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An Integrated Approach to Transportation and Land-Use Planning for the Analysis of Former Railway Nodes in Sustainable Transport Development: The Case of the Vasco-Navarro Railway

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Abstract: The disappearance of kilometers of railways that once structured their surrounding territory has become an alarming issue in the last decades. These days, several disused railway infrastructures have been converted into non-motorized transport infrastructures. Meanwhile, most of the railway nodes have been abandoned or reused without consideration of the linear infrastructure. This paper argues that former railway nodes can have potential in their surrounding environment and as part of a non-motorized transport axis, i.e., to again be nodes of the former linear infrastructure. Accordingly, the objective of the paper is to analyze the potential of disused railway nodes, focusing on the possibilities they could offer in the area, and defining future approaches for more sustainable development. For that purpose, relations between former railway nodes and their surrounding environment are studied considering transport and land use in the non-motorized influence areas. Existing node/place models were adapted and a multiaxial model was created to measure the balance between transport and land use and typify the defined area. The proposed methodology was applied in a case study, classifying node areas in different development typologies that will be related to different future approaches.

Keywords: sustainable development; transport and land use; multiaxial models; non-motorized transport; disused railway lines; former railway nodes

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1. Introduction

The disappearance of many kilometers of railway lines has become an alarming issue in the last decades. These transport infrastructures once served to structure their surrounding territory. The system, formed by a linear element (the railway) and the functional nodes created around it (stations), made a model of suburban mobility possible and wove a network of movement and activity that connected urban centers with the rest of the territory.

From this point of view, railway stations are understood as node/place geographic entities comprising two partly contradictory natures [1,2]. One the one hand, they work as nodes. They are access points of a network and their role is to connect people with destinations. They are therefore part of the rail mobility infrastructure. On the other hand, they are places of activity. They are part of a segment of the city that consists of infrastructures, buildings, or open areas, and become destinations themselves [3,4]. Accordingly, the analysis of each station area in relation to its surrounding territory should consider both node and place approaches, as has been widely done in the literature [5–7].

In the case of disused railway lines, former railway stations are neither nodes nor places. However, they have the potential and infrastructure to become both. This would require recovering the functional use of these systems as local transport infrastructures.

The characteristics of existing roads (gentle slopes and track width), as well as the appearance of new electric mobility systems (e.g., scooters and electric bicycles), give these routes great potential to become axes of territorial mobility once again. Recovering the operability of these routes would constitute a basis for creating a sustainable and healthy mobility system on a regional scale. It would offer a green and safe infrastructure based on non-motorized systems for daily trips [8]. This strategy would have a particular impact on regional polynuclear systems, with large volumes of daily trips between nearby urban areas, as is the case in several European countries.

In addition, the former railway nodes could also have potential to improve their surrounding environment. Recovering disused infrastructure as an axis for non-motorized transport would revitalize the stations as nodes of connection and activity [9]. This could have multiple positive consequences in the territory. The availability of activities within acceptable distances of non-motorized travel could potentially affect the travel behavior of pedestrians and cyclists [10], integrating these areas with the transportation infrastructure. Furthermore, it would improve the connection to equipment and facilities, as well as the accessibility and attractiveness of the nodes, which can be essential to promote regeneration and integration processes in degraded urban areas.

In this context, it is important to analyze a disused railway as a complex territorial system and not as a simple linear structure. Both component elements and relations created within the territory should be studied [11], with the potential of nodes in their surrounding environment as one of the main issues to consider in order to define the future approach for disused railway lines.

In this regard, the objective of the paper is to analyze the potential of disused railway nodes, focusing on the possibilities that they could offer in the area and defining future approaches for more sustainable development. Accordingly, transport and land use features in the non-motorized influence areas of nodes were measured in order to achieve the goal set. The interest of this paper lies in the use of complementary models with an integrated approach to transportation and land-use planning to understand the potential of these nodes in their surrounding environment, especially when it comes to territories and landscapes of varied nature, including both urban and rural areas.

The paper is structured in five main sections. First, the scientific references on which the research is based are presented in two subsections: the first examines the interaction between land use and transport in the achievement of sustainable development objectives and the potential of disused railways in this respect, and the second looks at the models for analyzing the abandoned railway areas in the topic of concern. Subsequently, the methods generated to carry out the phases of the research are described. The proposed methodology was applied to a specific case study, the Vasco-Navarro Railway in Northern Spain. The next section contains the results of the study, subdivided into the same phases as those presented in the methodology. Finally, a discussion of the results and the most relevant conclusions reached are briefly presented.

2. Literature Review

2.1. Potential of Disused Railways for Sustainable Land Use and Transport Development

More sustainable urban growth involves more sustainable transport modes, such as public and non-motorized transport [12], but it also involves a more sustainable structuring of land use [13]. In this regard, the two-way interaction between transport and urban spatial development has been highlighted in many works [14–16]. Thus, the idea of a land-use transport feedback cycle was created. Accordingly, the allocation of activities defined by the land-use pattern creates a new transport demand, and consequently a need for transport services. New infrastructures and the resulting increase in accessibility, in turn, determine land-use patterns and start the cycle again. It continues until a balance is reached or some external factor intervenes [17]. Hansen claimed that locations with good accessibility had a higher chance of development and at higher density [18]. Digil et al.'s research based on experiences from 151 existing cities [19] demonstrated that this relationship depends on the characteristics of the urban context and the infrastructure being promoted. While the expansion of road networks and highways has led to lower population density in Chinese and American cities [20,21], other studies have shown that expanding the railway network increases the population density in the areas around the stations or tracks [22–24]. In any case, the interaction between land use and transport is clear (land use determines traffic flows and transport infrastructure changes land-use patterns) [25], and it is necessary to analyze them together in order to achieve effective sustainable development policies.

In this framework, since the late 19th century, several proposals were presented as optimal solutions for land use and transport problems that differed according to density, spatial structure, land-use distribution, or transport modes [25]. Since the late 20th century, however, the debate between the compact city and dispersed development has gained relevance. According to the European Commission [26], the compact city may represent the most efficient land-use transport system. Nevertheless, diverse development proposals have been made due to continuous decentralization processes that move populations and industries to peripheral areas, the tertiarization of city centers, highway constructions, etc. [27]. In this regard, halfway between compact cities and dispersed development, the idea of land-use transport systems based on polycentric or decentralized concentration emerged, promoting densification of some suburban or highly accessible territorial areas.

As an example of decentralized concentration, the concept of transit-oriented development (TOD) was originated by Peter Calthorpe in his book "The Next American Metropolis: Ecology, Community, and the American Dream" [28], but this type of development has been frequently suggested in the literature [3,29–33]. Currently, TOD policies have been implemented in several cities and metropolitan areas all over the world, and the concept can be understood as "a mix of moderately dense and pedestrian-friendly development around transit stations" [34]. In general terms, TOD is an integrated approach to transportation and land-use planning [35]. In this regard, TOD is presented in terms of dual elements [3,4], where public transport stations are intended to connect people with other destinations as nodes, while the areas become destinations themselves as places where activities occur. Hence, a node/place model was presented by Bertolini [3], in which ideal scenarios are linked to the balance between the two approaches.

In this context, disused railway lines and their stations could have an important role in the mentioned balance in order to achieve more sustainable development. At the same time, the linear infrastructure could be part of the current transport network, creating a secondary non-motorized network that can structure the territory at a local or territorial level but is out of reach of large infrastructures of a regional or global nature [11]. On the other hand, each former railway station or area could be part of the new network and an activity destination itself [36]. As a result, disused railway systems should be analyzed in a similar way to TOD.

2.2. Models for Analyzing Abandoned Railway Areas

The node/place [3] and similar models are considered below to create a methodology for the analysis of disused railway nodes. The main difference between them lies in the number of variables considered and diagrams created, where the number of axes is related to the number of variables.

The node/place model by Bertolini (operationalized by Zweedijk [37] and Serlie [38]) focuses on station areas and is based on the transport land use feedback cycle. Accordingly, it is based on the definitions of the elements and their combination, which are represented in a biaxial diagram. The node element is located on the y-axis and refers to accessibility or the "potential for physical human interaction". The place value is represented on the x-axis and corresponds to the amount and variety of activities that take place in the area, or the "degree of actual realization of the potential for physical human interaction". The two parts are based on the idea that the more people who can get to the area or the more activities that can happen there, the more interaction can occur [3]. In this regard, four ideal situations, represented as particular relative positions on the node/place diagram, are distinguished in the model [3,6]: accessible or balanced areas where the railway stations are located along the middle diagonal line (node and place values are equally strong); stressed areas where the maximum or fullest node and place values are included; dependent areas where low node and place values are included and stations are located at the bottom part of the middle line of the diagram; and unbalanced areas, which include station areas that have a considerably stronger relative position in either the node or place value (unsustainable nodes or places). According to the model, unbalanced locations have the highest development potential, so they are the most interesting ones [6]. Hence, the balance between node and place provides one of the conditions to assess sustainability regarding land use and infrastructure [5].

In addition to the node/place model, Joan Moreno Sanz used a three-axis model to analyze important railway stations that were also related to main road infrastructures, which he called "urban corners". In this case, the potential of these areas as territorial centers depends on the balance between the concentration of flow (nodus), human activity (civitas), and the urban morphology that promotes interaction (urbs). Thus, the place approach of Bertolini is divided into two variables, civitas and urbs, while the node approach is maintained. Using these three variables, the NCU model is created, which is represented in a triaxial diagram. Each variable (nodus, civitas, and urbs) is located on one of the axes (N, C, and U), and quantitative (traffic intensity, activity density, and urban compactness) and qualitative (diversity of means of transportation, mixture of uses, and quality of life) measures are equally distributed [39].

Derived from the node/place model, a circular model with four axes was also proposed for the City Line (Stedenbaan) in The Netherlands [40,41]. Accordingly, the relations of the railway stations were analyzed considering both spatial and network conditions. For this purpose, four indicators corresponding to the four axes of the diagram were used: degree of access by public transport, degree of access by car, degree of mixed use, and local density of inhabitants and jobs. The resulting polygons of the diagram were classified in nine potential developments, where the potential of stations, considering their node and place value, are represented and the features that must be changed to facilitate a particular development are illustrated [41]. Although this model is based on Bertolini's model, each variable is located on two axes, which is the main difference from previous diagrams. This change could turn out to be interesting for the application of the model in varied territories, where urban and rural areas are included. Accordingly, multiaxial diagrams are of interest because they can represent several variables in the same image, hence the representation of data related to urban and rural areas regarding the node and place approaches is possible. In this regard, Poiraud et al. [42] analyzed geosites using a multiaxial diagram, which was used to assess all necessary criteria to create an inventory of different geosites. Nine criteria were distinguished and grouped into three variables [42]. Each criterion was scored and represented on one of the axes of the diagram, so a nine-axis diagram was used. A multiaxial model of this type can represent several criteria that are related to a few variables. Therefore, the analysis of disused railway lines considering urban and rural features is possible within the framework of a node and place assessment.

Finally, the application of multicriteria decision analysis (MCDA) methods was proposed as decision-support instruments for heritage elements when dealing with multiple variables [43]. In this regard, MCDA helps to classify strategies and facilitates agreement on the implementation of development strategies [44].

3. Definitions of Models and Proposed Methodology

The proposed methodology is structured in several phases, which were briefly presented by Eizaguirre-Iribar and Grijalba [11] as part of a comprehensive analysis of disused railways as territorial structuring elements. Going further, this section focuses on the definition and development of the method and the specific results obtained. In this regard, the methodological proposal, and hence the application of the method, is divided into three steps, defined below. First, former and possible new nodes are identified and their influence areas are delimited. Data collection is carried out for the defined areas. Second, the analysis of each node area is developed based on different models. For this second step, the variables and indicators are defined first, and then multiple criteria decision analysis (MCDA) is used to address the distribution of indicators (weighting) in each model. Finally, the results of the different nodes are compared and clustered in order to identify development typologies, for which principal component analysis (PCA) and k-means clustering are used. The three stages are presented below.

3.1. Definition of Node Influence Areas and Data Collection

Consideration of former and possible new railway nodes is proposed for identification of the nodes and the limits of their influence areas in the territory.

Two approaches are proposed for the identification of possible new nodes: analysis of transports and land use around the disused railway line at territorial level, and analysis of non-motorized accessibility in the areas around it. For the first approach, a 2.5 km buffer around the disused infrastructure is defined and studied considering the different transport systems that operate at the territorial level and the natural or built areas that have the same scale. For the second approach, the accessibility level of each section of the disused infrastructure is assessed. In this regard, some of the sections can have higher accessibility levels than their surrounding segments, so these areas may contain possible future nodes that should be considered. For that purpose, the number of cities or towns from where it is possible to access each section of the infrastructure in a specific time (45 min) is measured, where PgRouting in QGIS (drivingDistance) is used to assess simple network distance measures [8].

Then, the creation of catchment areas related to different non-motorized transport modes is proposed at the urban level, measuring accessibility within 10 min of travel time. Distance accessibility measures (isochrones) are used considering all transport infrastructure and urban networks in addition to the disused railway infrastructure, and network analyses are developed by PgRouting in QGIS (alphashape) [8]. Accordingly, three areas and related transport modes are distinguished in each node (Figure 1): 500 m, walking round-trip; 1000 m, walking non-round-trip, running or cycling round-trip; and 2000 m, cycling non-round-trip. They make it possible to study the different transports and land uses in each influence area or, in other words, that are reached from each node using certain means of transport.

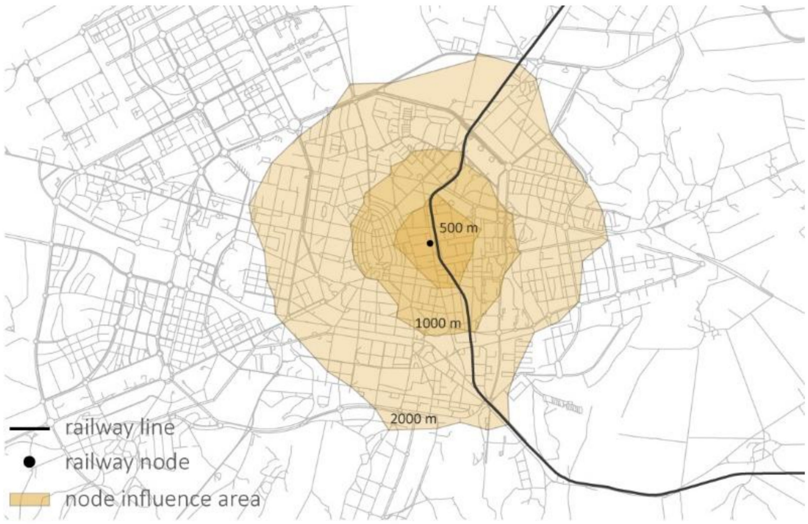
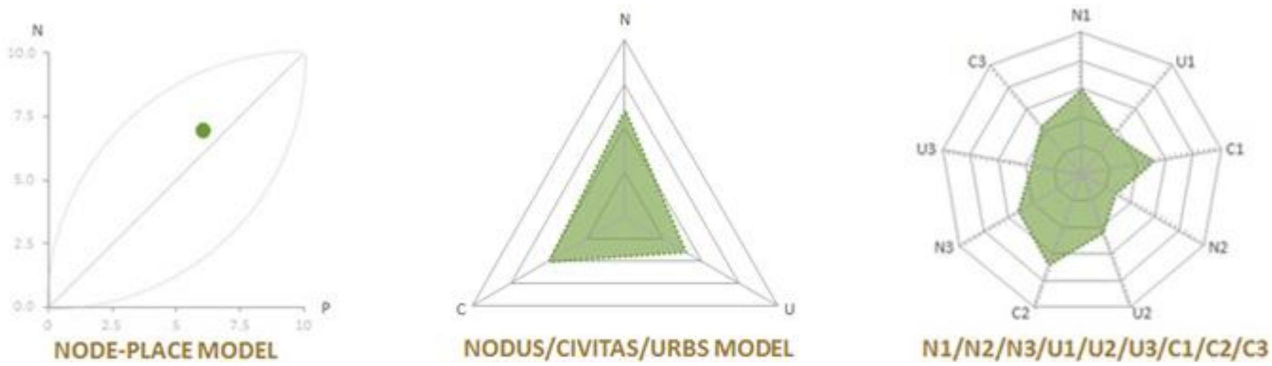


Figure 1. Catchment areas of former railway stations according to non-motorized transport system.

For transport and land use data collection, open source data from spatial data infrastructures and statistical institutes or public data provided by governments are commonly used. However, fieldwork and information from private sources can make it necessary to complete the information. Furthermore, available data sometimes need to be transformed in order to obtain the necessary data and make the information from different sources comparable.

3.2. Analysis of Node Areas Based on Multiaxial Models

The node and place approaches of defined node areas are measured, using the node-place model created by Bertolini. For that purpose, the variables for each approach are defined and a two-axis diagram is created (Figure 2). Transport and land use aspects of each node area are also studied using Moreno's NCU model, which includes the morphological features that promote interaction in the area separately. This approach could prove interesting in cases where disused railways are located in various territories, since the morphological features of node areas can vary significantly. Hence, a triaxial diagram is created, where the first axis refers to the node value (N), the second represents the urbs value (U), and the third corresponds to the civitas value (C) (Figure 2). These models enable determination of the balance between transport and land use, making future management and decision-making easier. However, they are not able to represent the existing reality and characterize different node areas, especially in territories where disused railway lines run through urban and rural areas.



(**a**) (**b**) (**c**)

Figure 2. (**a**) Node/place model, (**b**) nodus/civitas/urbs model, (**c**) multiaxial model.

For that purpose, a multiaxial model is proposed, which represents criteria that are related to a few variables. The previous three main variables (node, urbs, and civitas) are used, but urban and rural criteria are distinguished. Criterion 1 refers to the urban approach of the node area, while criterion 3 corresponds to rural issues. Criterion 2 includes the indicators that can be related to either urban or rural areas. Therefore, a nine-axis diagram is created from the combination of the three main variables and three criteria (Figure 2). Hence, an analysis of disused railway lines considering both urban and rural features is possible within the framework of their node and place assessment. Further, the potential of each defined node area can be assessed by classifying the node areas in different development typologies (see Section 3.3).

The application of the models must include two main steps: defining indicators and distributing or weighting the indicators for each model.

3.2.1. Definition of Indicators

The variables proposed for the analysis correspond to the presented three models, while indicators are defined by considering the criteria of previous authors and both urban and rural approaches of the disused railway system (Table 1).

Table 1. Proposal of variables and indicators for three models.

Variables			Indicator	Definition of Indicator
NODE	NODUS	N_1	N_{11}	No. of rail stops
			N_{12}	No. of rail directions served
			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
		N_2	N_{21}	Distance from the closest motorway access
			N_{22}	Distance from the closest secondary road
			N_{23}	Parking capacity
		N_3	N_{31}	Cycling path length
			N_{32}	Pilgrimage routes in the area
			N_{33}	Long distance routes (GR) in the area
PLACE	URBS	U_1	U_{11}	Distance to the town center
			U_{12}	Housing density
			U_{13}	Urban land-uses
		U_2	U_{21}	No. of residents in the area
		U_3	U_{31}	Forest cover
			U_{32}	Agricultural land-uses
	CIVITAS	C_1	C_{11}	No. of workers in industry
			C_{12}	No. of workers in services
			C_{13}	No. of students in education
			C_{14}	Open areas
			C_{15}	Degree of multifunctionality
		C_2	C_{21}	Elements of interest
			C_{22}	Heritage elements
		C_3	C_{31}	Protected natural areas
			C_{32}	Linking corridors
			C_{33}	Agricultural land
			C_{34}	Degree of multifunctionality

In the node approach, three variables are distinguished according to the type of transport: motorized public transport (N1), motorized private transport (N2), and non-motorized transport (N3). The first one measures the accessibility of different types of public transport by considering the number of stops and directions served. The second is related to private car accessibility, which is calculated by the distance to the closest main road access and the number of parking lots of the main parking areas in the defined node area. The inverses of the distances are used to assign higher values to the closest elements. Finally, non-motorized transport infrastructures are studied in the third variable, measuring the length of cycling lanes and greenways and the number of territorial walking routes in the area, such as pilgrimage and long-distance routes.

The place approach comprises indicators related to the morphological features of the area (urbs) and the activities that can take place there (civitas). The urbs approach considers the percentage of a specific type of land use in the area and the density of the main elements located there. Accordingly, agricultural land use and forest density are considered for the rural variable (U3), while urban land use and housing density are measured for the urban variable (U1). The latter also includes the inverse value of the distance from the node to the town center. Conversely, the number of residents of the defined node area is considered for the general approach of morphological issues (U2).

Lastly, different activities located in the area and their mixture are considered in both urban and rural areas. The number of workers or students of the companies or education centers in the area and the surface of open areas that can support different activities are considered in the urban variable (C1). Meanwhile, the areas that can support tourism, leisure, or agricultural activities are considered in the rural variable (C3). Furthermore, the degrees of multifunctionality are assessed in different ways in those two approaches. In urban areas, the Herfindahl–Hirschman index (HHI) is used (Equation (1)):

$$\mathrm{HHI} = \sum_{j=1}^{n} P_j^2, \quad (1)$$

where P_j is the percentage of land use type j in the area and n is the number of land use types j. If there is only one type of land use, HHI equals 1, and if all types appear equally, HHI equals 1/n. Hence, higher values of HHI are related to less multifunctionality or land use mixture. Unlike the formula used in the previous node/place models, this integral estimation measure does not result in invalid parameter values when one of the activities is missing. On the other hand, a simple classification was created in rural areas: if none or only one of the three parameters exists, the degree of multifunctionality is considered 0; if two exist, 0.5; and if all of them exist, 1. In the case of agricultural land surface, values >20% are considered for the existence of this parameter. Finally, the general approach of civitas (C2) comprises the number of heritage constructions with regional protection and other elements of interest sited in the defined node area.

3.2.2. Weighting of Indicators: Multiple Criteria Decision Analysis

The complex problem is structured using the same variables and indicators in the three models (Figure 3), and multicriteria decision analysis (MCDA) is used to address the problem. Firstly, all of the criteria are structured and weighted using the analytic hierarchy process (AHP). Once this is done, scores of each variable are measured for each model and the first results are obtained. Finally, sensitivity analysis is used to determine the variability of the parameters and assess the suitability of previously established weights. If they are suitable, the final results are obtained and the diagrams related to each model are created; if not, the AHP is reviewed and edited.

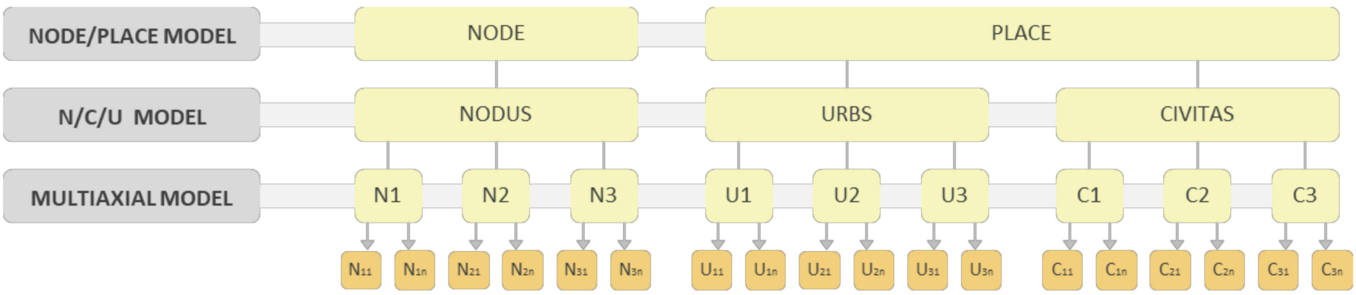


Figure 3. Structure of three models (variables in yellow and indicators in orange).

The AHP, originally developed by Saaty [45], was selected as the multicriteria decision analysis method. Hence, the problem is decomposed and structured in several criteria and sub-criteria to define the weights of each criterion. A single decision maker with knowledge of the case study was used for an initial judgment. In this regard, indicators for each variable are weighted to represent their relative importance, but variables are not weighted to make the three models comparable. The alteration of variables will also change the weights of the indicators in the models, and this will make them non-comparable with each other. Firstly, their relative importance is evaluated by means of a pairwise comparison for each of the nine variables and priorities between them are established. Then, the comparison matrix is normalized and average weights are obtained. To conclude, a consistency analysis is used to check whether the initial rating is consistent. For that purpose, the consistency index (CI), which reflects the consistency of judgment, was calculated using the equation proposed by Saaty (Equation (2)) [45]:

$$\mathrm{CI} = (\lambda\mathrm{max} - n)/(n - 1), \quad (2)$$

where λmax is the largest eigenvalue and n is the order of the matrix. Afterward, the consistency ratio (CR) is measured by dividing the consistency index by the random index (RI). The RI refers to the consistency index of a randomly generated pairwise comparison matrix, which was calculated by Saaty using large samples of random matrices of increasing order. He suggested that if CR exceeds 0.1, the initial judgment might be inconsistent; if CR equals 0, the initial rating is consistent.

Values referring to each indicator of each defined node area are measured after the available data are compiled, which were mainly processed using geoprocessing tools in QGIS to obtain the necessary data. However, data obtained for each station area and indicator could be different and not so comparable, so total values are rescaled to obtain scores between 0 and 1 (node areas with the highest values in each indicator are assigned 1, and the ones with lowest values 0). Furthermore, some of the indicators were previously log-transformed with the aim of reducing the disparity in their original values, as in previous studies [5,6]. Then, the previous weights were used to obtain the results for each variable and model. The three diagrams were created to show the potential of defined node areas and their level of balance between variables.

To sum up, the variability of weights should be determined and their suitability should be assessed, since a single decision-maker is used for their initial evaluation. A sensitivity analysis is proposed for that target, where the influence of each weight on the output model is evaluated. Using a total weight of 10 for each variable, indicators are distributed using integer values. For each possible combination of indicators, results for all defined node areas are obtained and the percentage of improvement in general results is assessed. In addition, some extra conditions are established in order to not give too much importance to some of the indicators and to follow some logical criteria, such as establishing maximum or minimum weights or equality between the weights of some indicators.

3.3. Comparison and Classification of Node Areas

Once the models for each node area are created, the node areas are compared in a single diagram based on the node/place model. However, this stage does not contribute any further information to the NCU and multiaxial models, so the node areas should be compared by zones or groups of nodes. In this regard, the first two models provide suitable information for general comprehension of the node areas. Meanwhile, the third model provides a suitable characterization of each node and zone. However, the use of several variables makes the comparison between them difficult. Accordingly, a statistical analysis based on principal component analysis (PCA) and k-means clustering is proposed to overcome this shortcoming and to compare and classify the node areas.

PCA can be useful to reduce the number of variables and find a suitable correlation between them, hence simplifying the comparison of the multiaxial model before applying k-means clustering for classification or grouping of node areas. Accordingly, as a first step, PCA is used to identify new components that combine different variables. The data are projected on the new components, making the comparison easier. The creation of two components, for example, would allow a comparison of all node areas in a single diagram, as with the node/place model. PCA is parameterized using Pearson correlation with a significance level at 95% applied at the initial matrix. As part of this analysis, principal components, their coordinates, and the contribution of each variable to them are calculated for each node area. As a second step, defined node areas are grouped using k-means clustering, where each node area belongs to the group with the nearest mean. Hence, each cluster or group has similar features regarding the variables considered. The k-mean classification is employed with 500 iterations and a convergence value of 0.00001. It should be added that k-means clustering is carried out with the coordinates of both the initial nine variables and the component axes obtained from PCA.

By means of the clustering, different node areas are compared, and the resulting polygons of the diagrams are classified in different development typologies. This enables illustration of the features that must be changed to promote a particular development and to represent the potential of each defined node area considering their node and place value [42] as nodes along a territorial active transport system. Accordingly, former railway nodes and their influence areas should be considered as strategic connecting poles in the context of regional planning, as the railway node areas were previously.

4. Application of the Method on a Case Study

The proposed methodology was applied to the Vasco-Navarro Railway, one of the main disused railway lines of the Basque Country and Navarre (Northern Spain) that went from Mekoalde (Gipuzkoa) through Vitoria-Gasteiz (Araba/Álava) to Lizarra (Navarre). Although its first section was opened in 1887, the entire route was not completed until 1927, and the whole line was closed in 1967. Part of the Maltzaga-Zumarraga railway (a smaller railway connected to the previous one) was also considered, together covering three provinces and 145 km and creating the connection to the current railway and motorway axis. In this regard, the analysis of each station area of the disused infrastructure in relation to its surrounding territory was developed considering transport and land use. The infrastructure goes through a diverse territory composed of narrow valleys and mid-sized towns in the north, and mainly plain terrain and rural areas in the south.

4.1. Definition of Node Influence Areas and Data Collection

Different transport systems and land uses around the disused railway line at territorial level and non-motorized accessibility along the disused infrastructure were considered for the identification of possible new nodes. In the case of the Vasco-Navarro Railway, some infrastructures and activities operate at a territorial level in the delimited buffer, and several sections or points of the linear infrastructure show higher accessibility levels than the surrounding areas. However, most of the identified areas or segments already comprise former railway nodes. Some sections do not have any of them, but even these areas are sited relatively close to certain railway nodes, so the assumption of new possible nodes is unnecessary. Hence, the studied nodes correspond to points or areas of the disused railway where railway buildings were erected, even if they do not currently exist. In other words, they correspond to the 55 nodes that represent the main railway's heritage elements from the disused railway system. For all nodes, three influence or catchment areas were defined using a 10 min accessibility area and considering different transport modes.

Data for the analysis of transport and land use were collected from different sources to define the proposed indicators (Table A1 of Appendix A). The main sources of information were spatial data infrastructures, statistical institutes, and governments. This was supplemented with information gathered from fieldwork and private websites. In several cases, the data had to be transformed to extract relevant data points and achieve comparability as the area included two autonomous communities and three provinces, whereas most of the datasets related to one autonomous community.

4.2. Analysis of Node Areas Based on Multiaxial Models

Information related to transport and land use was visually studied before the proposed models were created. Figure 4 shows graphically three node areas to comprehend their characteristics. The images on the left refer to the main city (Vitoria-Gasteiz), where more infrastructures and activities are located, which correspond mainly to urban indicators. Regarding land use, although it includes the highest service and industry rates, it also includes natural and protected areas at a lower scale. Meanwhile, the central images correspond to one of the northern towns (Bergara), where the motorway and motorized transports are closely related to the area, lowland areas are highly urbanized, and protected natural areas are not located close to the node areas. Finally, a node located in a mountain port (Arlaban) is represented on the right. It is only related to a secondary road, but several walking routes are placed in the area. Likewise, there are almost no urban activities in the area, but there are protected natural elements of certain importance. At first glance, the results can vary considerably from one node area to another, since the former railway nodes are located in diverse territories. At a second glance, however, urban and rural approaches can complement each other, obtaining similar results in a node/place or nodus/urbs/civitas model in some of the cases. Hence, the use of the third model in the analysis (multiaxial model) allows us to define the urban or rural characteristics of the area and to measure the balance between different factors (node/place and nodus/urbs/civitas) by means of the previous two models.

Figure 4. Transport and land use approach of three defined node areas: Vitoria-Gasteiz (**left**), Bergara (**middle**), and Arlaban (**right**).

Accordingly, in line with the proposed methodology, as the first step, total values regarding the defined node areas were measured for each indicator using the collected data. In this regard, although most of the values correspond to collected raw data, some are percentages of data or are grouped to obtain comparable results. Then, those total values were rescaled between 0 and 1, using log-transformation to reduce the disparity of some indicators (the number of parking lots, inhabitants, workers, and students). Once the rescaled values of each node area were obtained, MCDA was developed following the three steps outlined in the proposed methodology: definition of weights, multicriteria analysis, and sensitivity analysis.

Indicators were weighted to represent their relative importance using AHP (initial weights in Table 2). In the node approach, transport by bus, proximity to motorway access or parking areas, and singular walking routes were considered to be more important for each of the variables in the case of the Vasco-Navarro Railway. Meanwhile, urban land use was not initially considered as important as other indicators regarding the morphology of the area, and the multifunctionality level was defined as an essential indicator in the civitas variable. The rescaled values of the defined node areas for each indicator were weighted and the results (between 0 and 10) were obtained for each of the presented models. The values of the three areas were scaled all together in order to compare them, which means that for 500 and 1000 m areas, the highest indicator values do not correspond to a score of 1. Although it is possible to create the three diagrams related to the three models and rank the node areas at this phase, a sensitivity analysis was carried out to confirm the suitability of the initial judgment. Sensitivity analysis of all indicators was performed considering the nine multiaxial variables. Accordingly, the combinations of weights initially presented for variables N2, N3, and U1 were changed in order to obtain better results in most of the defined node areas. The initial combination of N2 was changed to the best combination (+23.5%), while for N3 and U1, the second best combinations were used since they were closer to the initial judgment, and improvement was also obtained. They altered the values from 2.18 to 6.21% and from −0.64 to 22.96%. Using the reformulated weights (final weights in Table 2), the final results for each defined node area were obtained. Although the final results slightly increased in most of the node areas, the highest, lowest, and null values were related to the initial results.

Table 2. Initial and reformulated weights of indicators.

	URBAN						**GENERAL**			**RURAL**			
NODUS	$\mathbf{N_{11}}$	$\mathbf{N_{12}}$	$\mathbf{N_{13}}$	$\mathbf{N_{14}}$	$\mathbf{N_{15}}$	$\mathbf{N_{16}}$	$\mathbf{N_{21}}$	$\mathbf{N_{22}}$	$\mathbf{N_{23}}$	$\mathbf{N_{31}}$	$\mathbf{N_{32}}$	$\mathbf{N_{33}}$	
initial weights	1	1	3	3	1	1	4	2	4	3	4	3	
final weights	1	1	3	3	1	1	3	2	5	3	5	2	
URBS	$\mathbf{U_{11}}$	$\mathbf{U_{12}}$	$\mathbf{U_{13}}$				$\mathbf{U_{21}}$			$\mathbf{U_{31}}$	$\mathbf{U_{32}}$		
initial weights	4	4	2				10			5	5		
final weights	5	2	3				10			5	5		
CIVITAS	$\mathbf{C_{11}}$	$\mathbf{C_{12}}$	$\mathbf{C_{13}}$	$\mathbf{C_{14}}$	$\mathbf{C_{15}}$		$\mathbf{C_{21}}$	$\mathbf{C_{22}}$		$\mathbf{C_{31}}$	$\mathbf{C_{32}}$	$\mathbf{C_{33}}$	$\mathbf{C_{34}}$
initial weights	1.8	1.8	1.8	1.8	3		5	5		3	2	2	3
final weights	1.8	1.8	1.8	1.8	3		5	5		3	2	2	3

In this regard, the final results (Table A2 of Appendix A) show that the Vitoria-Ciudad node area has the highest node and place values, and lowest node values are located in the mountain port between Gipuzkoa and Araba/Álava and the main tunnels of Arquijas and Laminoria. The latter also includes the lowest place values. On the other hand, regarding the multivariable model (nine variables), Vitoria-Ciudad includes the maximum score (10) for three variables (N1, U2, and C2), but the small town areas of Maeztu and Antoñana also show a high score (8.9) in one variable (C3). However, it is more common to find node areas with null values for more than one variable, such as Mazmela, Zarimuz, Marin, Brigada Tunel, Laminoria, Arquijas, and Granada.

As the final step, each node area was featured using the three presented models. The first two models determine the balance between transport and land use, and in this case, although some of the node areas are balanced, many others show very low node values. They generally refer to quite isolated rural areas, even if they comprise some activities or a certain urbanity level. Conversely, the multiaxial model shows the urban or rural character of the analyzed area in addition to its potential, considering more specific criteria. Hence, the understanding of each area becomes easier. Moreover, the characteristics that can be enhanced to achieve the balance between transport and land use or to encourage a particular development are illustrated.

Three node areas (Vitoria-Gasteiz, Bergara, and Arlaban) are presented again as examples (Figure 5) to represent the reality of the Basque-Navarre territory. In the case of Vitoria-Gasteiz, urban and general criteria and the variable related to non-motorized transport (N3) show high scores; however, the variable related to private motorized transport (N2) shows medium scores, since main road infrastructures are located outside of the city. Meanwhile, criteria related to rural morphology and activities (U3 and C3) present lower scores. Similarly, the diagram of Bergara shows urban and general features in the area, while rural characteristics are not included at all. Moreover, results are located close to the dependency area of the diagram in the node/place model, hence the node approach needs to be promoted in order to get more balanced node areas. In this case, it will be necessary to promote non-motorized transport infrastructures (N3). Finally, although all variables have generally low scores in Arlaban, the rural criterion, the population variable (U2), and the private vehicle variable (N2) are highlighted. In this case, results correspond to the dependency area of the node/place diagram. Therefore, to achieve balance in the area, it will be necessary to promote activities or strategies more related to tourism (supporting variable C2) together with variables U1 and C1 of the rural core located in the area, which can be representative of local development as part of regional planning strategies.

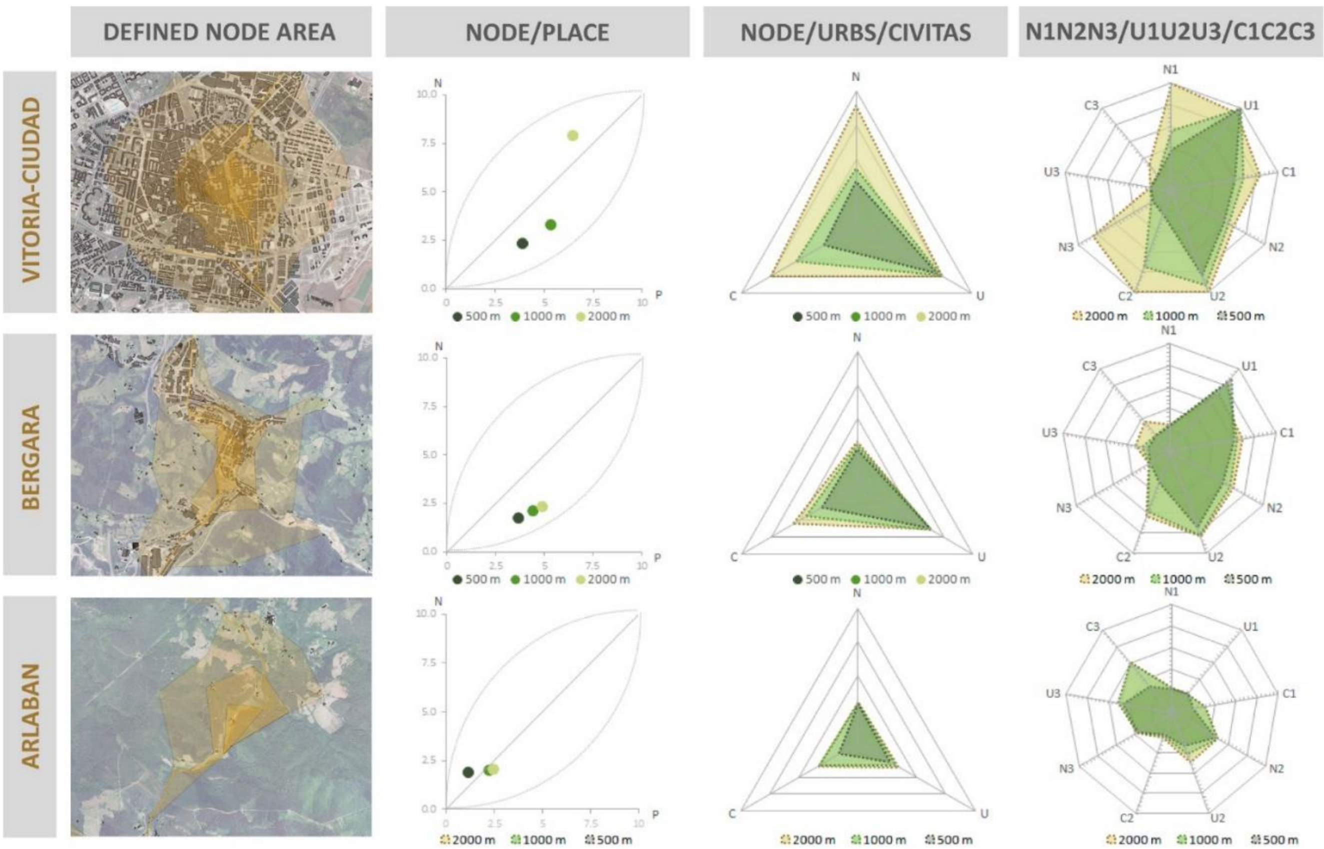


Figure 5. Characterization of three defined node areas according to the three models.

4.3. Comparison and Classification of Node Areas

The results of the defined node areas were compared to study their transport and land use balance, on the one hand, and to distinguish several groups with common characteristics that can represent the existing development typologies, on the other.

All railway station areas are included in three diagrams representing types of catchment areas in order to compare the results of the node/place model (Figure 6). For that purpose, indicators were separately rescaled from 0 to 1 for each diagram, i.e., the three influence areas were separately studied and compared.

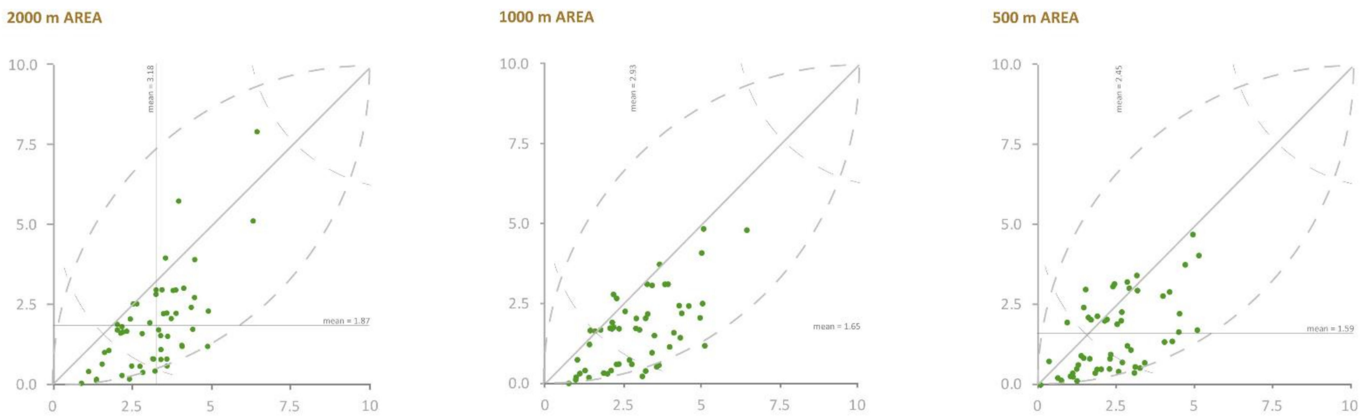


Figure 6. Node/place model of all defined node areas in the 2000, 1000, and 500 m zones.

According to the resulting diagrams, although most of the former railway station areas are in the balanced area (40 in the 2000 m area, 32 in the 1000 m area, and 30 in the 500 m area), values are significantly low. In this regard, no stations are located in the balanced stressed area or the unsustainable node area. In the 2000 m area, Vitoria-Ciudad is the only one that is close to the stressed area, although not in it. In addition, some of the node areas are located quite far from the line of equilibrium in the balanced area. Thus, the node approach should be enhanced in order to obtain more balanced results, since the reduction of the place index could turn them into dependent areas. Moreover, many of the balanced station areas are in the dependent area, where both node and place values are low. In this regard, 10, 17, and 24 stations were respectively classified in the 2000, 1000, and 500 m zones. Conversely, some unsustainable places were identified, the number of which varies with the size of the analyzed area (5 in the 2000 m area, 6 in the 1000 m area, and 1 in the 500 m area). Erentxun is the only station area that remains an unsustainable place in the three diagrams, while Maeztu and Zubielqui maintain cycling and intermediate influence zones but modify the walking zone (balanced area). As a result, the node index mean values are 1.87, 1.65, and 1.59 for the three areas, and the place index mean values are 3.18, 2.93, and 2.45.

The balance between transport and land use was studied and compared using a single diagram in the node/place model. However, a single diagram could not be created in the case of the NCU and multiaxial models. In the NCU model, in addition to the balance between the three variables, the distribution of land use according to the activities and morphology of the area can be distinguished, while in the multiaxial model, urban and rural approaches of each defined node area are represented. Furthermore, the multiaxial model makes it easier to distinguish different groups that have similar features. However, the use of several variables makes it difficult to compare the areas, and a division into zones or groups is necessary. In this regard, PCA was used to check whether components that can represent several variables can be created to overcome this shortcoming.

PCA was applied to the 55 defined node areas of 2000 m. The correlation matrix revealed that all urban and general criteria are intercorrelated and are negatively correlated with the variable referring to rural morphology (U3). On the other hand, the rural activity variable (C3) is negatively correlated with other variables (C1, N2, U2, C2, N3, and U3), while the non-motorized transport variable (N3) is only correlated with the public transport variable (N1). Accordingly, new components that represent the nine previous variables were created with the aim of representing all data in few new components. The first three components account for 84.14% of total variance, with variance up to 7.17%, while eigenvalues fall to less than unity after the first three components. The first component (F1) has a variance of 56.7% and is positively determined by the urban and general criteria (N1, U1, C1, N2, U2, and C2), and negatively determined by the rural morphology variable (U3). On the other hand, component F2 (20.27%) is characterized by non-motorized transport (N3) and rural activities (C3), accounting for 76.97% of total variance. Finally, the third component, F3 (7.17%), shows very low correlation with the variables. In this regard, the first two components can easily represent all of the variables, and a model based on F1 and F2 would correspond to a two-axis diagram representing the urban and general approach of the node areas versus their rural approach. Nevertheless, they are inadequate for interpreting the differences between such diverse nodes, since one of the components would include seven of the nine variables.

Therefore, clustering of the defined node areas for the 2000 m zone was developed based on the multiaxial model and considering its nine variables. A visual grouping based on the resulting polygons of the multiaxial diagrams was developed, using the territorial zones and types of urban areas defined for the Vasco-Navarro Railway (Table A2 of Appendix A) [8] and defining the adequate number of groups or development typologies. In addition, statistical clustering (k-means clustering) was performed to compare them and validate or enhance the first grouping. This second classification or grouping was developed considering the initial nine variables, and different numbers of classes (8, 9, and 10) were used to compare the resulting groups with the previously obtained ones. In the three cases, the intra-class variance was lower than the inter-class variance. In the initial grouping, the 55 node areas were classified in nine main typologies, which were finally supported by the statistical clustering and adopted as the final typologies.

Although the statistical clustering with nine classes showed similarities in the resulting groups, it did not determine the suitability of most of the initial groups. In this regard, the clustering made by 8 or 10 classes was adequate for the definition of some groups. Great similarities between the k-means clustering and the first grouping were easily identified in the division with eight classes, where most of the groups corresponded exactly to the previously defined typologies. Nevertheless, two differences were observed: typology 9 does not exist, so the four node areas located there were distributed in other groups (two each in groups 7 and 8), and the nodes located in typologies 2 and 3 were differently distributed (group 2 was limited by variable C2 in the k-means clustering, while variable U1 seemed to be a high conditioning factor to divide typologies 2 and 3). The clustering developed with 10 classes showed another classification of the node areas related to typologies 2 and 3. In this case, the initial division was used to create groups 2 and 3, but another group (10) was also created with the node areas that have some peculiarities (Lizarra and Olarizu). However, these small differences were not considered significant enough to justify the inclusion of a new typology in the initial grouping. Furthermore, typologies 1 and 8 were maintained in the k-means clustering of 10 classes, while the other typologies experienced small changes.

As a result, nine final typologies or groups that correspond to the initial classification were created (A–I) (Figure 7). They refer to different development typologies and show the variety of results related to their multiaxial model features, as described below:

- Group A: node areas of main city centers located along the line.
- Group B: node areas of intermediate cities or towns. Most of them are in Gipuzkoa, and they are characterized by high urbanity and activity levels, a predominance of private motorized transport, and a lack of rural or natural areas in their immediate environment.
- Group C: nodes located in the industrial outskirts of urban areas. These are areas with significant levels of activity and population, but they are located outside of the city, where transport infrastructures have an important role in their operability. Nowadays, predominant transport infrastructures are related to motorized means of transportation.
- Group D: node areas of rural towns that show a high level of rural criteria. They are mainly balanced areas that have low values of motorized transport infrastructures.
- Group E: strategic node areas located in small towns. These are unsustainable places based on high levels of morphological features and rural activities but low levels of transport infrastructures.
- Group F: nodes located in rural areas that have some urban or general features in addition to their rural character.
- Group G: nodes located in rural areas. Rural morphology and activity indicators are significant, while population levels are medium. Meanwhile, other variables show low values, so they correspond to unsustainable places.
- Group H: nodes located in undeveloped or monofunctional areas. They do not show any interesting rural or natural elements, although they can have low population or activity density.
- Group I: nodes that have a small influence area due to the lack of suitable transport networks in their surroundings.

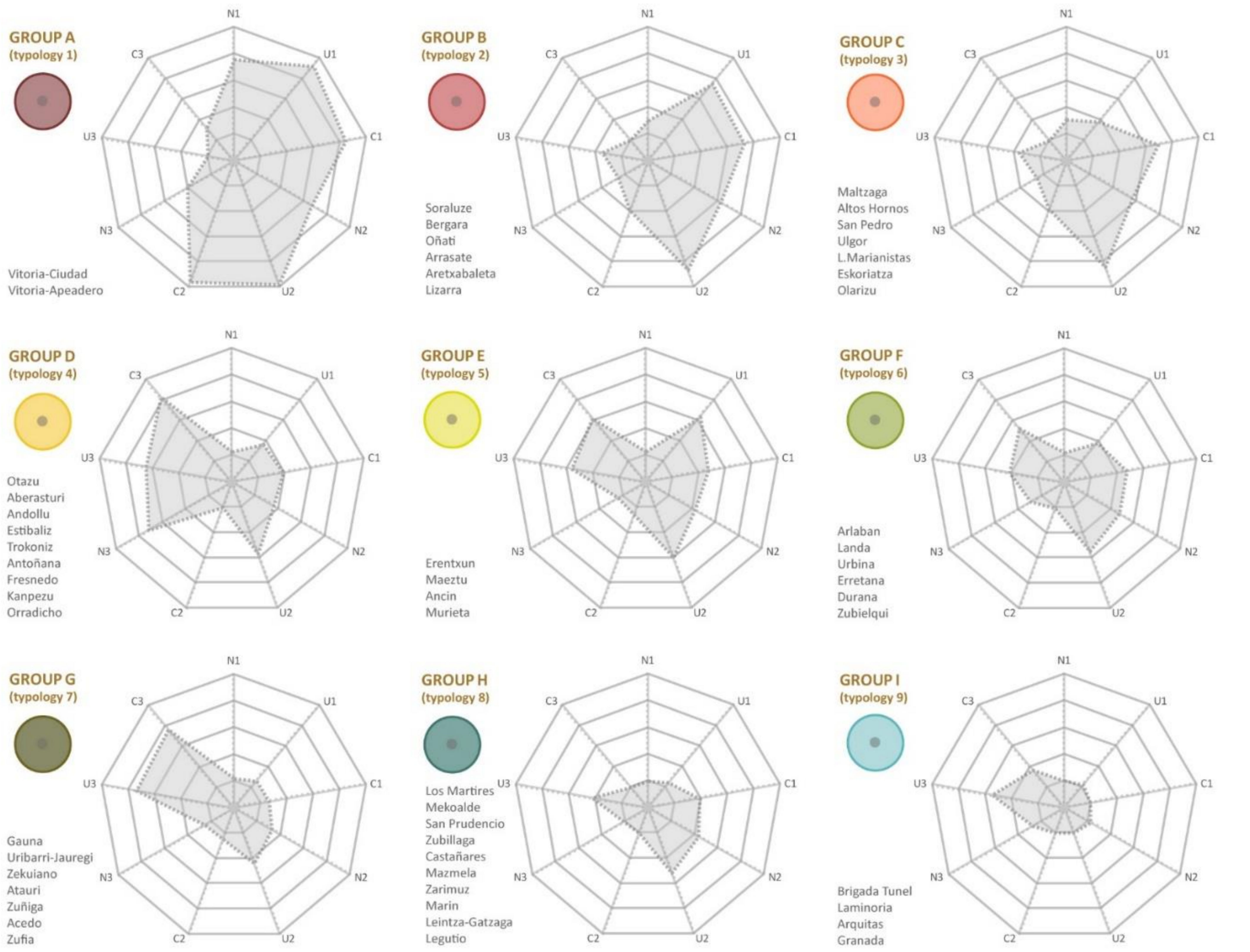


Figure 7. Classification of node areas according to development typologies.

Accordingly, common guidelines of the node areas of the same group can be proposed for more sustainable development by achieving balance in the models. In addition, the nodes of each group that may have higher potential can also be identified. Including urban cycling lines in addition to the territorial non-motorized infrastructure, for example, would turn group B into balanced node areas, such as Lizarra in this group.

These identified groups that classify the node areas are not regularly distributed along the line (Figure 8). The northern section includes node areas classified as groups A, B, C, F, and H, and the southern section includes groups D, E, G, and I. In the southern end of the line, as an exception, there are two node areas of groups B and F. In this regard, groups that have strong urban features are in the north, in addition to other node areas with less significant overall value, while groups with high levels of rural and natural characteristics (except group I) are in the south. In Gipuzkoa, nodes from three groups (B, C, and H) are interspersed. Nodes from groups B and C are coupled, working together as an urban area (Bergara and Oñati), or are grouped, creating an area of urban cores (Arrasate-Aretxabaleta-Eskoriatza). Similarly, several sections of nodes are related to a single group in the plain terrain of Araba/Álava (Urbina-Erretana-Durana (F), Vitoria-Gasteiz (A and D), and Otazu-Trokoniz (D)), so each section or zone would be related to a specific future strategy. Furthermore, the mountains of Araba/Álava include several groups (D, E, G, and I), in which nodes of group D are clustered, while the others are scattered. Hence, two situations were identified: on the one hand, nodes located between Antoñana and Orradicho are in group (D), and on the other hand, a combination of one node in group E and two nodes in group G was distinguished in two areas (Erentxun-Gauna-Uribarri and Zekuiano-Maeztu-Atauri). In this regard, two strategies should be implemented regarding the different situations. Finally, there are five node areas of four groups in Navarre.

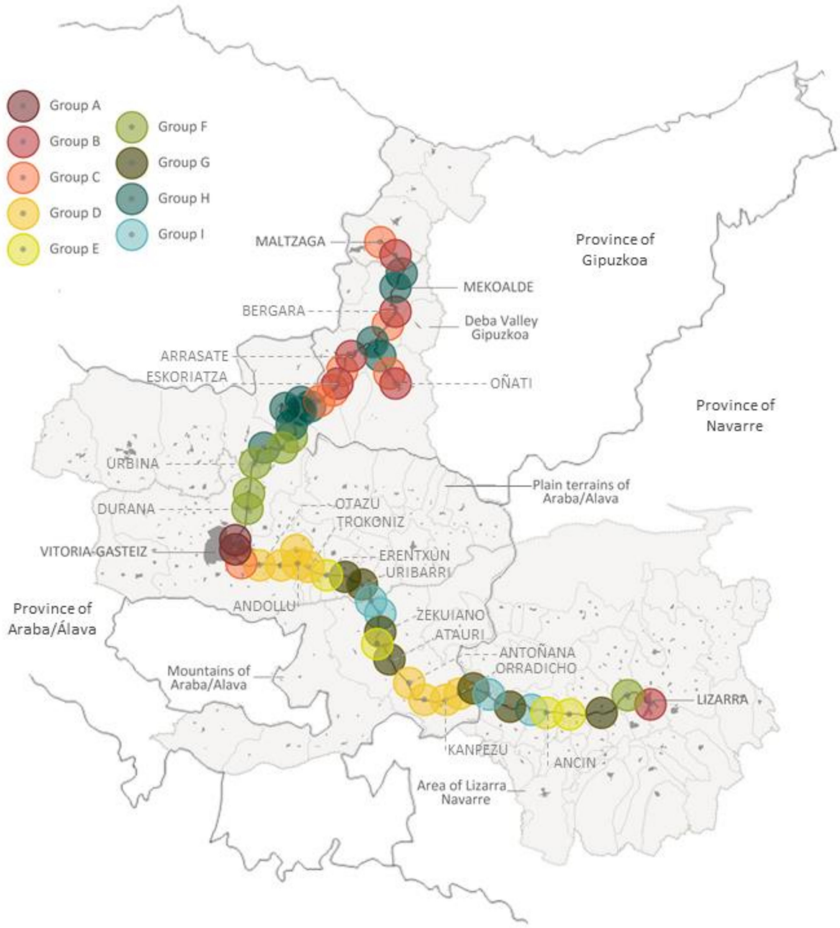


Figure 8. Final clustering of node areas along Vasco-Navarro Railway.

Taking into account the distribution of the different types of node areas, strategies can be created at a territorial level and connections between the nodes can be identified using former railway stations and their influence areas as poles of attraction and strategic points for urban regeneration and integration processes in degraded or underused urban and rural areas. The following general strategies are identified in the case of the disused Vasco-Navarro Railway:

- Creating integrated guidelines for node areas that can be directly connected or concatenated when urban node areas (A and B) or strategic node areas (E) are located close to unsustainable rural node areas (G) or undeveloped areas (H). As part of the territorial transport system, internal structural connections can be promoted in order to facilitate enhanced development processes in underused areas that can be attracted by the main node areas. As examples, several zones of intermediate cities or towns (B), nodes of their industrial outskirts (C), and nodes in undeveloped areas (G) were identified in the northern area of Vasco-Navarro, while zones of strategic nodes (E) and unsustainable rural node areas (G) were detected in the southern part.
- Creating specific guidelines for nodes located at strategic points of the territorial transport infrastructure, such as points that connect different territorial zones, in order to promote sustainable transport connections at the territorial level. Two nodes at strategic points were identified in the Vasco-Navarro Railway, Erentxun and Ancin.

- Prioritizing actions for nodes located in rural towns or areas when nodes of the same group are clustered. At the territorial level, it is often not feasible to act in all node areas, so those with higher potential or main areas that could promote the surrounding areas should be selected to create pilot actions. In Araba/Álava, one zone with nodes of group F and two zones with nodes of group D were identified, where Durana, Andollu, and Kanpezu are the main nodes or the ones with the highest potential.

5. Discussion

This paper focuses on the relations between former railway stations and their surrounding territory in order to define the potential for more sustainable development of node areas. For that purpose, transport and land use balance is sought and development based on active transport is suggested. Accordingly, the node/place and NCU models proposed for TOD development were adapted for nodes of non-motorized transport infrastructures in order to manage their balance between transport and land use and to propose suitable future general approaches. However, these two models are not able to represent the reality in territories of varied nature (urban and rural). In this regard, a multiaxial model was created for comprehensive characterization of node areas and the proposal of future specific guidelines. Hence, three models that complement one another were used, where the results refer to the potential of node areas in a non-motorized axis and the future possible directions that each node area could include. This conception makes it possible to understand railway heritage nodes as territorial structuring elements. From the point of view of regional planning, connections along sustainable transport infrastructures can be promoted by developing former railway stations and their influence areas.

In addition to the urban criteria proposed by previous authors, new variables and indicators were defined for adaptation and construction of the models. Accordingly, criteria related to the character of disused railways in varied territories were included, i.e., data related to rural features and activities were assessed. Hence, proposing former railway stations as nodes in a non-motorized infrastructure is possible at the territorial level, where not only urban cores are studied.

Furthermore, the combination of the two methods was used for clustering of the results of the node areas; a visual analysis of the diagrams was made to understand the main features that comprise each group and the differences that may exist between them; and a statistical method was used to validate or enhance the initial grouping.

The proposed models are applicable to disused railway nodes located in diverse territories but could be widespread, referring to the type of transport (changes in distances) or even the system itself (any territorial system composed of several nodes).

In this case, the methodology was applied to the Vasco-Navarro Railway, hence its node areas were characterized by the three models. Low node index values were generally obtained, therefore several unsustainable places or balanced dependent areas were identified. Accordingly, most of the strategies or guidelines are related to transport improvement. Moreover, different development typologies, from totally urbanized and industrialized areas to rural and natural areas, were distinguished by the comparison and grouping of multiaxial diagrams. Going further, the distribution of different types of node areas in the territory allowed us to suggest some general strategies to be considered in regional planning for sustainable development: (i) promote internal structural connections taking advantage of the attraction of the main node areas to facilitate development processes in underused areas, (ii) promote sustainable transport connections at the territorial level taking advantage of nodes located at strategic points between territorial zones, and (iii) prioritize actions in zones where there is no structuring of identified development typologies (nodes of the same type are clustered).

Finally, some problems or shortcomings were detected in the research process. On the one hand, data that correspond to different provinces and autonomous communities were compiled, since the Vasco-Navarro Railway crosses several administrative boundaries. Data of different sources were not comparable in several cases, so percentages of real data were used for the analysis of some node areas. On the other hand, sensitivity analysis was proposed for validation of the initial non-objective weights. Another way to overcome the shortcomings could be to include multiple decision-makers in the initial judgment. However, the more node areas in the analysis, the lower the influence of the indicator weights, so results will not vary greatly in the case of the Vasco-Navarro Railway.

6. Conclusions

Previous models from the literature used for the analysis of railway node areas were focused on urban or developed areas [3,39]. For the analysis of active transport development, however, different indicators must be considered, and previous models may prove to be unsuitable. Accordingly, the proposed multiaxial model is a more flexible model that can be applied in diverse node areas, including urban and rural or undeveloped areas. Hence, the integration of small towns, rural population areas, and natural areas can be promoted in a territorial structuring system, in this case a territorial active transport system, encouraging more sustainable development.

The proposed methodology can characterize diverse node areas; hence it facilitates the definition of strategies or guidelines to create balanced node areas that are related to sustainable development. Accordingly, the method is presented as a decision-support instrument that facilitates agreement on what to do with former railway heritage nodes and their areas as part of a territorial active transport axis. Going forward, as part of a comprehensive analysis of disused railways as territorial structuring elements [11], the method can support the definition of territorial strategies by considering non-motorized accessibility along the territorial active transport, where former railway areas can act as connected poles.

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Informed Consent Statement: Not applicable.

Data Availability Statement: Data available in a publicly accessible repository that does not issue DOIs. Publicly available datasets were analyzed in this study. This data can be found here: (see Table A1 of Appendix A).

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Data source and available data for each indicator.

Indicator	Definition of Indicator	Available Data	Source
N_{11}	No. of rail stops	rail stops	geoeuskadi/IDENA
N_{12}	No. of rail directions served	rail lines	geoeuskadi/IDENA
N_{13}	No. of bus stops	bus stops	geoeuskadi/Google Maps
N_{14}	No. of bus directions served	Bus lines	geoeuskadi/Google Maps
N_{15}	No. of tram stops	Tram stops	geoeuskadi

Table A1. *Cont.*

Indicator	Definition of Indicator	Available Data	Source
N_{16}	No. of tam directions served	Tram lines	geoeuskadi
N_{21}	Distance from the closest motorway access	Motorways and other road networks	geoeuskadi/IDENA/euskalgeo/IGN
N_{22}	Distance from the closest secondary road	National and main local roads (red and orange) and others	geoeuskadi/IDENA/euskalgeo/IGN
N_{23}	Parking capacity	Parking areas	google earth
N_{31}	Cycling path length	Cycling lanes and greenways	geovitoria-gasteiz/bizikletaz/ vías verdes
N_{32}	Pilgrimage routes in the area	Routes of the Way of St. James/Ignatian Way route	www.caminoignaciano.org/www.rayyrosa.com
N_{33}	GR routes in the area	Different long distance (GR) routes	www.senderosgr.es/
U_{11}	Distance to the town center	Road network	geoeuskadi/IDENA/euskalgeo/IGN
U_{12}	Housing density	No of dwellings (2011)	eustat/INE
U_{13}	Urban land-uses	Undeveloped land areas	geoeuskadi/land registry (N)
U_{21}	No. of residents in the area	Population (2011)	eustat/IEN/INE
U_{31}	Forest cover	Forest areas	geoeuskadi/IDENA
U_{32}	Agricultural land-uses	Agricultural land areas	geoeuskadi/IDENA
C_{11}	No. of workers in industry	No. of companies depending on the no. of workers (2015/2016)	eustat/IEN
C_{12}	No. of workers in services	No. of companies depending on the no. of workers (2015/2016)	eustat/IEN
C_{13}	No. of students in education	No. of students per municipality (2016)/No. of students per center (2016)	Dept. of Education (BC) (N)
C_{14}	Open areas	Open and green areas	geoeuskadi/IDENA/master plans (N)
C_{15}	Degree of multifunctionality	Herfindahl–Hirschman Index	literature review
C_{21}	Elements of interest	Elements of interest	fieldwork/Google Maps
C_{22}	Heritage elements	Heritage elements	Dept. of Education (BC)/IDENA
C_{31}	Protected natural areas	Protected natural areas	geoeuskadi/IDENA
C_{32}	Linking corridors	Natural areas	geoeuskadi/IDENA
C_{33}	Agricultural land	Agricultural land areas	geoeuskadi/IDENA
C_{34}	Degree of multifunctionality	Calculations from C_{31}, C_{32} and C_{33}	geoeuskadi/IDENA

geoeuskadi: Spatial Data Infrastructure of the Basque Country (www.geo.euskadi.eus/s69-15375/eu); euskalgeo: Spatial Data Infrastructure of the Basque Country and Navarre (www.euskalgeo.net/eu); IDENA: Spatial Data Infrastructure of the Navarre (www.idena.navarra.es/Portal/Inicio); Dept. of Education (N): Navarre Department of Education; Dept of Education (BC): Department of Education, Language Policy and Culture of the Basque Government; Master plans (N): master plans of the municipalities of Navarre; geovitoria-gasteiz: mapping application of Vitoria-Gasteiz (www.vitoria-gasteiz.org/buscaturuta); bizikletaz: Department of Mobility and Road Infrastructure of the Regional council of Gipuzkoa (www.gipuzkoabizikletaz.eus/eu); vias verdes: Spanish greenway programme of the Association of Spanish Railways (FFE) (www.viasverdes.com/); IGN: National Geographic Institute (Spain); Eustat: Basque Statistics Institute; IEN: Statistical Institute of Navarre; INE: National Statistical Institute (Spain); Land registry (N): land registry of Navarre.

Table A2. Values resulting from multicriteria decision analysis (MCDA) and related to cycling non-round-trip areas (2000 m).

ZONE	URB. AREA TYPE [1]	RAILWAY STATION AREA	NODE PLACE		NODUS URBS CIVITAS			N1-N2-N3 U1-U2-U3 C1-C2-C3									URBAN GENERAL RURAL			TOTAL	
(Eizaguirre-Iribar et al., 2016)		NAME	N	P	N	U	C	N1	U1	C1	N2	U2	C2	N3	U3	C3	Urban	Gener.	Rural	NP	NUC
Northern towns (GIPUZKOA)	-	MALTZAGA	2.54	2.53	2.54	3.19	1.87	2.04	0.75	5.50	5.34	6.05	0.12	0.23	2.79	0.00	2.86	3.72	0.92	2.54	2.53
	2	SORALUZE	1.52	3.62	1.52	4.95	2.28	0.47	5.56	4.87	3.93	6.97	1.97	0.17	2.34	0.00	3.53	4.15	0.76	2.57	2.92
	-	LOS MARTIRES	1.62	2.13	1.62	3.01	1.25	0.44	0.26	3.17	3.87	5.19	0.58	0.55	3.59	0.00	1.34	3.11	1.27	1.88	1.96
	-	MEKOALDE	1.72	2.02	1.72	2.65	1.40	0.47	0.43	3.58	4.37	4.64	0.58	0.33	2.88	0.04	1.55	3.12	0.99	1.87	1.92
	2	BERGARA	2.31	4.91	2.31	5.28	4.53	0.61	6.29	6.08	5.99	8.00	5.51	0.34	1.54	2.02	4.23	6.42	1.29	3.61	4.04
	-	ALTOS HORNOS	2.54	2.64	2.54	3.38	1.91	0.51	1.17	5.16	6.68	6.97	0.55	0.43	2.00	0.01	2.33	4.62	0.76	2.59	2.61
	-	SAN PRUDENCIO	1.90	2.02	1.90	2.31	1.73	0.75	0.35	2.80	4.21	3.36	0.38	0.73	3.22	2.00	1.35	2.62	1.92	1.96	1.98
	-	ZUBILLAGA	1.65	2.19	1.65	2.50	1.89	0.53	0.45	3.43	3.96	4.84	0.22	0.47	2.22	2.01	1.52	2.91	1.54	1.92	2.01
	-	SAN PEDRO	1.72	3.33	1.72	3.09	3.57	0.57	0.91	6.08	4.02	6.93	4.62	0.58	1.44	0.02	2.60	5.10	0.64	2.53	2.80
	2	OÑATI	1.74	4.41	1.74	4.91	3.92	0.57	5.99	6.27	4.13	7.76	5.48	0.53	0.97	0.00	4.19	5.69	0.48	3.08	3.52
	2	ARRASATE	2.43	4.36	2.43	5.69	3.04	1.24	6.86	6.61	5.32	8.38	2.47	0.73	1.84	0.03	4.80	5.24	0.82	3.40	3.72
	-	ULGOR	2.23	3.48	2.23	4.13	2.84	1.39	2.29	6.21	4.60	8.10	2.30	0.70	2.01	0.01	3.34	4.85	0.85	2.86	3.07
	2	ARETXABALETA	2.08	3.73	2.08	5.04	2.42	0.64	5.87	6.00	5.02	7.41	1.25	0.58	1.85	0.00	4.08	4.42	0.76	2.90	3.18
	-	LANDETA-MAR.	2.98	3.44	2.98	3.80	3.08	0.69	2.38	6.10	7.66	7.71	3.12	0.58	1.31	0.01	3.09	6.09	0.60	3.21	3.28
	2	ESKORIATZA	1.95	3.05	1.95	3.75	2.36	0.61	1.75	4.94	4.79	6.90	2.11	0.45	2.59	0.04	2.46	4.49	0.95	2.50	2.69
	-	CASTAÑARES	1.08	1.76	1.08	2.60	0.91	0.20	0.45	2.73	2.92	4.19	0.00	0.12	3.16	0.01	1.16	2.28	0.99	1.42	1.53
Mountain port	-	MAZMELA	1.02	1.62	1.02	2.44	0.80	0.00	0.55	2.40	2.93	3.96	0.00	0.12	2.81	0.01	1.00	2.21	0.89	1.32	1.42
	-	ZARIMUZ	0.14	1.36	0.14	2.40	0.33	0.00	0.34	0.98	0.42	3.45	0.00	0.00	3.40	0.00	0.45	1.18	1.02	0.75	0.96
	-	MARIN	0.17	1.37	0.17	2.51	0.22	0.17	0.22	0.66	0.35	3.36	0.00	0.00	3.94	0.02	0.36	1.13	1.19	0.77	0.97
	4	LEINTZ-G.	1.82	2.17	1.82	2.77	1.57	0.33	0.44	1.69	3.07	4.64	1.53	2.07	3.23	1.50	0.84	3.00	2.22	2.00	2.06
	-	ARLABAN	2.06	2.44	2.06	2.53	2.34	0.33	0.21	1.38	3.59	3.68	0.65	2.27	3.69	5.00	0.66	2.59	3.65	2.25	2.31
	-	LANDA	1.68	2.32	1.68	2.08	2.56	0.17	0.33	2.09	3.71	3.32	0.58	1.16	2.59	5.03	0.89	2.50	2.94	2.00	2.11
Area of Vitoria-Gasteiz (ARABA/ÁLAVA)	4	LEGUTIO	0.65	1.54	0.65	1.62	1.47	0.00	0.87	1.91	0.79	2.16	0.38	1.17	1.83	2.10	0.93	1.06	1.69	1.10	1.25
	3	URBINA	1.61	2.81	1.61	3.11	2.51	0.26	2.25	3.39	3.40	4.38	0.10	1.17	2.71	4.04	1.95	2.54	2.64	2.21	2.41
	4	ERRETANA	0.81	3.17	0.81	3.33	3.01	0.20	1.64	3.96	1.02	4.17	0.02	1.21	4.18	5.06	1.95	1.62	3.45	1.99	2.38
	3	DURANA	1.54	3.40	1.54	3.61	3.18	0.37	1.70	4.56	3.78	5.12	0.02	0.48	4.00	4.97	2.23	2.87	3.11	2.47	2.78
	1	VITORIA APEAD.	5.13	6.32	5.13	6.28	6.37	6.99	9.05	8.06	5.86	9.78	9.54	2.55	0.00	1.50	7.98	8.33	1.42	5.73	5.93
	1	VITORIA-CIUDA	7.93	6.44	7.93	6.43	6.45	10.00	9.30	7.86	5.78	10.00	10.00	8.00	0.01	1.50	9.04	8.52	3.33	7.18	6.94
	-	OLARIZU	5.75	3.97	5.75	4.68	3.26	5.66	2.95	7.50	4.71	8.74	1.37	6.89	2.34	0.91	5.49	4.75	3.43	4.86	4.56
	3	OTAZU	2.84	3.25	2.84	4.00	2.50	0.24	2.94	1.46	2.79	4.36	0.89	5.48	4.70	5.14	1.48	2.60	5.13	3.04	3.11
	3	ABERASTURI	2.25	3.59	2.25	4.29	2.89	0.24	3.47	0.24	0.33	4.16	0.19	6.18	5.23	8.25	1.21	1.43	6.62	2.92	3.14
	3	ANDOLLU	2.96	3.79	2.96	4.14	3.44	0.33	2.08	2.39	2.02	4.64	0.05	6.53	5.70	7.87	1.58	2.11	6.75	3.37	3.51
	4	ESTIBALIZ	3.97	3.55	3.97	3.63	3.47	2.27	1.67	2.09	3.68	4.67	0.26	5.97	4.56	8.06	2.02	2.78	6.28	3.76	3.69
	3	TROKONIZ	2.74	4.47	2.74	4.98	3.96	0.30	5.16	3.54	1.63	4.35	0.19	6.28	5.44	8.14	2.89	1.94	6.68	3.60	3.89
	3	ERENTXUN	0.60	3.60	0.60	4.94	2.26	0.24	5.16	1.01	0.37	4.51	0.38	1.18	5.14	5.38	1.99	1.62	3.84	2.10	2.60

Table A2. *Cont.*

ZONE	URB. AREA TYPE [1]	RAILWAY STATION AREA	NODE PLACE		NODUS URBS CIVITAS			N1-N2-N3 U1-U2-U3 C1-C2-C3									URBAN GENERAL RURAL			TOTAL	
(Eizaguirre-Iribar et al., 2016)		NAME	N	P	N	U	C	N1	U1	C1	N2	U2	C2	N3	U3	C3	Urban	Gener.	Rural	NP	NUC
Small towns (ARBA/ÁLAVA)	4	GAUNA	0.59	2.48	0.59	3.22	1.74	0.17	0.58	0.01	0.39	3.58	0.00	1.22	5.50	5.20	0.24	1.21	3.90	1.54	1.85
	4	URIBARRI-JAUR.	0.58	2.74	0.58	3.81	1.67	0.17	0.41	0.24	0.37	3.80	0.38	1.21	7.22	4.39	0.27	1.41	4.12	1.66	2.02
	-	BRIGADA TUNEL	0.42	1.12	0.42	1.54	0.69	0.00	0.26	0.00	0.33	0.00	0.00	0.93	4.37	2.06	0.08	0.12	2.36	0.77	0.88
	-	LAMINORIA	0.05	0.89	0.05	1.08	0.70	0.00	0.18	0.00	0.00	0.00	0.00	0.16	3.06	2.10	0.05	0.00	1.71	0.47	0.61
	4	ZEKUIANO	0.81	3.59	0.81	3.56	3.62	0.00	0.90	2.94	1.96	4.98	0.58	0.47	4.80	7.36	1.30	2.38	4.18	2.20	2.66
	3	MAEZTU	1.21	4.88	1.21	5.35	4.42	0.24	5.28	3.58	2.76	4.94	0.77	0.62	5.84	8.90	2.92	2.72	5.08	3.04	3.66
	4	ATAURI	0.82	3.15	0.82	3.49	2.80	0.24	0.77	0.80	1.56	2.97	0.58	0.66	6.74	7.02	0.59	1.64	4.71	1.98	2.37
	4	ANTOÑANA	2.97	3.87	2.97	4.35	3.39	0.24	2.53	0.70	1.88	4.15	0.60	6.79	6.39	8.89	1.09	2.11	7.40	3.42	3.57
	-	FRESNEDO	2.97	3.25	2.97	3.74	2.76	0.24	0.80	2.84	2.48	5.14	0.41	6.20	5.29	5.05	1.32	2.55	5.52	3.11	3.16
	4	KANPEZU	3.03	4.13	3.03	3.97	4.29	0.24	1.19	4.06	2.69	5.71	0.60	6.16	5.01	8.20	1.86	2.86	6.53	3.58	3.76
	-	ORRADICHO	2.24	3.88	2.24	3.40	4.37	0.24	0.33	3.97	0.40	4.29	0.77	6.09	5.58	8.36	1.57	1.70	6.73	3.06	3.34
	4	ZUÑIGA	0.80	3.40	0.80	3.82	2.99	0.34	0.89	0.51	1.52	3.96	0.60	0.54	6.60	7.85	0.56	1.93	4.92	2.10	2.53
	-	ARQUITAS	0.30	2.17	0.30	2.59	1.76	0.31	0.38	0.00	0.01	0.00	0.19	0.57	7.37	5.09	0.22	0.07	4.20	1.24	1.55
	3	ACEDO	1.11	3.40	1.11	4.31	2.50	0.31	1.97	1.90	2.43	4.30	0.96	0.58	6.67	4.64	1.36	2.48	3.82	2.26	2.64
	-	GRANADA	0.18	2.41	0.18	3.20	1.61	0.00	0.43	0.00	0.01	1.75	0.38	0.55	7.42	4.46	0.13	0.66	3.98	1.30	1.67
Area of Lizarra (NA.)	3	ANCIN	1.24	4.06	1.24	5.38	2.75	0.34	5.47	2.44	2.89	5.01	0.96	0.48	5.66	4.85	2.61	2.85	3.56	2.65	3.12
	3	MURIETA	1.21	4.08	1.21	4.99	3.16	0.34	5.43	3.41	2.78	5.02	0.77	0.50	4.54	5.30	2.94	2.75	3.39	2.64	3.12
	4	ZUFIA	0.39	2.83	0.39	3.81	1.85	0.34	1.13	0.71	0.84	3.98	0.19	0.00	6.33	4.65	0.71	1.55	3.53	1.61	2.02
	3	ZUBIELQUI	0.43	3.22	0.43	3.79	2.64	0.31	2.75	2.80	0.72	4.71	0.77	0.27	3.92	4.37	1.91	1.94	2.80	1.83	2.29
	2	LIZARRA	3.92	4.48	3.92	5.48	3.47	1.22	6.64	6.35	5.36	7.96	1.73	5.19	1.83	2.34	4.64	4.87	3.18	4.20	4.29

[1] Types of urban areas: 1—city; 2—town; 3—rural town; 4—rural area [1].

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