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Nigro, A.; Bertolini, L.; Moccia, F.D.

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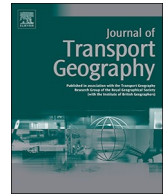
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Land use and public transport integration in small cities and towns: Assessment methodology and application

Antonio Nigro^{a,*}, Luca Bertolini^b, Francesco Domenico Moccia^a^a University of Naples 'Federico II', Department of Architecture, Via Forno Vecchio 36, 80134 Naples, Italy^b University of Amsterdam, Department of Geography, Planning and International Development Studies, Amsterdam Institute of Social Science Research, PO Box 15629, 1001, NC, Amsterdam, The Netherlands

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ABSTRACT

It is widely accepted that land use and public transport planning should be harmonised in order to provide a viable alternative to car transport. Following the Transit-Oriented Development (TOD) concept, many studies and plans aim to concentrate urban development in areas accessible by high-quality public transport. Encouraged by studies asserting the positive relation between urban density and public transport use, scholars and practitioners focused their attention on tools and strategies that increase urban density, thereby overlooking geographical contexts where these strategies cannot be applied. TOD might however be also a valuable strategy in low-density contexts, like lower density parts of metropolitan areas, or suburban areas and small towns. It seems therefore relevant and interesting to develop a methodology to explore the value of TOD strategies in such contexts. Our paper fills this analytical and application gap and proposes to extend the conceptualization and implementation of land use and public transport integration to areas where low-density urban development has already occurred (e.g., low-density suburbs, or areas where the protection of natural and cultural heritage precedes urban development). In such cases, where is not possible to increase urban density around transport nodes, the quality of the transport network plays a decisive role.

The approach builds on the Node-Place Model by including evaluations of the quality of feeder networks. We applied the methodology to a case study in the Campania Region in southern Italy, indicating a possible way to evaluate land use and public transport integration while considering, at the same time, the quality of transport as network.

The application of the methodology allowed to highlight imbalances between accessibility – by main and feeder transport – and land use intensity, and to sketch urban development strategies and priorities of intervention on the transport network.

1. Introduction

Since the 1990s, Transit-Oriented Development (TOD) has been one of the most prominent approaches to land use and public transport integration (Calthorpe, 1993; Cervero et al., 2002). Following the motto that 'mass transit needs mass' (Suzuki et al., 2013), high urban density and high-capacity public transport constitute key elements of TOD. Following these principles, several cities and metropolitan regions are implementing plans and programs aimed to develop urban areas around transport nodes, especially rail transport hubs (Cervero, 1998; Curtis et al., 2009). The shift from theory to practical application has highlighted existing barriers and obstacles that can prevent the realisation of TOD principles (Curtis, 2008; Curtis and Low, 2012; Filion and McSpurren, 2007; Haywood, 2005). The classification of transport nodes has emerged as one effective tool to structure the discussion of how to identify and overcome those barriers: it

helps to direct the search for answers to questions on the required level of transport service, on urban density or whether a mixture of uses is necessary. Moreover, it reduces complexity, allows for comparisons and enables the formulation of common strategies (Kamruzzaman et al., 2014).

Numerous measurement methods of a transport node's characteristics are based on the Node-Place Model (Bertolini, 1999, 2005). In this model, 'node' measures the offer of transport services (e.g., in the case of rail transport nodes, this parameter is influenced by train service, number of directions served, etc.), which directly impacts, through accessibility, the attractiveness of the area. 'Place' measures the volume of actual users of an area (e.g., population, workers) and the degree of functional mix, which are seen as decisive factors in determining the potential demand for transport services. Interdependencies between 'node' and 'place' are seen as a key development dynamic and striking a balance between the two is a key policy objective.

* Corresponding author.

E-mail addresses: antonio.nigro@unina.it (A. Nigro), l.bertolini@uva.nl (L. Bertolini), fdmoccia@unina.it (F.D. Moccia).<https://doi.org/10.1016/j.jtrangeo.2018.11.004>

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In most cases, studies about land use and public transport integration focus on large cities and metropolitan areas. These geographical contexts are usually characterised by (1) high population densities and activities and (2) high-capacity transport infrastructures. However, these conditions are not present everywhere. Urban planners may face situations in which demographic and economic trends do not sustain substantial increases of urban density, for instance in ‘shrinking’ cities and regions (Großmann et al., 2013), or when transport nodes face natural and cultural constraints to development. In contexts characterised by low density, often there is no meaningful discussion on land use and public transport integration. Nonetheless, as shown by some authors, urban density is not the only factor that influences the appeal of public transport; many other elements, mainly related to the quality of the public transport network, can significantly increase the attractiveness of public transport (Dodson et al., 2011; Walker, 2012). By utilising figures relating to North American, Australian and European cities, Mees (2010) demonstrates that areas or metropolitan regions with similar levels of density show remarkable differences in public transport uses. Hence, he contends, the role of urban structures and the relative attractiveness of transport modes is not adequately considered, while the effects of urban density are overestimated.

In fact, very few studies on land use and public transport integration explicitly focus on geographical contexts characterised by medium or low densities of population and activities, slow rates of population growth, and the absence of high capacity public transport networks. In these contexts, the focus of present studies on the immediate ‘walkable’ area around a public transport stop as the relevant ‘place’ of a ‘node’ is problematic, as it disregards the interactions of the transport node with a wider geographical area. In order to fill this knowledge gap and to provide a tool that can be used by land use planners, transport authorities and public decision-makers, this paper aims to extend the existing framework of analysis that considers these wider interactions. While essential in non-metropolitan contexts, this expansion can be of interest also in metropolitan areas, as it highlights the role of feeder transport in determining the extent and level of connection of stations’ catchment areas.

The paper is structured as follows: Section 2 contains the state-of-the-art of current research efforts. Section 3 illustrates the proposed methodology, with the indicators used and the innovation in comparison to the usual node-place analysis, while Section 4 illustrates the application to a case study in the Campania Region, in southern Italy. Section 5 discusses the results and finally, Section 6 draws conclusions, underlines some limitations of the study and sketches further research directions.

2. State-of-the-art

Existing studies on transport node classification for supporting land use and public transport integration heavily focus on dense urban development and high-capacity transport nodes. They typically define a station area (i.e. the ‘place’ related to a ‘node’) as the ‘walkable area’ around the station. However, this approach is not applicable in low-density areas (small cities, towns, suburbs, rural areas, low-density sectors of metropolitan areas, etc.) because stations are often accessed not just by walking but from a wider area through different forms of feeder transport (e.g. biking, other public transport, car).

In order to address these limitations, we systematically looked for studies or practices explicitly aiming to apply TOD or land use and transport integration assessments to the cited non-metropolitan contexts, or else provide a methodology to integrate the role of ‘feeder transport’ in the analysis of the ‘place’.

Recent studies expand the application of node-place analyses, considering different modes of access to transport nodes and/or including indicators describing urban pattern within catchment areas. Caset et al. (2018) apply the “butterfly model” to the Brussels RER Network, thus comprising stations located within dense urban cores as well as stations placed in semi-urban or rural areas. One of the main goals of their work is to verify the variations of node and place parameters when the radius of

stations’ catchment areas change. The cited authors, in fact, adopt radiuses of 700, 800 and 1200 m, considering different modes of access to stations.

Vale et al. (2018) elaborate an “extended” version of the node-place model, explicitly considering different access modes to stations. The authors also introduce, in addition to node and place indexes, the “design index”, in order to investigate the factors that influence pedestrian accessibility of stations’ catchment areas. Design index allows, according to the cited scholars, to better distinguish between “balanced” situations. This study underlines the potential of future development of node-place analyses, using combined multimodal evaluations of station catchment areas, in order to produce more robust results.

The contributions of Kamruzzaman et al. (2014) and Lyu et al. (2016) provide an exhaustive overview of the state-of-the-art in terms of transport nodes’ assessment. From them, we obtained the following contributions that discuss classification of transport nodes: Atkinson-Palombo and Kuby (2011); Austin et al. (2010); Center for Transit-Oriented Development (2011, 2013); Chorus and Bertolini (2011); Ivan et al. (2011); Monajem and Nosratan (2015); Reusser et al. (2008); Schlossberg and Brown (2004); Vale (2015); Zemp et al. (2011). We added five additional sources: Bertolini (1999); City of Denver (2014); Dittmar and Poticha (2004); Duffhues, Mayer, Nefs, & Van der Vliet (2014); Higgins and Kanaroglou (2016); Papa et al. (2013); Peek et al. (2006). To complement and update this database, we used the keyword ‘node-place model’ to scan well-used academic web search engines,¹ yielding four additional sources: Babb et al. (2015); Chen and Lin (2015); Ngo (2012); Stoilova and Nikolova (2016). In conclusion, the articles and documents found amount to 24 sources (also including Kamruzzaman et al., 2014; Lyu et al., 2016), covering a period of almost twenty years, from 1999 to 2016.

The literature review has shown that since its elaboration in the 1990s, the node-place model has been interpreted and used in many different ways, and improvements have been advocated and implemented. Several authors underline the necessity of considering context factors, e.g. Lyu et al. (2016), claim the necessity of a ‘context-based typology’, and propose a methodology for developing this. Furthermore, in recent years, studies about the node-place model and TOD in general, tend to focus more on the aspect of the design of urban areas around stations. For instance, Monajem and Nosratan (2015) recognise the importance of the design of the street network, and in order to assess these integrate different indicators in the node-place model. In the same vein, Vale (2015) adds an evaluation of the “pedestrian friendliness” of station areas to the model, while Van Nes and Stolk (2012) consider the spatial configuration of street network design, evaluate it through space syntax method and integrate this evaluation in their model.

We systematically analysed this group of sources but could not find studies that explicitly focus on non-metropolitan contexts, or consider the relationship between transport nodes and a wider catchment area, and evaluate the quality of different feeder transport modes. In conclusion, as emerges from the analysis of the actual state-of-the-art, studies and discourses about transport node classification to support land use and public transport integration overwhelmingly focus on metropolitan areas. Conversely, very little attention is put on areas with medium or low density, or low-density sectors of metropolitan areas. Moreover, analyses and projects often focus on area immediately surrounding transport nodes (typically, a maximum distance of around 800 m, roughly corresponds to a 10-minute walk, usually considered as acceptable access/egress time to transport nodes), while in small cities

¹ Google scholar: <https://scholar.google.it/>
Catalogue plus (UvA): http://lib.uva.nl/primo_library/libweb/action/search.do?vid=UVA

Scopus: <https://www.scopus.com/home.uri>

Web of Science/Web of knowledge: https://apps.webofknowledge.com/UA_GeneralSearch_input.do?product=UA&SID=W2uJGs71zFzAfPkraud&search_Mode=GeneralSearch

The search regarded the entire text.

or suburban areas many points of origin and destination are further away. In these contexts, the following key factors have to be considered:

- Accessibility of transport nodes by different ‘feeder’ modes;
- Origins and destinations of journeys in a wider geographic context.

Thus, and as discussed below, we have considered these two elements, in order to extend the application of land use and public transport integration assessment also to ‘non-metropolitan areas’.

3. Methodology

3.1. Extended station catchment area

As already illustrated, the node-place analysis is used as a tool to define the characteristics of transport nodes in terms of transport quality and intensity and diversity of land use of the surrounding areas. In the light of this research's goals and the gap identified in the literature, the cited method has been extended (see Fig. 1) taking into account not just walking as access and egress transport mode, but also considering bus and/or other feeder public transport, and bike and car-based transport. Trip chains within public transport are common and well-studied. The concept of bicycle TOD has been recently introduced by Lee et al. (2016) in order to expand stations' catchment areas, and estimate their spatial extent through a survey among bicycle and public transport users. Kager et al. (2016), underline the advantages of the bicycle-train trip combination, in terms of speed – granted by the train – and flexibility – granted by the bike. These two means of transport seem to act in synergetic cooperation, as confirmed by data from the Netherlands, where they are a common practice. Other studies highlight how metro stations can improve their level of service by integrating a public bicycle sharing system (Cheng and Lin, 2018), while yet others explore the benefits of public transport and bike integration in specific

cities (Ji et al., 2017). Considering cars as feeder public transport modes could appear contradictory with several sustainable development objectives. However, from an individual traveller point of view, because of strong constraints to car access in city cores (congestion, lack of parking areas, traffic calming measures, etc.), but lack of them in more peripheral areas, there is a strong rationale for using this ‘park and ride’, or possibly ‘kiss and ride’ option, especially in stations at the interface of low-density suburban areas and high-density urban areas. From a policy point of view, a ‘car-train’ transport combination seems a preferable option than ‘car only’ and more realistic than ‘train only’, thus striking a better balance between collective and individual costs and benefits. (See Table 1.)

In fact, the cited modes allow people to travel farther and reach more destinations than are accessible by walking. Thus, the new analysis relies on a four-fold catchment area, made up by the zones reachable by walking, bike, feeder public transport and car-based transport – in contrast to existing studies, which only consider the ‘walkable’ catchment area.

Furthermore, as can be observed in Fig. 1, we defined catchment areas by using isochrones based on network distance, as a better indicator for the heterogeneous characteristics of road and feeder transport network (Gutiérrez and García-Palomares, 2008). In the definition of walking, bike and car isochrone areas, we considered the existing road network, since it can be assumed that every transport node can make use of it. In the case of bus and other public feeder transport, we only considered roads covered by bus lines connected to a transport node (some nodes may have no ‘public transport catchment area’, if no lines are connected to it).

In order to determine the extent of catchment areas we used the concept of ‘interconnectivity ratio’ defined by Krygsman et al. (2004). This is defined, by the cited authors, as the proportion of access and egress time to total trip travel time. According to this concept, the acceptable access/egress times to transport nodes are influenced by the overall duration of the journey, which varies according to the context. The values of travel time, access/egress times and speed will be specified below in the section about the case study.

3.2. Indicators

The indicators belong to three families (see Appendix A for the complete list):

- Node indicators;
- Place indicators (differentiated by catchment areas);
- Feeder transport indicators (differentiated by transport modes).

The combination of these indicators yields a ‘three-component’ node-place analysis, where the ‘place’ dimension is determined by land use intensity and diversity – described with place indicators – and by quality of feeder transport – described with feeder transport indicators (determining the size of the area). The ‘node’ dimension is determined

Table 1
Class distribution, extreme and middle values.

Travel time of trips by train, Italy, year 2011: home-to-work plus home-to-school travels			
Travel time	N.	Extreme values	Central values
Total	865.684	–	–
0 to 15 min	28.405	0 to 15	7.5
16 to 30 min	111.352	16 to 30	22.5
31 to 60 min	340.148	31 to 60	45
more than 60 min	385.779	61 to ∞ ^a	75

^a For the last class is hypothesised an extreme upper value of 90 min, thus equalizing the width (30 min) of the previous class.

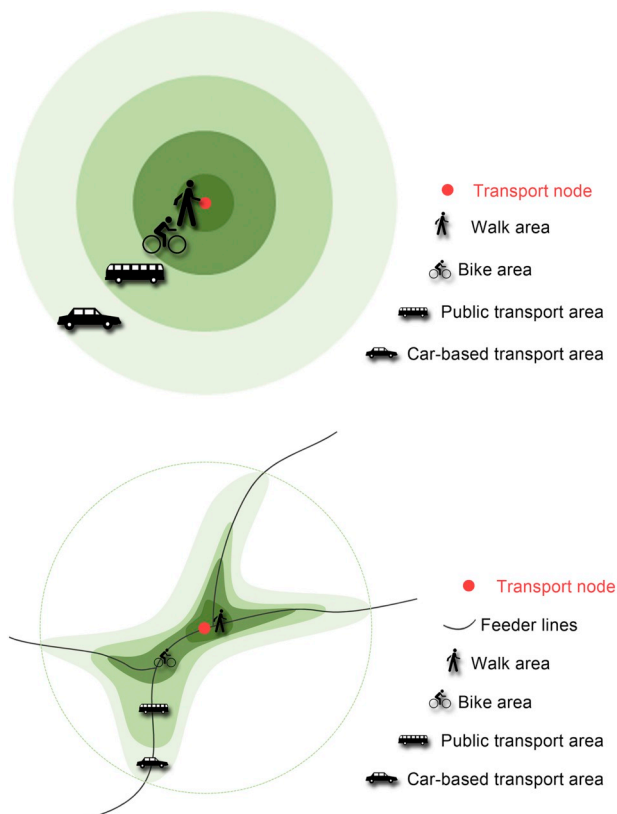


Fig. 1. Comparison between Euclidean catchment areas and isochrones.

by node indicators only.

Node indicators, by means of averaging, are translated into a Node Index, while the procedure used to obtain a Place Index is more complex. In this case, in fact, land use and feeder transport indicators are first transformed – separately – into average values (identified by the codes Pw, Pb, Pp, Pc for place indicators; Tw, Tb, Tp, Tc for feeder transport indicators). Next, these values are multiplied in pairs according to the transport mode considered, in order to obtain Place Indexes referred to each catchment area (e.g. walk area average value is multiplied by walk transport average value, etc). Each pair describes a certain catchment area. For example, the walking catchment area is associated with Pw (average of walk area place indicators) and Tw (average of walk transport indicators); therefore, the walking catchment area's Place Index is $Pw * Tw$. As the final step, the average of Place Indexes allows for the calculation of a 'General' Place Index (see Fig. 2)

We included Tw, Tb, Tp and Tc Indicators in the place index because in our analysis they determine the geographical extension of the area in which the place component is assessed, and thus directly affect its values.

Considering the large volume of information involved, our methodology relies on a 'three-stage' node-place analysis, in which each step gives different insights, summarised as follows:

- a 'general' node-place analysis;
- a 'detailed' node-place analysis, differentiated by transport mode;
- a 'radar chart' analysis, able to display which catchment area could host more urban development, and whether an improvement of the main or feeder transport might be needed.

3.3. General node-place analysis

The general node-place analysis is based on the Node Index and General Place Index. The results are displayed by a xy diagram, as done by Bertolini (1999), where each transport node is represented by a point; however, in this case General Place index is not only influenced by land use characteristics – as usually happens in node-place analyses – but also by the quality of feeder transport modes – walk, bike, public transport and car-based transport, as these determine the extent of the area on which place characteristics are measured. It can thus occur that a high value of 'General' Place Index is determined by high urban density and diversity in some catchment areas or, conversely, high accessibility provided by some feeder transport (i.e. a larger catchment area). These aspects are still not clarified by the general node-place analysis, thus a deeper study is needed, as explained in the following paragraphs.

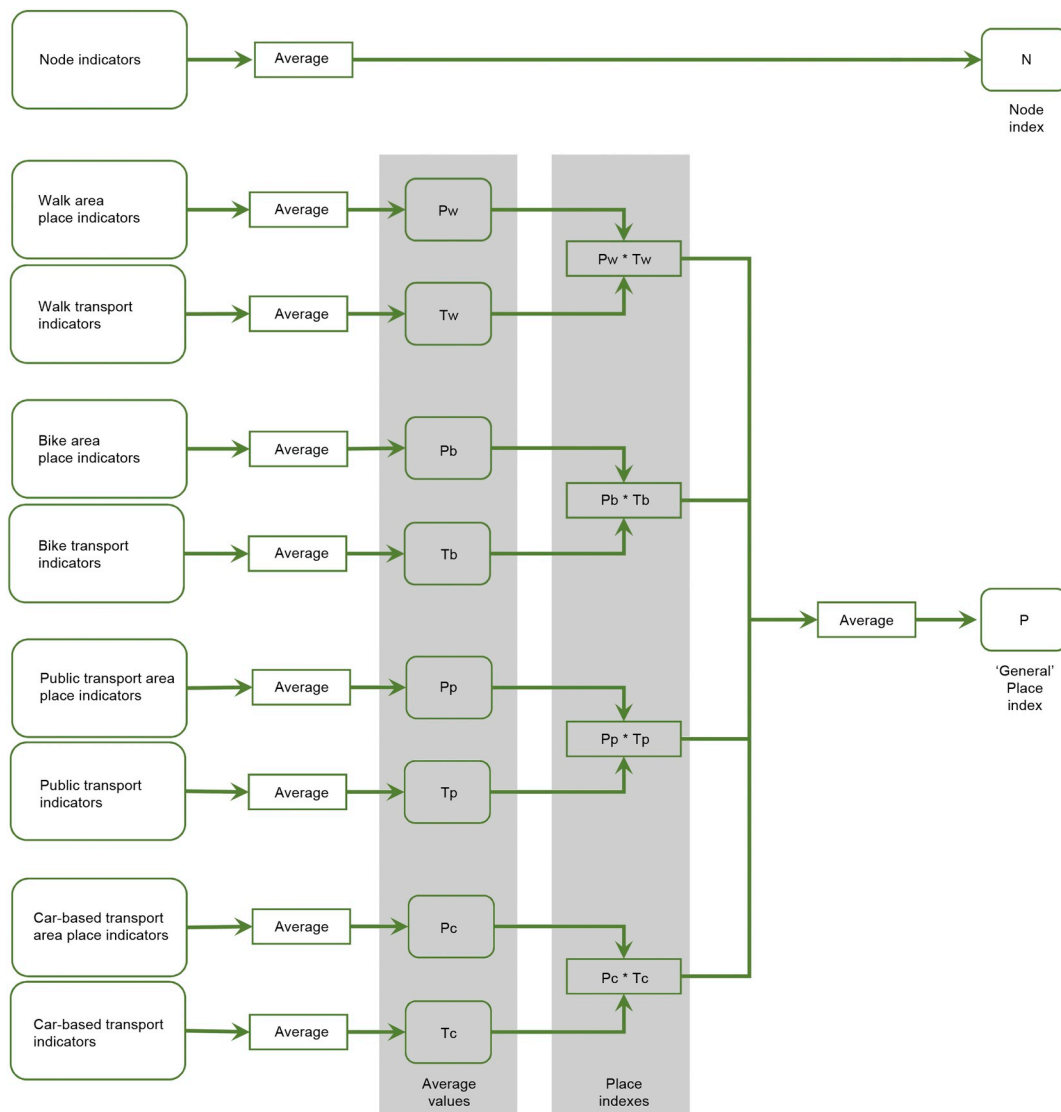


Fig. 2. From indicators to indexes.

3.4. Detailed node-place analysis

The second stage corresponds to a fourfold node-place analysis detailed by feeder transport and the relative catchment areas. In this case, the horizontal axes of the diagrams display Place Indexes ($Pw \cdot Tw$, $Pb \cdot Tb$, $Pp \cdot Tp$, $Pc \cdot Tc$), while vertical axes display Node Index (N) values – see Fig. 7.

The detailed node-place analysis helps to better understand the differences between the four catchment areas in terms of Place characteristics. However, a deeper study that can detect the respective influences of land use and feeder transport indicators is needed; therefore, we also administered a ‘radar charts’ analysis, illustrated in the next paragraph.

3.5. Radar chart analysis

The third stage is the triangular radar charts representing single catchment areas (a radar chart, also known as spider chart or star chart or Kiviat diagram is a diagram that shows multivariate data of three or more variables by using a bi-dimensional representation (Chen et al., 2007)). The scores of the Node Index (N), the Place average values (Pw, Pb, Pp, Pc), and the Feeder transport average values (Tw, Tb, Tp, Tc) are recorded on an axis – see Fig. 8.

This stage aims to highlight potential ‘imbalances’ (Bertolini, 1999, 2005) and to suggest policies that can simultaneously consider aspects referred to land use, node’s accessibility by main transport and node’s accessibility by feeder transports.

It is important to underline that radar analysis has to be seen as a tool aiming to ‘take a snapshot’ of the actual situation on the ground and to identify possible integrated land use transport strategies – but not determine them. Therefore, irregular triangles do not automatically mean that a deep transformation is inevitable or that the actual situation is unsustainable. Instead, they highlight areas where increase of population and jobs is possible, due to relatively high accessibility, or conversely, where the main or feeder transport offer might be insufficient to support the existing activities and population. Furthermore, a more contextual study focused on each catchment area is necessary, as the explained analysis does not consider peculiar factors that can occur locally, for example, the presence of constraints to urban or transport development or the existence of special destinations (like

tourist attractions, sport or entertainment facilities) that justify a high accessibility level despite medium or low population density.

Each axis of the radar charts can be associated to some stakeholders and public decision-makers that directly influence, with their choices, the values represented by the chart: ‘Node’ value is controlled by the main transport company or companies; ‘Place’ is influenced by planning offices; the quality of feeder transport is determined by the decisions of local transport providers (in the case of bus transport, bike and car parking) and can be conditioned by planning offices (e.g., when deciding on location of bike lanes and pedestrian areas).

One of the goals of this analysis is, thus, to help urban and regional planners to define their planning strategies, not only underlining ‘mismatches’ between land use and transport, but also highlighting possible solutions for better integration. On the other side, transport authorities and companies can use it to adjust their transport offer based on potential demand.

4. Campania case study

The study area is identified by a railway line stretching for 17.6 km, linking the towns of Salerno and Mercato San Severino, located in the Campania Region, in southern Italy.² The line crosses a hilly territory spotted by several urban centres, industrial and commercial areas, and education facilities. Even though the analysed railway is single-track and non-electrified, it is important for mobility in the study area, since it links many small towns and settlements to Salerno, the most populous and attractive urban centre of the area (See Fig. 3).

The area encompasses six municipalities: Salerno, Pellezzano, Baronissi, Fisciano, Mercato San Severino and Calvanico. We selected the stations located in municipalities classified as ‘Towns and Suburbs’ by Eurostat, as they represent areas with medium urban density. We used the classification of Eurostat (Dijkstra and Poelman, 2014) since it categorises municipalities throughout EU, allowing to apply the methodology to different European countries.³

The railway stations located within the municipalities classified as Towns and Suburbs by Eurostat are Mercato San Severino, Fisciano, Baronissi, Acquamela, Pellezzano and Fratte. Though Fratte station is located on the border between Salerno and Pellezzano, it was considered anyway. The stations located within Salerno municipal borders have been excluded because this municipality is classified as ‘City’, while the small town of Calvanico, although classified as ‘Rural Area’, has been considered anyway because its territory partially belongs to some catchment areas. The detrimental consequences of car-oriented land use planning – i.e. poor accessibility by public transport, low efficiency of public transport – are becoming evident in the area, and projects to restructure public transport network are under discussion (although implementation cost is a major obstacle). Several higher education facilities in the area, especially high schools and university campuses, present a particularly interesting opportunity as they attract strong commuting flows. The University of Salerno is located in the area at the university campus of Fisciano and at the secondary location of Baronissi campus. The complex of Fisciano University Campus was built at the beginning of the 1980s as a new location for the University of Salerno. While car accessibility is very strong (it is located at the intersection of three motorways), very low consideration was given to public transport accessibility. During time, the presence of Fisciano University Campus in an area served by scarce public transport connections, has highlighted the necessity

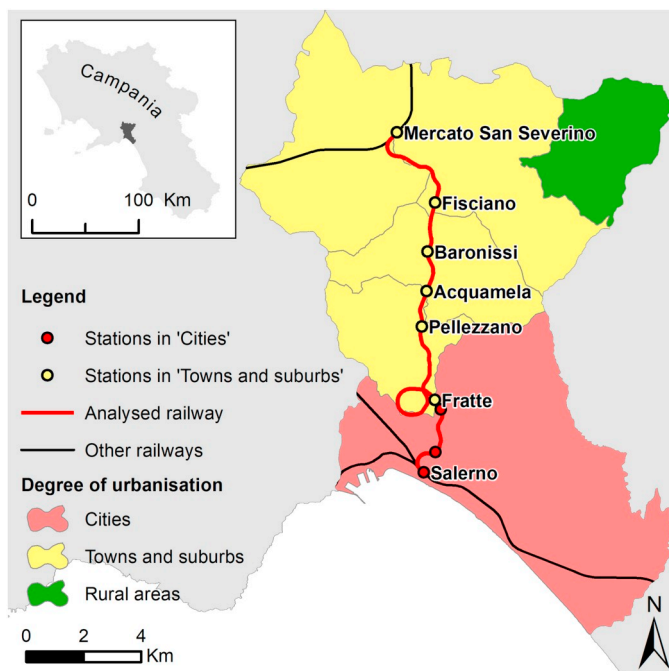


Fig. 3. Analysed railway corridor.

² All the maps in this chapter are based on geographic data freely available at <https://www.openstreetmap.org/>, <http://sit.regione.campania.it/portal/portal/default/Home>, <https://geodrupal.sister.it/content/carta-utilizzazione-agricola-dei-suoli> and <http://land.copernicus.eu/pan-european/corine-land-cover/clc-2012> (retrieved on 15/03/2017).

³ Eurostat classifies the municipalities of EU countries according to their ‘Degree of Urbanisation’. It identifies three categories: ‘Cities’, ‘Towns and Suburbs’ and ‘Rural Areas’.

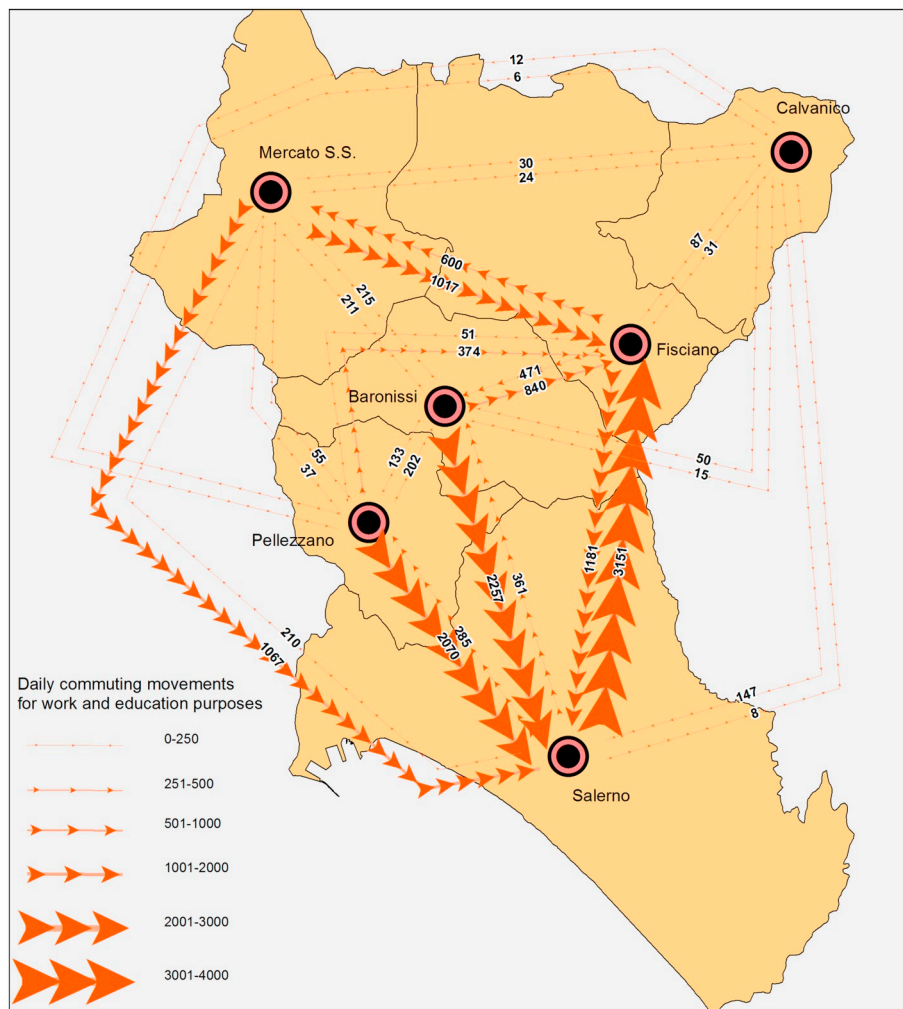


Fig. 4. Daily commuting movements within the study area.

for improvement of accessibility. A bus terminal was built inside Fisciano University Campus, and the railway line between Salerno and Mercato San Severino (closed since 1967) was reopened in 1990.⁴

According to the latest available data provided by ISTAT,⁵ daily commuting flows in the study area are directed mainly towards Salerno, where several workplaces and services are located. However, Fisciano attracts a considerable movement from conterminous municipalities, especially from Salerno itself. As shown by Fig. 4, about 3000 people who live in Salerno commute every day to Fisciano. These figures prove the strong relations existing between the municipalities in the study area, with Salerno and Fisciano that act as main ‘attractors’. The main access of the Fisciano campus is only 3.2 km – less than 2 km as the crow flies – from Fisciano station, spurring a debate on the best way to connect the campus with railway infrastructure. Two different proposals have emerged in the last years (see Fig. 5). The first intends to divert the actual railway line through the campus, realising a direct railway link from Salerno to Mercato San Severino passing through the campus. The project comprises the realisation of four new stations: *Madonna del Soccorso*, *Fisciano campus* (serving the main campus), *Lancusi*, and *Baronissi Città dei giovani* (serving the Baronissi campus)

(Gerundo et al., 2005).

The second proposal, seen as less expensive, corresponds to the realisation of a ‘people mover’, a rope-guided transport system connecting the station of Fisciano with the two locations of University of Salerno (Simeone and Papa, 2010). However, as the proposals are still pending without advances in the decision process, the issue of connections between university campuses and rail transport remains unresolved.

4.1. Travel time and distance

In order to estimate the access/egress travel time to stations, we used data on average travel times from the 2011 Italian national census, administered by ISTAT (*Istituto Nazionale di Statistica*). The statistics provided by ISTAT are differentiated on the basis of transport modes and travel purpose.⁶ In the light of the goals of our research, we chose figures from the second category, since they seem to represent better the type of travel in the area.

⁴ Source: https://it.wikipedia.org/wiki/Ferrovia_Salerno-Mercato_San_Severino (retrieved on 22/05/2017).

⁵ ISTAT provides, together with the National Census, data about daily commuting for work and education purposes. The latest data are thus referred to 2011. Source: <https://www.istat.it/it/archivio/139381>.

⁶ Transport categories used by ISTAT are: train, tram, metro, intercity bus, urban bus/trolleybus, school bus/company bus, motorbike, bike, car (driver), car (passenger), walking, other. These modes are considered ‘main’ modes, i.e. modes covering the main section of travels. Travel purposes distinguish between home-to-school and home-to-school plus home-to-work travels. Available at: <https://www.istat.it/it/archivio/139381> (retrieved on 13/3/2017).

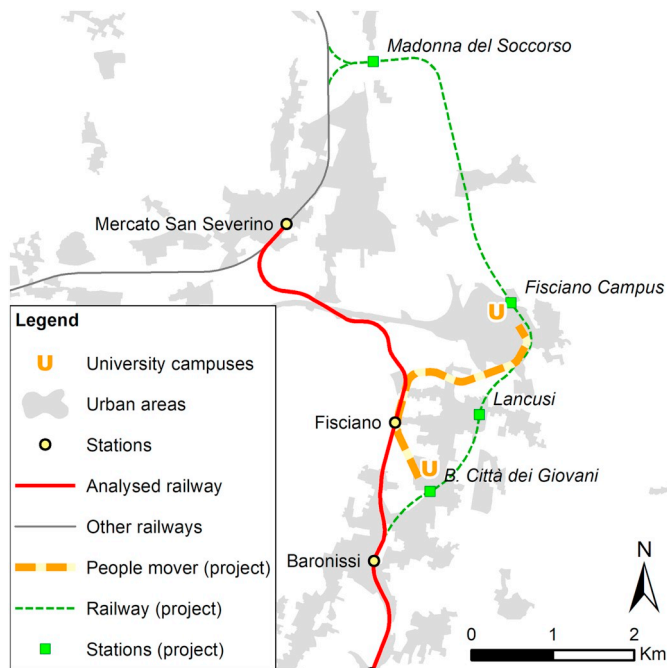


Fig. 5. Existing railways and planned interventions to give accessibility to university campuses.

ISTAT asks people who travel daily for work and education purposes to report the time that they spend for their trips,⁷ thereby obtaining a grouped class distribution. We considered journeys made by train and used the values to estimate average travel time, applying the weighted mean method, using the central value of classes as representative of each class⁸ (Mecatti, 2010).

We obtained 54.2 min as the average travel time with train as the main mode, for home-to-work and home-to-school travels. Then, we used this figure to estimate access and egress times, by applying the concept of ‘interconnectivity ratio’, introduced by Krygsman et al. (2004), obtaining the access/egress time of 12.2 min (rounded off to 12 min)⁹ (see Table 2).

With the help of Google Maps, we estimated plausible speed for walking, bus and car transport – respectively 5, 22 and 30 km/h – while for bike transport we used the value of 13 km/h, following the Dutch CBS¹⁰ as data about bike average speed for Italy is not available. Then, we multiplied the values of speed by the access/egress time of 12 min, obtaining the corresponding distance for each transport mode (see Table 3).

We designed the stations’ catchment areas with the help of GIS software, through the application of the network distance analysis (Gutiérrez and García-Palomares, 2008). While walk, bike and car areas are based on the road network, the public transport catchment area is based on the actual pattern of bus lines, thus showing a more irregular

⁷ Extreme values of classes: 0 to 15, 16 to 30, 31 to 60 more than 60. All values are in minutes.

⁸ Central values: 7.5, 22.5, 45 min, the last class (more than 60 min) is linked to the value of 75 min.

⁹ $(54.2 \text{ min} * 0.45) / 2 = 24.4 \text{ min} / 2 = 12.2 \text{ min}$

¹⁰ CBS (Centraal Bureau voor de Statistiek) is the Dutch National Statistical Authority which leads a yearly survey specifically focussed on travel habits across the Netherlands, also differentiated by ‘urban degree’ (Stedelijkheidsgraad). The last available data, referred to 2015, report an average bike speed of 12.9 km/h for bicycle trips made within ‘moderate urban’ contexts. The value has been rounded off to 13 km/h. <http://statline.cbs.nl/Statweb/publication/?DM=SLNL&PA=83500NED&D1=1-2&D2=0&D3=1,4,6-7&D4=0&D5=19&D6=1&HDR=T&STB=G1,G4,G3,G2,G5&VW=T> (retrieved on 20/06/2017).

shape (see Fig. 6). It is important to remark that in the definition of walk and bike areas, motorways are not considered part of the road network, since they cannot be accessed by pedestrians and cyclists. Catchment areas sometimes show a partial overlap, especially in the case of stations separated by short distances. In that case, conflicting polygons are automatically ‘cut’ by the software on the basis of the closest station. This operation allowed us – based on the closest station in metres – to assign residents and jobs to just one node, avoiding the same residents and jobs to be counted twice.

4.2. Indicators

The following paragraphs report the indicators used for this case study (see Appendix A). The value of each indicator is divided by the maximum value found among the analysed stations, in order to assign a normalised score between 0 and 1, representing respectively the lowest and the highest score (see Appendix B).

4.2.1. Node indicators

Node indicators describe main transport quality by considering the number of directions served, frequency and presence of ticketing service. They are:

- Directions;
- Frequency (workdays);
- Frequency (holidays);
- Ticketing.

4.2.2. Place indicators

Regarding Place indicators, we considered, beyond the usual indicators referring to residential and job density, also one indicator referred to places of education. In fact, one of the main defining mobility issues of the study area is the accessibility of education facilities. The municipalities host four high school and two university locations, with about 1600 high school students and 34,000 university students.¹¹ With a total number of 65,000 registered residents in the municipalities, it was necessary to include this substantial additional indicator (total number of students), as it is not captured by the census data.

The ISTAT database provides data about population, firms and employees related to the last censuses of population (2011) and industry and services (2012). These data are referred to as census tracts, and their borders do not match the borders of the station’s catchment areas. The borders of catchment areas split census tracts into two or more sub-parcels, for which the data from the original census tracts are no longer usable. In order to overcome this limitation, we used a method to estimate the population belonging to each sub-parcel with the help of GIS software. First, we calculated residential and jobs density for each census tract, using the census tracts geographic database, available at the ISTAT website.¹² Second, we overlaid catchment areas with census tracts map in order to extract those census tracts, or their parcels, that belong to the catchment areas. The results are new census tracts sections with information on residential and employee density. We then calculated the area of new census tracts sections, and multiplied the values by residential and job density – obtained in the first step – thus arriving at the figures of population and employees. Although this method presents some limitations, since it is based on the assumption that population and jobs are equally distributed in each census tract, it relies on the most accurate and systematic survey available in Italy. Moreover, the potential imprecisions are mitigated by the design of the census tracts, more detailed in correspondence of

¹¹ Sources: <http://cercalatuascuola.istruzione.it/cercalatuascuola/> (high school students); <http://web.unisa.it/ateneo/statistiche> (university students) (retrieved on 22/05/2017).

¹² <https://www.istat.it/it/archivio/104317> (retrieved on 24/06/2017).

Table 2
Travel times and related access/egress times.

Home-to-work and home-to-school trips: outbound travel time by train (min)	Interconnectivity ratio	Access time + egress times (min)	Time for access/egress only (min)
54.2	0.45	24.4	12.2

Table 3
Speed of feeder transports and corresponding distances.

Feeder transport	Average speed (km/h)	Source	Distance covered in 12 min (km)
Walking	5	Google Maps	1
Bike	13	CBS (NL)	2.6
Public transport - bus	22	Google Maps	4.4
Car	30	Google Maps	6

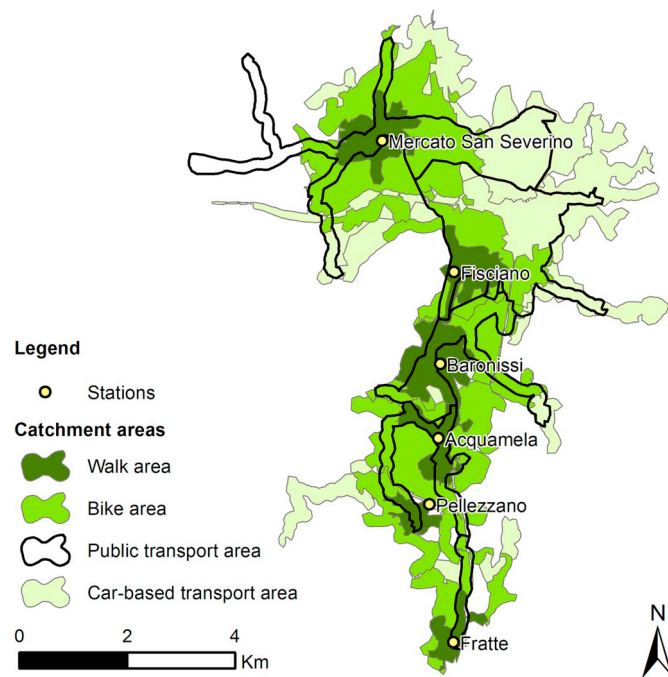


Fig. 6. Catchment areas.

urban cores, while bigger tracts are often referred to lands with little or no population and employment centres, corresponding to impervious or inaccessible areas.

The number of students for each education facility is associated with the point feature representing the location of the education facility itself. If the point is included within a certain catchment area, the related number of students is associated with said catchment area. Place indicators are:

- Estimated residential density;
- Estimated job density;
- Number of students.

4.2.3. Feeder transport indicators

In the case of walk and bike transport we based all indicators on qualitative analyses. In particular, we selected four elements seen as having a decisive impact on the bike modal choice: presence and quality of bike lanes, traffic intensity (Buehler and Pucher, 2012; Xing et al., 2010), average size of the roads that give access to stations, average slope of the roads within the cycling area (Dill and Voros, 2007). Regarding feeder public transport (in this case corresponding to bus transport) we roughly used the same set of indicators referred to for main transport, with the addition of indicators related to the degree of

fare integration, attractiveness and the quality of waiting places, factors that are believed to have a strong influence on public transport (Mees, 2010; Walker, 2012). In this case, if feeder public transport cannot be found, the first indicator equals to zero, thus invalidating all indicators about feeder public transport. For car-based transport, we considered the availability of car parking and its distance to the station, as factors that could influence the use of car-based transport as feeder mode. Feeder transport indicators are:

- Walking;
- Bike lanes;
- Expected traffic intensity;
- Road size;
- Road slope;
- Feeder transport;
- Feeder lines;
- Bus stop accessibility;
- Frequency (workdays);
- Frequency (holidays);
- Fare integration;
- Passenger facilities;
- Car parking;
- Car parking accessibility.

5. Results and discussion

5.1. General node-place analysis

This paragraph reports the results of the three-stage node-place analysis, with a short discussion of potential policy implications and possible planning actions (see Appendix C for the detailed information used to create the following diagrams).

According to the general node-place analysis (see Fig. 7), transport nodes are characterised by the prevalence of ‘unbalanced nodes’, meaning that, despite a medium or good accessibility by train, catchment areas are not well connected to nodes and/or land use intensity is not very high. The station of Mercato San Severino has the highest node score, while the stations of Fisciano, Baronissi, Pellezzano and Fratte have very similar Node Index, due to the substantial homogeneity of railway service along the line, with all trains stopping at all cited stations. The only exception is the small station of Acquamela, where only a few trains stop.

Regarding the Place Index, we can observe that the nodes of Mercato S.S., Baronissi and Fisciano have the highest scores, reflecting the location of these nodes within urban cores – especially Mercato S.S. and Baronissi – while the stations of Fratte, Acquamela and Pellezzano are located far from urban areas or in zones with difficult accessibility. The Fisciano station is characterised by an intermediate position between these two.

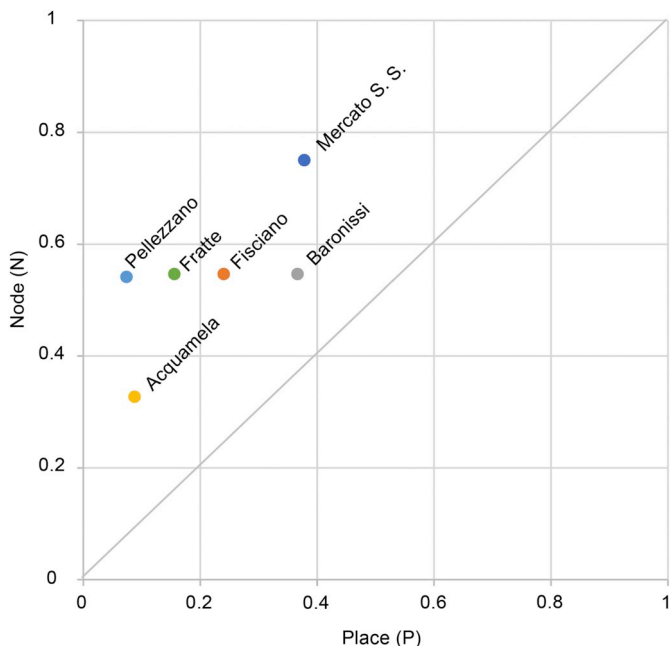


Fig. 7. Node-place analysis.

5.2. Detailed node-place analysis

The detailed node-place analysis (see Fig. 8) confirms the impression given by the general node-place analysis: ‘unbalanced nodes’

are still prevailing in each diagram, with only few exceptions, i.e. the points representing Baronissi and Mercato S.S. walking transport and areas located closer to the bisector line. These two cases are the only ones that show balance between node and place, signalling a relatively high urban density and/or a good walking environment, favoured by the location of these stations in urban centres.

5.3. Radar diagrams

The third stage of the study is represented by the radar diagrams reported in Fig. 9.

In the case of Mercato S.S., the place indicator for walk and bike is stronger than the feeder transport indicator, suggesting that actions aimed to improve feeder transport are needed. In the case of Fisciano, we can observe more balance between the three axes, but with a tendency towards a higher place indicator in the cases of bike, bus and car transport, suggesting that improvement of accessibility by these modes is needed. Fisciano University Campus falls within the bus transport catchment area, but the related place indicator is not as high as we could expect: this is probably due to the low residential and job density of that catchment area. Baronissi station is placed in the core of a vibrant, walking-friendly urban area, as reflected by the radar diagram referred to walk transport and area. Increases of urban density would require substantial improvement of main transport and feeder transport quality (except for the walking environment). Acquamela station is a single-track stop in the south sector of the municipality of Baronissi, located in agricultural areas and far from urban centres, and accordingly this node shows low values of accessibility and land use intensity. This station has a remarkable potential as area of urban development, but this would require a great improvement of main and feeder transport quality. Similarly, the Pellezzano station is characterised by good

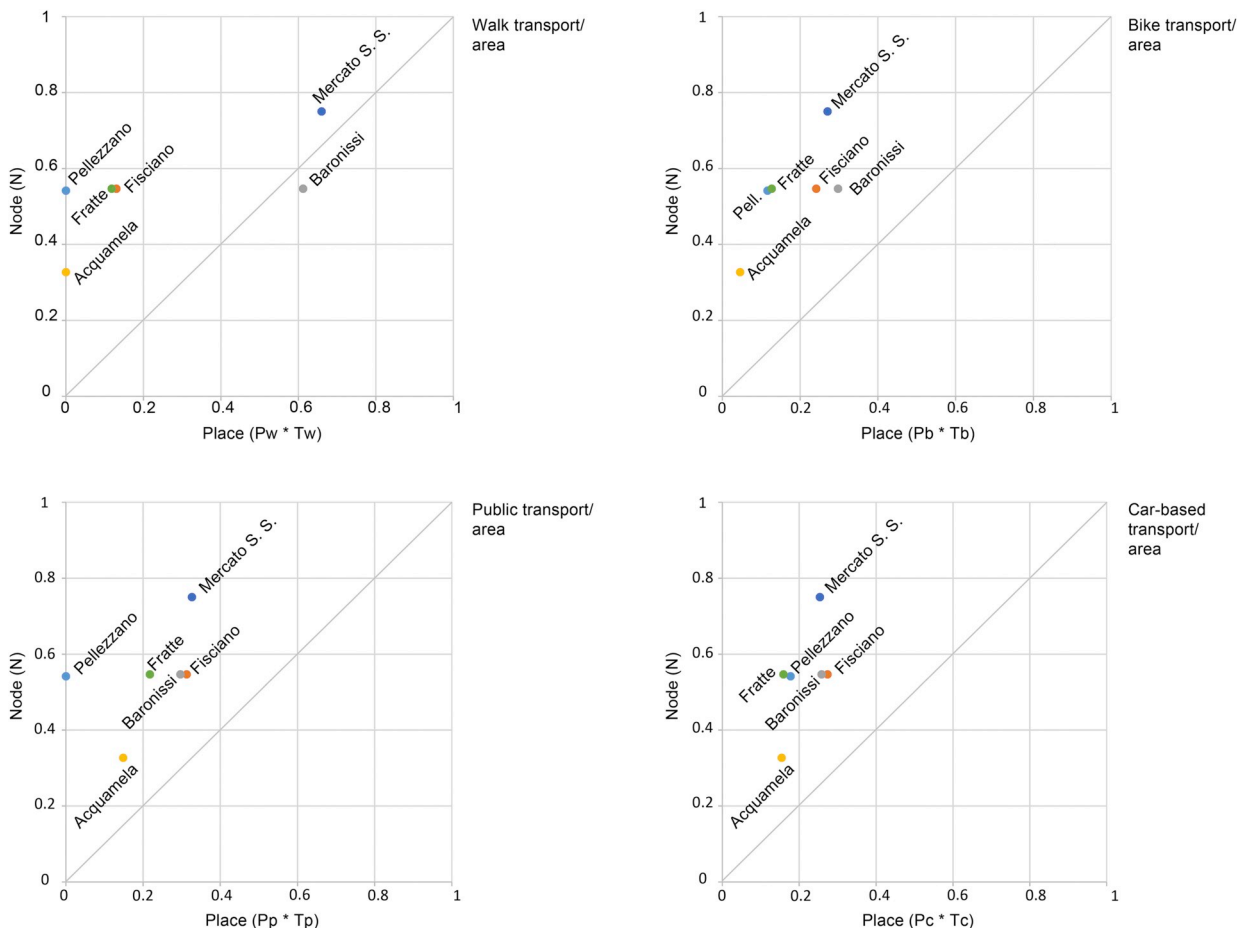


Fig. 8. Detailed node-place analysis.

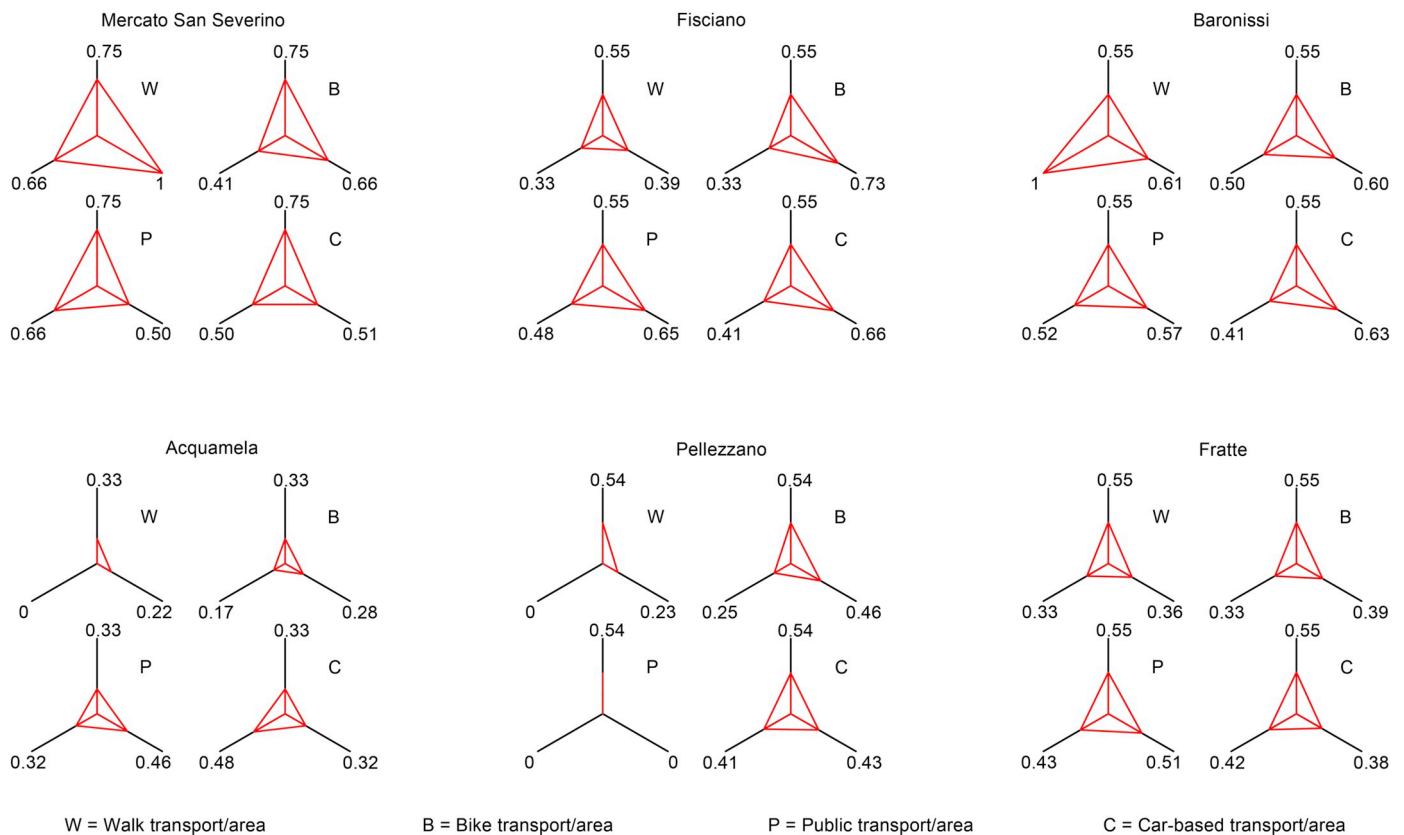


Fig. 9. Radar diagrams.

potential in terms of land use intensification, especially in the case of walk and public transport areas, but actions aimed to improve accessibility by walking and public transport are needed. In fact, the station can be reached only by a road with no sidewalks, and there are no bus lines that stop at the station. The analysis of Fratte station, showing a balance between the three indexes, indicates that an increase of urban density should be possible only with a simultaneous improvement of accessibility. In conclusion, as emerges from radar diagrams, the studied area shows medium values of accessibility – by either train and feeder transport – and medium urban intensity. Accordingly, urban intensification seems possible, even though it should go at the same pace with the improvement of transport connectivity.

It is important to remark that there is not a ‘right or ‘ideal’ balance between the aspects of accessibility and land use intensity. The aim of radar diagrams is rather to highlight potential opportunities for and disadvantages of urban development, the scope for transport improvement or reduction, or a combination of these actions. Radar charts help to disentangle how much the value of the place component is determined by the qualities of feeder transport – as they impact its geographical the extension – and how much by the land use features – as they impact density and diversity of activities within its borders – and ad how this relates to the node component.

6. Conclusions

The aim of this research was to extend the node-place analysis in order to investigate the relations between land use and public transport specifically focused on ‘non-metropolitan’ contexts. The analytic tool, based on the node-place model (Bertolini, 1999), was expanded in order to consider the role of different feeder modes and not only walking in determining the catchment area of the main transport nodes. We developed a flexible methodology that can be used both to assess the degree of land use and public transport integration and to identify planning choices that might improve it. Moreover, its application can trigger a debate about land use and public transport integration. In low-density areas, transport modes

other than walking (e.g. bike, car, other transit) are often used to reach the main transport node, and are often an essential component in the overall door to door trip. Accordingly, TOD in low-density areas needs to consider these multiple feeder transport (not just walking) in order to capture the interaction of the main transport node with destinations outside of its walking range but still within its catchment area. The focus of TOD strategies should be directed to this larger catchment area. These strategies should both include feeder transport strategies to e.g. enlarge the catchment area, and land use strategies to e.g. increase destinations within the catchment area. While essential for low-density areas, this approach could also strengthen TOD strategies in high-density areas, in the measure that access to the main transport node also there might be done by other means than walking.

We chose a case study with the following characteristics: medium urban density, poor integration between land use pattern and accessibility by ‘sustainable’ transport, remarkable transport demand coming from non-residential activities. The methodology underlined where interventions on transport network are needed and where there is potential for urban development. However, this research is characterised by some limitations. First, the quality and consistency of available data influenced the choice of indicators and the accuracy of results. Second, we could not define and operationalise the relative relevance of different qualities measured by indicators, making the necessary assumption that all characteristics have equal effect. Third, the methodology does not consider local constraints to urban or transport development that can hamper the integration between land use and public transport: their existence should be verified on a case-by-case basis. Fourth, the calculations are basic and explorative and can be refined, e.g. by controlling the variables for normality and transforming them to increase normality. Regarding data about travel time, values deduced by national statistics were used. However, as possible development of the research, we suggest the use of data coming from ‘on the field’ assessments of the access and egress times. Another aspect that could be refined is the evaluation of accessibility through quantitative indicators instead of

qualitative ones, e.g. in the case of walk and bike transport. In the paper, these aspects have been assessed mainly with qualitative indicators (e.g. quality of sidewalks, quality of bike environment), while the use of quantitative indicators (e.g. length of sidewalks and bike lanes, average road slope, etc.) would produce a more accurate assessment. Our methodological objective was to highlight transport nodes where interventions – in the urban and/or transport system – are possible, rather than identifying specific solutions. Moreover, some ‘unbalanced’ nodes could correspond to peculiar situations in which, e.g., high accessibility is necessary despite of low land use intensity, due to the presence of destinations not adequately captured by this methodology, as in the case of tourist attractions or amusement centres.

It is important to underline that, as in other node-place applications, the notion of ‘balanced’ or ‘unbalanced’ is relative to the context of the application, in this case the analysed railway corridor. While limited in size, this seems still a meaningful context, as it captures the main functional relationships and travel flows in the case study area. Additionally, we acknowledge that the calculation of the ‘General’ Place Index could be problematic, since smaller catchment areas are mostly contained by larger ones, resulting in multiple counting bias. For this reason, we introduced detailed node-place analysis where different areas are analysed separately, while the general node-place diagram, should be read as an indicator of a general pattern, which has to be inspected further. In future research, the issue of competition between feeder modes within overlapping catchment areas, and the related risk of over-estimating the overall potential transport demand of the main transport node, should be considered more explicitly. One way of doing this could be by proportionally reducing origins and destinations

located in overlapping catchment areas.

Looking at directions for future research, we expect to refine the illustrated methodology by addressing the cited limitations and by implementing it in different contexts. A possible extension of the research suggested by radar diagrams is the inclusion of more dimensions. The results would be further shared with stakeholders and decision-makers in order to receive feedbacks and acquire new insights on the practical usability and usefulness of this research. More in general, broader areas of enquiry can be sketched, for example the use of the methodology in ‘metropolitan’ areas where the accessibility by feeder modes and the interaction with a wider geographical areas are issues of concern; or the use of the methodology for specific goals, such as the assessment of the integration between train and bike, train and bus, etc. Furthermore, the methodology can be used to evaluate existing or proposed projects or planning instruments, identifying their strengths and weaknesses with respect to public transport and land use integration.

Acknowledgements

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Appendix A. Main transport

Indicators	Description	Measure unit	Score	Code
Train ^a	Directions	Number of directions served	n/MAX value	–
	Frequency (workdays)	Arrivals or departures per day on workdays	n/MAX value	–
	Frequency (holydays)	Arrivals or departures per day on holidays	n/MAX value	–
	Ticketing ^b	Ticket machine/desk	Y/N	0/1
	Node Index	–	–	Average of scores

12-minutes Isochrone area	Name	Measure unit	Score	Code
Walking area	Esteemed residential density ^c	Population/km ²	Density/MAX density	–
	Esteemed job density ^d	Jobs/km ²	Density/MAX density	–
	Number of students ^c	n	n/MAX	–
	Walking area average value	–	–	Average of scores
Bike area	Esteemed residential density	Population/km ²	Density/MAX density	–
	Esteemed job density	Jobs/km ²	Density/MAX density	–
	Number of students	n	n/MAX	–
	Bike area average value	–	–	Average of scores
Public transport area	Esteemed residential density	Population/km ²	Density/MAX density	–
	Esteemed job density	Jobs/km ²	Density/MAX density	–
	Number of students	n	n/MAX	–
	Public t. area average value	–	–	Average of scores
Car-based transport area	Esteemed residential density	Population/km ²	Density/MAX density	–
	Esteemed job density	Jobs/km ²	Density/MAX density	–
	Number of students	n	n/MAX	–
	Car-based t. area average value	–	–	Average of scores

Feeder transport	Indicator	Description	Score	Code	
Walking	Sidewalks	Quality of sidewalks	0	No presence of sidewalks	–
			0.33	Sidewalks only on some roads, generally with poor quality	–
			0.66	Sidewalks on most of roads, generally with good quality	–
			1	Every road has good-quality sidewalks	–
Walk transport average value	–	–	–	Average of scores	Tw

Feeder transport	Indicator	Description	Score	Code	
Bike	Bike lanes	Presence of bike lanes, quality of bike environment	0	No presence of bike lanes	–
			0.33	Bike lanes only on some roads, generally with poor quality	–
			0.66	Bike lanes on most of roads, generally with good quality	–
			1	Every road has good-quality bike lanes	–
	Expected traffic intensity ^f	This indicator describes, in a qualitative way, the usual traffic intensity on the roads located in the bike area	0	Very high	–
			0.33	High	–
			0.66	Medium	–
			1	Low	–
	Road size ^g	This indicator describes if the roads located in the bike area are large enough to allow the use of bike beside motorised vehicles	0	Insufficient	–
			0.33	Low	–
			0.66	Medium	–
			1	Good	–
Road slope ^h	This indicator describes the degree of slope that, on average, characterizes the roads in bike area	0	Strong	–	
		0.33	Medium	–	
		0.66	Low	–	
		1	Very low - flat	–	
Bike transport average value			–	Average of scores	Tb

Feeder transport	Indicator	Description	Measure unit	Score	Code
Public tr. ⁱ	Feeder transport	Presence of at least one line	Y/N	If the answer is NO, all other indicators in this section are invalidated	–
	Feeder lines	Number of lines	n	n/MAX value	–
	Bus stop accessibility	Distance station – bus stop	m	1- (n/MAX value)	–
	Frequency (workdays)	Departures per day on workdays	n	n/MAX value	–
	Frequency (holidays)	Departures per day on holidays	n	n/MAX value	–
	Fare integration	Degree of fare integration	n/n ^j	n integrated companies/n transport companies	–
	Passenger facilities	Waiting room	Y/N	0/1	–
		Bar/kiosks	Y/N	0/1	–
Public transport average value			–	Average of scores	Tp

Feeder transport	Indicator	Description	Measure unit	Score	Code
Car-based transport	Car parking	Car parking area	m ²	m ² /MAX value	–
	Car parking accessibility	Distance station –car parking	m	1- (n/MAX value)	–
Car-based transport average value			–	Average of scores	Tc

^a All information about train timetable are available at: https://prm.rfi.it/qo_prm/ (retrieved on 18/05/2017).
^b Source: <http://www.lestradeferrate.it/mono18.htm> (retrieved on 23/06/2017).
^c Source: ISTAT (Italian Statistical Institute), Population Census 2011.
^d Source: ISTAT (Italian Statistical Institute), Industry and Services Census 2012.
^e Sum of high school students and university students. Sources: <http://cercalatuascuola.istruzione.it/cercalatuascuola/>, <http://web.unisa.it/ateneo/statistiche> (retrieved on 22/05/2017).
^f In the study area, main roads are characterised by higher congestion. Accordingly, catchment areas embracing main roads have a score of ‘High’ or ‘Very high’.
^g Catchment areas marked with ‘Insufficient’ and ‘Low’ are characterised by many roads where bikes would interfere with the circulation of motorised vehicles and pedestrians, resulting into potential dangerous situations. On the other hand, catchment areas marked with ‘medium’ and ‘good’ embrace many roads with enough space to accommodate bike lanes, even though they are not currently present.
^h Scores of ‘Low’ and ‘Very low - flat’ represent areas where land morphology does not represent an obstacle to bike transport. Short slopes correspond to small flyovers or underpasses, while only few roads have moderate slope. Scores of ‘Medium’ and ‘Strong’ describe areas where steep roads are common, often unsuitable for bike transport.
ⁱ Source: <http://www.fsbusitaliacampania.it/#orari> (retrieved on 22/05/2017).
^j Transport companies for Italian case study: Trenitalia, Busitalia.

Appendix B. Main transport

Indicators	Value						Score					
	Mercato S.S.	Fisciano	Baronissi	Acquamela	Pellezzano	Fratte	Mercato S.S.	Fisciano	Baronissi	Acquamela	Pellezzano	Fratte
Directions	4	3	3	2	3	3	1	0.75	0.75	0.5	0.75	0.75
Frequency (workdays)	49	37	37	24	36	37	1	0.75	0.75	0.49	0.73	0.75
Frequency (holidays)	22	15	15	7	15	15	1	0.68	0.68	0.31	0.68	0.68
Ticketing	N	N	N	N	N	N	0	0	0	0	0	0
Node Index (N)	–						0.75	0.55	0.55	0.33	0.54	0.55

Place indicators		Value						Score					
		Mercato S.S.	Fisciano	Baronissi	Acquamela	Pellezzano	Fratte	Mercato S.S.	Fisciano	Baronissi	Acquamela	Pellezzano	Fratte
Walk area	Est. residential density	4695	3497	4572	317	1803	3167	1	0.74	0.97	0.06	0.38	0.67
	Est. job density	1664	730	926	245	493	663	1	0.44	0.56	0.15	0.30	0.40
	N. of students	850	0	260	370	0	0	1	0	0.31	0.44	0	0
	Walk area average value (Pw)	–						1	0.39	0.61	0.22	0.23	0.36
Bike area	Est. residential density	1821	2061	3080	1607	2922	2048	0.59	0.67	1	0.52	0.95	0.66
	Est. job density	902	475	628	156	401	442	1	0.53	0.70	0.17	0.44	0.49
	N. of students	1020	2700	260	370	0	0	0.38	1	0.10	0.14	0	0
	Bike area average value (Pb)	–						0.66	0.73	0.60	0.28	0.46	0.39
Public transport area	Est. residential density	1787	1331	2529	2576	0	1344	0.69	0.52	0.99	1	0	0.52
	Est. job density	706	401	577	333	0	922	0.77	0.43	0.63	0.36	0	1
	N. of students	1020	32,000	2960	370	0	0	0.03	1	0.09	0.01	0	0
	Public t. area average value (Pp)	–						0.50	0.65	0.57	0.46	0	0.51
Car-based transport area	Est. residential density	1272	1240	2571	1702	2045	1657	0.49	0.48	1	0.66	0.80	0.64
	Est. job density	571	284	502	162	280	277	1	0.50	0.88	0.28	0.49	0.48
	N. of students	1020	34,700	260	370	0	0	0.03	1	0.01	0.01	0	0
	Car-based t. average value (Pc)	–						0.51	0.66	0.63	0.32	0.43	0.38

Feeder transport indicators - walking

Indicator	Value						Score					
	Mercato S.S.	Fisciano	Baronissi	Acquamela	Pellezzano	Fratte	Mercato S.S.	Fisciano	Baronissi	Acquamela	Pellezzano	Fratte
Quality of walking environment	–	–	–	–	–	–	0.66	0.33	1.00	0.00	0.00	0.33
Walk transport average value (Tw)	–						0.66	0.33	1.00	0.00	0.00	0.33

Feeder transport indicators - bike

Indicator	Value						Score					
	Mercato S.S.	Fisciano	Baronissi	Acquamela	Pellezzano	Fratte	Mercato S.S.	Fisciano	Baronissi	Acquamela	Pellezzano	Fratte
Bike lanes	–	–	–	–	–	–	0	0	0	0	0	0
Exp. traffic int.	–	–	–	–	–	–	0.33	0.33	0.66	0.33	1	0
Road size	–	–	–	–	–	–	0.66	0.66	1	0	0	0.66
Road slope	–	–	–	–	–	–	0.66	0.33	0.33	0.33	0	0.66
Bike transport average value (Tb)	–						0.41	0.33	0.50	0.17	0.25	0.33

Feeder transport indicators - public transport

Indicator	Value						Score					
	Mercato S.S.	Fisciano	Baronissi	Acquamela	Pellezzano	Fratte	Mercato S.S.	Fisciano	Baronissi	Acquamela	Pellezzano	Fratte
Feeder transport	Y	Y	Y	Y	N	Y	–	–	–	–	–	–
Feeder lines	6	3	4	2	–	1	1	0.5	0.67	0.33	–	0.17

Bus stop accessibility	250	100	250	75	–	50	0.00	0.60	0.00	0.70	–	0.80
Frequency (workdays)	90	59	94	22	–	37	0.96	0.63	1	0.23	–	0.39
Frequency (holidays)	18	18	28	0	–	18	0.64	0.64	1	0	–	0.64
Fare integration	Y	Y	Y	Y	–	Y	1	1	1	1	–	1
Bar/kiosks	Y	N	N	N	–	N	1	0	0	0	–	0
Waiting room	N	N	N	N	–	N	0	0	0	0	–	0
Public transport average value (Tp)	–	–	–	–	–	–	0.66	0.48	0.52	0.32	0.00	0.43

Feeder transport indicators - Car-based transport

Indicator	Value						Score					
	Mercato S.S.	Fisciano	Baronissi	Acquamela	Pellezzano	Fratte	Mercato S.S.	Fisciano	Baronissi	Acquamela	Pellezzano	Fratte
Car parking	3100	400	1000	1450	400	450	1.00	0.13	0.32	0.47	0.13	0.15
Car parking accessibility	100	30	50	50	30	30	0.00	0.70	0.50	0.50	0.70	0.70
Car-based transport average value (Tc)	–	–	–	–	–	–	0.50	0.41	0.41	0.48	0.41	0.42

Appendix C. General node-place analysis

	Mercato S.S.	Fisciano	Baronissi	Acquamela	Pellezzano	Fratte
Node (N)	0.75	0.55	0.55	0.33	0.54	0.55
'General' place index (P)	0.38	0.24	0.37	0.09	0.07	0.16

Detailed node-place analysis	Mercato S.S.	Fisciano	Baronissi	Acquamela	Pellezzano	Fratte
Node (N)	0.75	0.55	0.55	0.33	0.54	0.55
Walk place index (Pw*Tw)	0.66	0.13	0.61	0.00	0.00	0.12
Bike place index (Pb*Tb)	0.27	0.24	0.30	0.05	0.12	0.13
Public transport place index (Pp*Tp)	0.33	0.31	0.30	0.15	0.00	0.22
Car-based transport place index (Pc*Tc)	0.25	0.27	0.26	0.15	0.18	0.16

References

Atkinson-Palombo, C., Kuby, M., 2011. The geography of advance transit-oriented development in metropolitan Phoenix, Arizona, 2000–2007. *J. Transp. Geogr.* 19, 189–199.

Austin, M., Belzer, D., Benedict, A., Esling, P., Haas, P., Miknaitis, G., Zimbabwe, S., 2010. Performance-based transit-oriented development typology guidebook.

Babb, C., Duckworth-Smith, A., Falconer, R., Isted, R., Oлару, D., Biermann, S., 2015. The performance and potential of rail stations in and outside freeway medians: the application of a node/place model to Perth. In: *Australasian Transport Research Forum 2015 Proceedings 30 September - 2 October*, . <http://www.atrf.info/papers/index.aspx> (Sydney, Australia).

Bertolini, L., 1999. Spatial development patterns and public transport: the application of an analytical model in the Netherlands. *Plan. Pract. Res.* 14 (2), 199–210.

Bertolini, L., 2005. Sustainable urban mobility, an evolutionary approach. *Eur. Spatial Res. Policy* 12 (1), 109–125.

Buehler, R., Pucher, J., 2012. Cycling to work in 90 large American cities: new evidence on the role of bike paths and lanes. *Transportation* 39 (2), 409–432.

Calthorpe, P., 1993. *The Next American Metropolis: Ecology, Community, and the American Dream*. Architectural Press, Princeton.

Caset, F., Vale, D.S., Viana, C.M., 2018. Measuring the accessibility of railway stations in the brussels regional express network: a node-place modeling approach. *Networks Spatial Econ.* 1–36.

Center for Transit-Oriented Development, 2011. *Portland metro TOD program and TOD strategic plan case study*.

Center for Transit-Oriented Development, 2013. *Transit-oriented development typology for allegheny county*.

Cervero, R., 1998. *The Transit Metropolis: A Global Inquiry*. Island Press, Washington, DC, USA.

Cervero, R., Ferrell, C., Murphy, S., 2002. Transit-oriented development and joint development in the United States: a literature review. In: *TCRP Research Results Digest*. vol. 52.

Chen, X., Lin, L., 2015. Shanghai Hongqiao air-rail hub. *Habitat Int.* 49, 445–453.

Chen, C.H., Härdle, W.K., Unwin, A. (Eds.), 2007. *Handbook of Data Visualization*. Springer Science & Business Media.

Cheng, Y.H., Lin, Y.C., 2018. Expanding the effect of metro station service coverage by incorporating a public bicycle sharing system. *Int. J. Sustain. Transport.* 12 (4), 241–252.

Chorus, P., Bertolini, L., 2011. An application of the node place model to explore the spatial development dynamics of station areas in Tokyo. *J. Transport Land Use* 4 (1), 45–58.

City of Denver, 2014. *Transit Oriented Denver: Transit Oriented Development Strategic Plan*. City of Denver, Denver, CO.

Curtis, C., 2008. Planning for sustainable accessibility: the implementation challenge. *Transp. Policy* 15, 104–112.

Curtis, C., Low, N., 2012. *Institutional Barriers to Sustainable Transport*. Routledge, London, UK.

Curtis, C., Renne, J.L., Bertolini, L., 2009. *Transit Oriented Development: Making it Happen*. Ashgate Publishing, Farnham, UK (and Burlington, Vermont, USA).

Dijkstra, L., Poelman, H., 2014. A harmonised definition of cities and rural areas: The new degree of urbanisation. In: *Regional Working Paper 2014. Working Papers (1)*.

Dill, J., Voros, K., 2007. Factors affecting bicycling demand: initial survey findings from the Portland, Oregon, region. *Transport. Res. Record* 2031, 9–17.

Dittmar, H., Poticha, S., Ohland, 2004. Defining transit-oriented development: the new regional building block. In: Dittmar, H. (Ed.), *The New Transit Town: Best Practices in Transit-Oriented Development*. Island Press, Washington, DC, pp. 20–55.

Dodson, J., Mees, P., Stone, J., Burke, M., 2011. *The Principles of Public Transport Network Planning: A Review of the Emerging Literature with Select Examples*. Issues paper. pp. 15.

Duffhues, J., Mayer, I.S., Nefs, M., Van der Vliet, M., 2014. Breaking barriers to transit-oriented development: insights from the serious game SPRINTCITY. *Environ. Plann. B Plann. Design* 41 (5), 770–791.

Filion, P., McSpurren, K., 2007. Smart growth and development reality; the difficult coordination of land use and transport objectives. *Urban Stud.* 44 (3), 501–524.

Gerundo, R., Fasolino, I., Eboli, C., 2005. Una metropolitana a servizio del Campus universitario di Fisciano. In: *Area Vasta online*, 10/11, pp. 208–219.

Großmann, K., Bontje, M., Haase, A., Mykhnenko, V., 2013. Shrinking cities: notes for the further research agenda. *Cities* 35, 221–225.

Gutiérrez, J., García-Palomares, J.C., 2008. Distance-measure impacts on the calculation of transport service areas using GIS. *Environ. Plann. B Plann. Design* 35 (3), 480–503.

Haywood, R., 2005. Co-ordinating urban development, stations and railway services as a component of urban sustainability: an achievable planning goal in Britain? *Plann. Theory Practice* 6 (1), 71–97.

Higgins, C.D., Kanaroglou, P.S., 2016. A latent class method for classifying and evaluating the performance of station area transit-oriented development in the Toronto region. *J. Transp. Geogr.* 52, 61–72.

Ivan, I., Boruta, T., Horák, J., 2011. Evaluation of railway surrounding areas: the case of Ostrava city. In: *Urban Transport XVIII-Urban Transport and the Environment in the 21st Century*, pp. 141–152.

Ji, Y., Fan, Y., Ermagun, A., Cao, X., Wang, W., Das, K., 2017. Public bicycle as a feeder mode to rail transit in China: the role of gender, age, income, trip purpose, and bicycle theft experience. *Int. J. Sustain. Transport.* 11 (4), 308–317.

Kager, R., Bertolini, L., Te Brömmelstroet, M., 2016. Characterisation of and reflections

- on the synergy of bicycles and public transport. *Transp. Res. A Policy Pract.* 85, 208–219.
- Kamruzzaman, M., Baker, D., Washington, S., Turrell, G., 2014. Advance transit oriented development typology: case study in Brisbane, Australia. *J. Transp. Geogr.* 34, 54–70.
- Krygsman, S., Dijst, M., Arentze, T., 2004. Multimodal public transport: an analysis of travel time elements and the interconnectivity ratio. *Transp. Policy* 11 (3), 265–275.
- Lee, J., Choi, K., Leem, Y., 2016. Bicycle-based TOD as an alternative to overcome the criticisms of the conventional TOD. *Int. J. Sustain. Transport.* 10 (10), 975–984.
- Lyu, G., Bertolini, L., Pfeffer, K., 2016. Developing a TOD typology for Beijing metro station areas. *J. Transp. Geogr.* 55, 40–50.
- Mecatti, F., 2010. *Statistica di base*. McGraw-Hill, Milano.
- Mees, P., 2010. *Transport for Suburbia*. Earthscan, London, New York.
- Monajem, S., Nosrati, F., 2015. The evaluation of the spatial integration of station areas via the node place model; an application to subway station areas in Tehran. *Transport. Res. Part D Transport Environ.* 40, 14–27.
- Ngo, V.D., 2012. Identifying areas for transit-oriented development in Vancouver. *Trail Six* 6, 91–102.
- Papa, E., Moccia, F.D., Angiello, G., Inglese, P., 2013. An accessibility planning tool for Network Transit Oriented Development: SNAP. *Planum* 2 (27), 1–9.
- Peek, G.J., Bertolini, L., De Jonge, H., 2006. Gaining insight in the development potential of station areas: a decade of node-place modelling in the Netherlands. *Plan. Pract. Res.* 21 (4), 443–462.
- Reusser, D., Loukopoulos, P., Stauffacher, M., Scholz, R., 2008. Classifying railway stations for sustainable transitions—balancing node and place functions. *J. Transp. Geogr.* 16 (3), 191–202.
- Schlossberg, M., Brown, N., 2004. Comparing transit-oriented development sites by walkability indicators. *Transport. Res. Record* 1887 (1), 34–42.
- Simeone, A., Papa, E., 2010. I sistemi a fune come attrattori per la valorizzazione del territorio. *Tema* 3 (3), 33–50.
- Stoilova, S., Nikolova, R., 2016. Classifying railway passenger stations for use transport planning - Application to Bulgarian railway network. *Transport Probl.* 11 (2), 143–155.
- Suzuki, H., Cervero, R., Iuchi, K., 2013. Transforming cities with transit. In: *Transit and Land-Use Integration for Sustainable Urban Development*, Urban Development Series. World Bank, Washington, D.C..
- Vale, D., 2015. Transit-oriented development, integration of land use and transport, and pedestrian accessibility: combining node-place model with pedestrian shed ratio to evaluate and classify station areas in Lisbon. *J. Transp. Geogr.* 45, 70–80.
- Vale, D.S., Viana, C.M., Pereira, M., 2018. The extended node-place model at the local scale: evaluating the integration of land use and transport for Lisbon's subway network. *J. Transp. Geogr.* 69, 282–293.
- Van Nes, A., Stolk, E., 2012. Degrees of sustainable location of railway stations: integrating space Syntax and node place value model on railway stations in the province of North Holland's strategic plan for 2010–2040. In: Greene, M., Reyes, J., Castro, A. (Eds.), *Proceedings of the 8th International Space Syntax Symposium, January 3–6, 2012, Santiago de Chile, Chile*. PUC.
- Walker, J., 2012. *Human Transit: How Clearer Thinking about Public Transit Can Enrich our Communities and our Lives*. Island Press.
- Xing, Y., Handy, S.L., Mokhtarian, P.L., 2010. Factors associated with proportions and miles of bicycling for transportation and recreation in six small US cities. *Transp. Res. Part D: Transp. Environ.* 15 (2), 73–81.
- Zemp, S., Stauffacher, M., Lang, D., Scholz, R., 2011. Classifying railway stations for strategic transport and land use planning: context matters!. *J. Transp. Geogr.* 19 (4), 670–679.