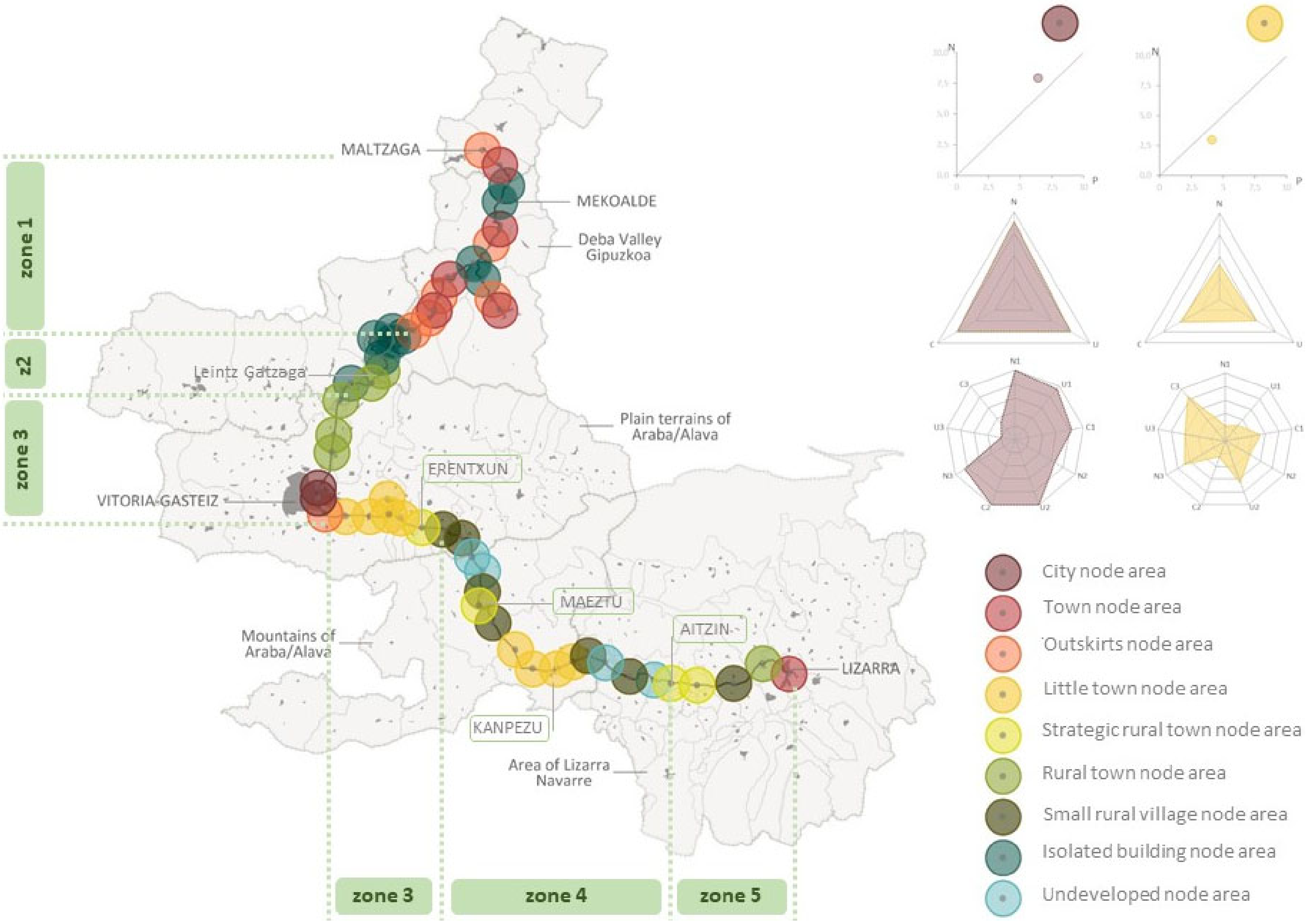


Figure 6. Territorial zones (green bars) and development typologies (coloured circles) of the Vasco-Navarro Railway (left) and transport and land use models of Vitoria-Gasteiz and Kanpezu node areas (right).

Taking into consideration the CAM's four areas of analysis, the northern area of the railway that corresponds to Zone 1 is represented in fig. 7. This section includes larger towns in Gipuzkoa, where only few railway heritage elements or buildings are preserved. Although the linear infrastructure has been converted into a cycling lane in several sections, the original route has not been always used and there are gaps at beginning and the end of this area. According to the accessibility analysis at interurban scale (AL2), walking accessibility is limited to main cores and their surrounding nodes, although a section of three cores (Arrasate-Aretxabeleta-Eskoriatza) is identified in the South of the area. Obviously, larger areas are accessible by running and cycling: two cores are included in the Northern area, while three or even four cores are part of the accessible areas in the South. Consequently, in addition to the walking trips within cores and their surrounding areas, running and cycling trips between different urban cores can be included in the infrastructure. Taking into consideration the urban and also industrial character of the whole area, these trips should be mainly related to daily activities. Furthermore, different types of node areas have been identified in the area. Town node areas refer to the main towns where sustainable transport systems should be promoted, while Outskirt node areas mainly refer to industrial areas where in addition to sustainable transport, elements of interest or rural activities should be included in order to balance transports and land uses. Finally, Undeveloped node areas comprise monofunctional and non-developed areas, in which connection to major cores becomes crucial.

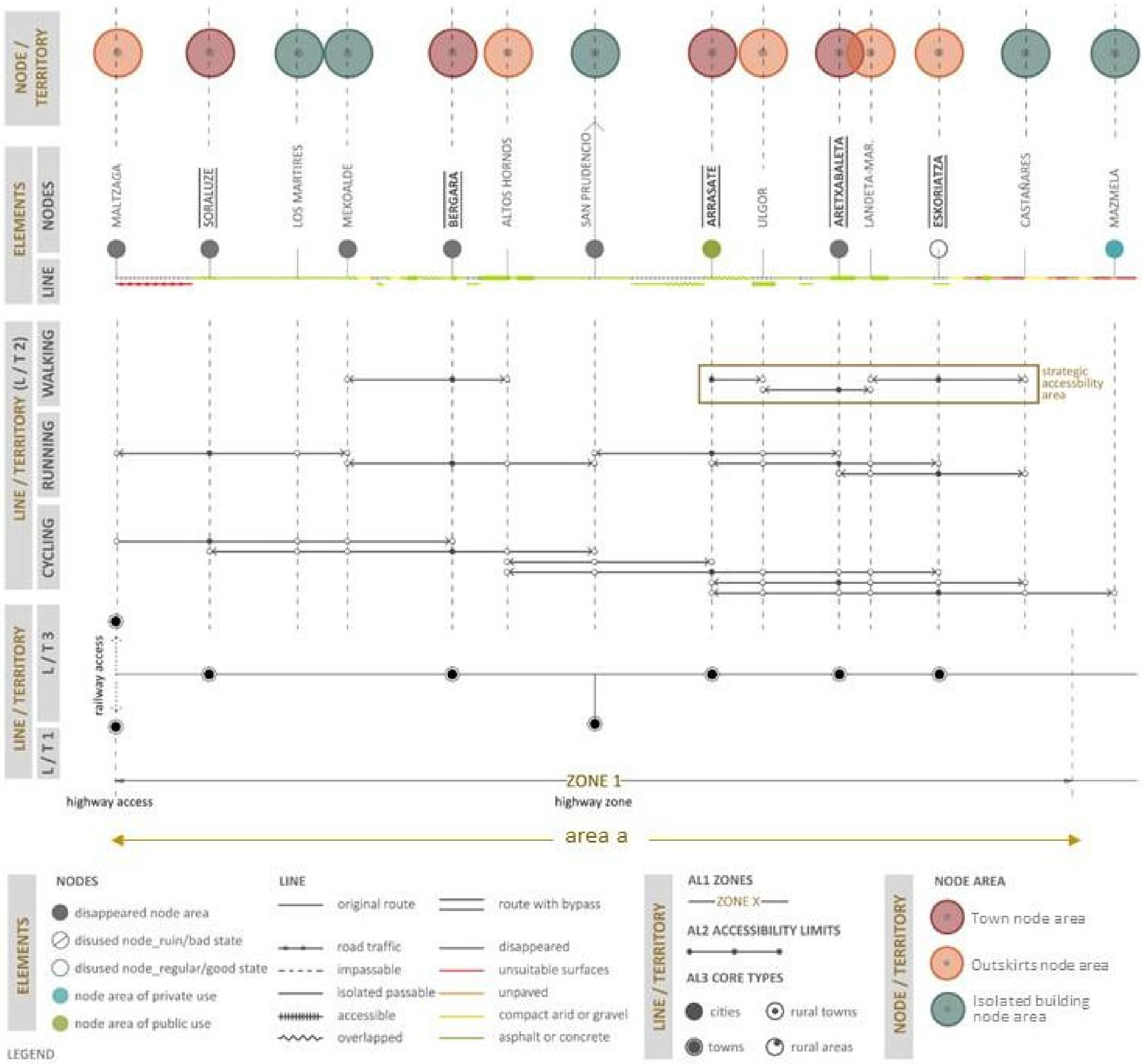


Figure 7. Graphical representation of the results of a CAM applied to the Vasco-Navarro Railway. This depicts to Northern area of the railway, Zone 1.

Moreover, the identification of smaller areas (a-j), that can follow similar guidelines and connect territorial zones, is possible in order to ensure the proper functioning of the territorial axis as a whole (table 1 and fig. 8). Zone 1 is the only zone that has not been divided into different areas, since its characteristics are quite homogenous throughout.

Table. 1 Strategy areas of the Vasco-Navarro Railway

Area a	Zone 1 including major towns.
Area b	Zone 2, beginning at the start of the zone 2 and ending at Leintz-Gatzaga.
Area c	The disused railway section from Leintz-Gatzaga to the entrance to Vitoria-Gasteiz. This point also coincides with the beginning of the Vasco-Navarro Railway Greenway.
Area d	The city of Vitoria-Gasteiz, whose urban expansion covers practically the whole area.
Area e	The disused railway section from Vitoria-Gasteiz to Uribarri-Jauregi, including the branch to the sanctuary of Estibaliz.
Area f	The Laminoria tunnel and surrounding areas from Uribarri-Jauregi to Zekuiano.
Area g	The main cores of Zone 4 (mountain area of Araba/Álava) and the connection to Navarre.
Area h	The zone of Arquijas, where the tunnel is located.
Area i	Zone 4 and almost all of Zone 5.

Area j	The municipality of Lizarra and the end of the greenway, which connects with the street network in the urban area.

As a final point, in addition to the territorial zones and smaller areas, two strategic accessibility areas or comprehensive functionality areas have been identified at interurban scale: Arrasate-Aretxabaleta-Eskoriatza (fig. 7 and fig. 8) and Antzin-Murieta (fig. 8). Although they do not affect the general functionality of the DRS, they include urban and rural cores that are locally important and accessibility between them is essential for all kinds of non-motorised transport modes. For this reason, strategies and guidelines developed with respect to development proposals will need to understand them as a single unit that encompasses an entire strategic area. In the first case, the mixture of uses facilitates the use of the non-motorised infrastructure for daily trips between the towns and their surrounding areas and for walking long stay or cycling trips between the towns. Furthermore, the preservation and use of the nodes located in the periphery of the areas of the areas (Arrasate and Eskoriatza) could promote the use of the areas as a whole.

In summary, although specific strategies must be applied to each zone and area, all of these must follow the same approach in order to ensure the cohesion of the system. A common general need relevant to all areas has been identified: the need for sustainable transport infrastructures. Disused railway lines are the most suitable infrastructure for the creation of non-motorised axes. Furthermore, the railway nodes and buildings located along the infrastructure should be related to the non-motorised axis in one way or another. These can enable the potential offered by the linear infrastructure to be realised. To this end, activities and features that refer to each specific node area must be taken into consideration when seeking a balance between transports and land uses in the area. However, consideration of surrounding areas is essential, since it will avoid the decomposition of the system.

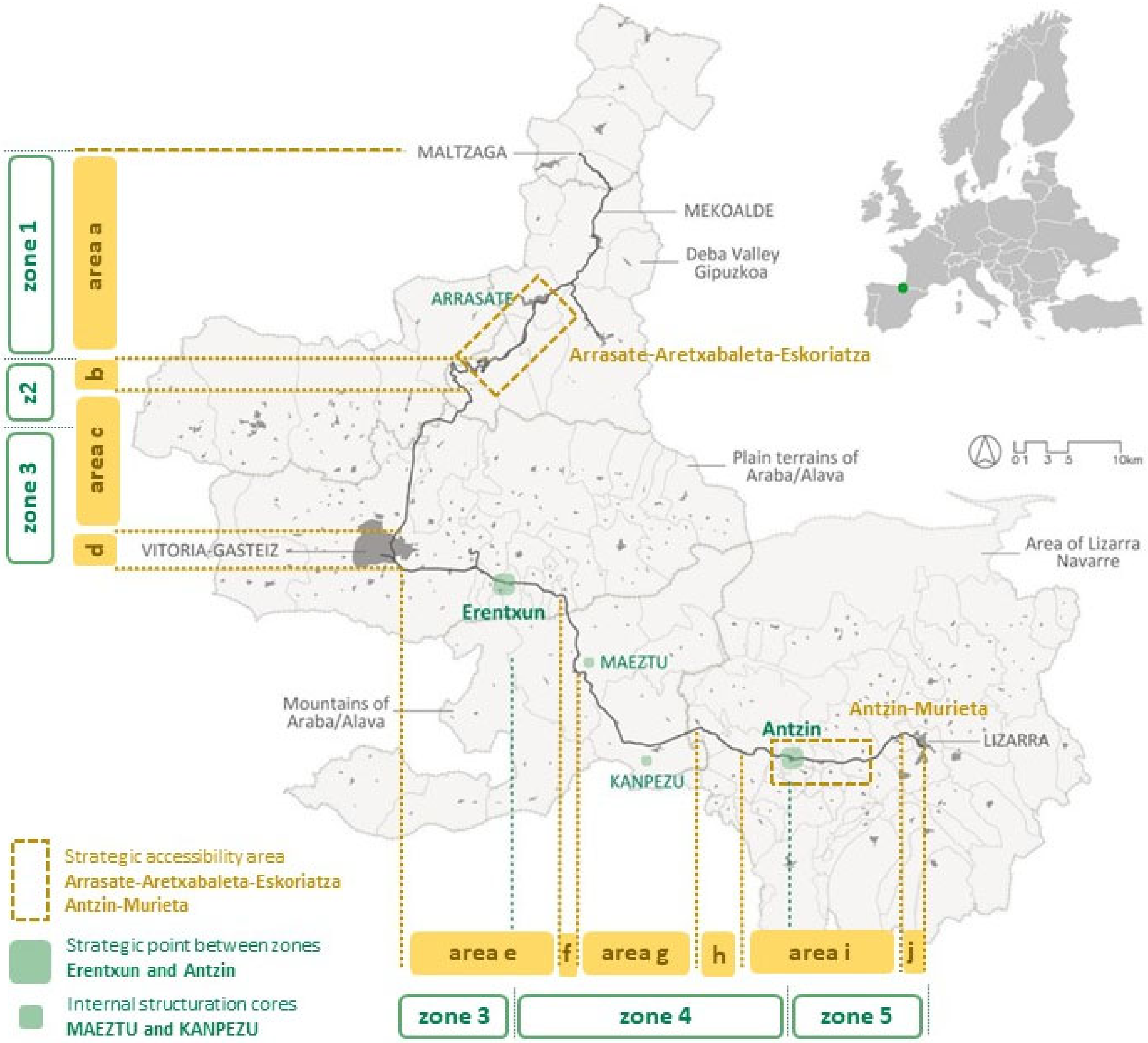


Figure 8. Territorial zones (green bars), strategy areas (yellow bars), strategic accessibility areas and strategic points between zones of the Vasco-Navarro Railway.

5. Conclusions

This paper presents a Comprehensive Analysis Method (CAM) for the analysis of Disused Railway Systems (DRS). Three theoretical and methodological conceptions are assumed. One refers to the composition of the subject of study (disused railways as heritage systems), while the other two denote future approaches to DRSs (former linear infrastructures as non-motorised axes; and balance between transports and land uses around former railway nodes). Accordingly, different areas of analysis and methods are used for the definition of the CAM. Each approach provides results for different railway elements and associated relationships, but also contributes to an overall analysis. The results assess the potential of a DRS as a territorial structuring system (a non-motorised transport axis with balanced node areas), including both the potential of the linear infrastructure and the potential of the nodes, in order to address new uses beyond the current greenways while also promoting the preservation of the railway heritage. In this regard, general strategies or guidelines and specific action points are defined for reconversion projects.

The CAM is structured in accordance with the different areas of analysis that address different railway elements and their corresponding relations, where the methodological processes are defined taking into consideration the models proposed. The connections between different areas of analysis are defined in order to complement specific aspects of other areas of analysis and more fully elaborate the potential of the railway elements and, hence, the potential of the whole system. The prioritization of different elements is also possible using the CAM.

The CAM is applicable to disused railways located in diverse territories, including where urban and rural cores are minimally spaced and do not form part of a metropolitan area. The analytical method could be applied to other territorial systems, composed of a linear infrastructure (or even a network infrastructure) with several nodes distributed throughout it.

In this case, the CAM has been applied to a specific DRS (the Vasco-Navarro Railway) and a graphic representation of the general results has been created. In addition to the five territorial zones defined, smaller areas, where similar guidelines can be implemented, have been identified and, accordingly, the disused railway has been divided into ten areas. The proposed strategies of the different areas mainly focus on the promotion of sustainable transport modes, especially non-motorised transport. However, in addition to the preservation of the heritage for its own sake, the restoration and rehabilitation of former railway nodes is also essential to strengthen local usage at specific points along the linear infrastructure and the development of new activities in the area. Several strategic areas and points related to specific approaches have been also identified. In this regard, two points are identified as key for the connection between different territorial zones, while another two have been defined as strategic accessibility areas. Finally, the lack of external connections should be also taken into consideration for the reconversion of the Vasco-Navarro DRS.

The case study makes it possible to validate the proposed method. Accordingly, non-motorised accessibility with a multilevel approach is proposed to determine the potential of a linear infrastructure located in a diverse territory, in addition to determine the current state of the infrastructure itself. Studies related to sustainable transports, such as non-motorised transports, have increased in recent years and multilevel analyses of infrastructures have been also proposed in literature. However, a combination of both has been necessary for the purpose of this study, focusing on non-motorised accessibility but taking into account the different levels in which a disused railway could operate. For that aim, different accessibility measures have been used and existing potential measures have been adapted to linear infrastructures. Additionally, characterisation of node areas and assessment of balance between transport and land uses is proposed to determine the potential of the different nodes, in addition to the current state of those nodes. Previous models are not able to represent the varied reality in territories, since they are mainly focused on urban areas. In this study previous models have been adapted including indicators referred to rural areas and a specific multiaxial model has been created.

At the same time, the case study has highlighted the limitations the CAM may have. On the one hand, the multilevel accessibility method does not mix transport and land use components. That is why the study of future possible new nodes related to the strategic accessibility points or areas obtained from these analyses is proposed in addition to the study of former railway nodes when assessing the potential of the node areas. On the other hand, proposed transport and land use models show difficulties regarding the availability of data, mismatches between different information sources or data processing. As a final recommendation, although the sensitivity analysis is used in this research, multiple decision makers may be also included in the initial judgment of the variables in order to avoid an individual evaluation.

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