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Land use and transport integration in small cities and towns

A methodology and three study cases

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Summary

The correlation between land use planning and transport management has become, during the last twenty-five years, a subject of a specific field of study. Influenced by the concept of sustainability, and fostered by the worries of environmental and social impacts of mobility of people, the integration of land use and sustainable transport is emerging as a radical way to encourage the use of 'sustainable' transport modes. The idea of integrated land use and transport development is not new, already in the past some urban models and plans considered simultaneously the locations of urban development and the design of public transport infrastructures.

Nowadays, several cities and metropolitan areas around the world are experiencing the negative impacts of car transport's bloating, with its detrimental effects on the quality of air, congestion, occupation of urban spaces, citizen's health, etc. As reaction, administrative boards have been trying to improve sustainable transport – public transport, walking and cycling – but a more radical approach emerged in the last twenty years, an approach aiming to reshape urban form in order to harmonise land use regulations and transport design. This field of study is often labelled with the acronym of TOD – Transit Oriented Development – a 'brand' that today embraces a wide field of study, with several theoretical and practical contributions coming from different scholars, urban planners and cities around the world. Today, as response to the hypertrophy of private motorised transport, cities and metropolitan areas are struggling to apply the principles of Transit Oriented Development.

This research is part of the field of land use and transport integration, applying its principles in contexts that are, at the actual state of the art, little explored, but pose unsolved questions to planners and local administrators. These contexts have been defined 'small cities and towns', or 'non-metropolitan areas', territories with medium or low population density, scarce accessibility by public transport, static demographic and economic dynamics. Although affected by the cited issues, 'non-metropolitan areas' often participate to globalised social and economic processes, consequently showing high mobility demand, that cannot be satisfied, in many cases, by an effective public transport system. Moreover, in the cited contexts, the 'vision' of intense urban development in limited areas around public transport nodes could conflict with the desires of local communities, or with the necessity of safeguarding natural and cultural heritage. This tension between the lack of accessibility on one side, and the increasing mobility demand on the other side, entails the risk of worsening problems related to isolation and lack of accessibility, fostering depopulation and economic desertification.

Sustained by these premises and by some recent developments of the academic literature, pointing at the opportunities of transport network empowerment rather than focussing only on urban development, this thesis aims to develop a context-related approach, aiming to widen the application of land use and transport integration.

Sommario

L'interrelazione fra pianificazione urbanistica e trasporti è diventata, durante gli ultimi venticinque anni, materia di uno specifico settore di studi. Influenzata dal concetto di sostenibilità, e alimentata dalle preoccupazioni legate agli impatti ambientali e sociali della mobilità delle persone, l'integrazione di pianificazione urbanistica e trasporto sostenibile si sta affermando come approccio radicale per incoraggiare l'uso di mezzi di trasporto sostenibili. L'idea di integrazione di pianificazione urbanistica è trasporti non è nuova, già nel passato alcuni piani e modelli urbani consideravano simultaneamente la localizzazione delle aree di crescita urbana e la progettazione delle infrastrutture di trasporto pubblico.

Attualmente, numerose città ed aree metropolitane soffrono gli impatti negativi dell'esplosione del trasporto automobilistico, che ha effetti dannosi in termini di qualità dell'aria, congestione, occupazione di spazi urbani, salute dei cittadini, etc. Per contrastare tali effetti, gli organi di governo urbano hanno tentato di migliorare il trasporto "sostenibile" – trasporto pubblico, mobilità ciclo-pedonale – ma un approccio più radicale si è affermato negli ultimi due decenni, un approccio diretto a ripensare la forma urbana per armonizzare le regole di uso del suolo con la programmazione del trasporto. Questa branca è spesso etichettata con l'acronimo TOD – Transit Oriented Development – un "marchio" che attualmente comprende un vasto settore di studi, con numerosi contributi teorici e pratici provenienti da diverse parti del mondo. Oggi, in risposta all'ipertrofia del trasporto privato motorizzato, città ed aree metropolitane cercano di applicare i principi del TOD.

Questa ricerca si inscrive nel settore di studi sull'integrazione di pianificazione urbanistica e trasporti, applicando i suoi principi in contesti geografici che sono, allo stato dell'arte, scarsamente indagati, ma che pongono questioni irrisolte ai pianificatori e agli amministratori locali. Questi contesti sono stati definiti "piccole città e centri minori" o "aree non metropolitane", territori con densità abitativa medio-bassa, scarsa accessibilità con trasporto pubblico, staticità demografica ed economica. Sebbene influenzati dalle problematiche summenzionate, le aree "non-metropolitane" partecipano spesso ai processi socio-economici dell'economia globalizzata, con conseguente elevata domanda di mobilità che non può essere soddisfatta unicamente dal trasporto pubblico. Inoltre, in questi contesti, la "visione" di intenso sviluppo urbano circoscritto alle aree intorno ai nodi del trasporto pubblico può confliggere con le aspirazioni delle comunità locali o con la necessità di salvaguardare il patrimonio naturale e culturale. Questa tensione fra mancanza di accessibilità da un lato e la crescente domanda di mobilità dall'altro, comporta il rischio di aggravare i problemi di isolamento e mancanza di accessibilità, alimentando fenomeni come spopolamento e desertificazione economica.

Sostenuta da queste premesse e da alcuni sviluppi recenti della letteratura accademica, che pongono l'accento sul potenziamento del trasporto come "rete", piuttosto che sulla visione unilaterale di sviluppo urbano, questa tesi punta a sviluppare un approccio modellato sul contesto, per ampliare l'applicazione dell'integrazione pianificazione urbana – trasporti.

Chapter 1

Foreword

Contemporary territories and societies seem to be transformed by two contrasting forces. On one side, the dispersion of activities, services, households, infrastructures, that leave city centres looking for more space or minor costs. On the other side, different activities, for which are still important direct personal relationships or the prestige offered by the city centre, continue to concentrate in minute areas. It is the case of financial, cultural and amusement services and activities (Hall, 1996; Sassen, 1991).

Due to the abovementioned phenomena – dispersion and concentration – people's need to move is steadily increasing, giving to transport systems a central role in shaping urban and land use patterns. Contemporary societies express a growing mobility demand, caused by the diffusion of new lifestyles (Castells, 1996). People's everyday life is made up by several activities which, to be undertaken, require long transfers – of people and goods – from place to place. In the reality happens that, despite the development of communication technologies, mobility's demand registers a constant increase (Sheller & Urry, 2006).

Transport mode	Variation 2000-2015
Car	+7%
Motorbike	+16%
Bus	-4%
Railway	+14%
Tram and metro	+22%
Air transport	+27%
Maritime transport	-7%

Table 1. Variation of transport's demand between 2000 and 2015. Source: European Environmental Agency (2015).

According to the European Environment Agency (2015), that analysed transport's demand in 33 European Countries, in the period 2000-2009, transport's demand has grown at a rate of 9%, slowing down during the following period because of the economic turndown of 2008. Considering the overall period 2000-2015, it has grown by 8.4 %, in spite of a demographic growth of 3.7%.

In the opinion of WBCSD[1], the average commuting trips, at the global level, have increased from 3.7 km per day in 1950 to 13.1 in 1997 (WBCSD, 2001), with a prediction of growth in terms of passenger-km by 1.7% per year until 2050 (WBCSD, 2004). Mobility, thus, assumes greater relevance in contemporary societies. The reasons have to be investigated among the socio-economic and physical transformation of territories, in which the opportunities – facilities, services, etc. – are not equally distributed (Martinotti, 1999; Stead & Marshall, 2001).

Contemporary cities and territories can be seen as a system made up by three typologies of infrastructures: mobility infrastructures, environmental infrastructures and technological infrastructures. One of the main tasks of urban and regional planning is to increase sustainability,

[1] World Business Council for Sustainable Development.

competitiveness and attractiveness of human settlements. In this, mobility infrastructures play a central role, since they can provide adequate accessibility together with low environmental impact. Moreover, a change of urban and regional planning framework seems necessary, especially in those countries, like Italy, where urban development is based on road infrastructures and car transport, with distortions and negative impacts still visible today (Oliva, 2015).

Structure of the thesis

This thesis is divided into six chapters and a conclusive paragraph, as shown in this paragraph. The first three chapters deal with the research background, the theoretical and methodological aspects, chapters 4, 5 and 6 display the results of the application of this research to three selected study cases, referred to the Netherlands and Italy. The last paragraph summarizes the main findings and acknowledges the limitations of the research, sketching future developments and methodological improvements.

Chapter 1 provides an overview of the research background and the reasons behind the choice of investigating the field of land use and transport interaction, exploring the subject from an historical point of view. It also contains a broad theoretical picture of the most recent orientations in this field, providing insights of the most used methodologies.

Chapter 2 investigates the barriers and obstacles that impede the complete realisation of land use and public transport integration, highlighting how the classification and evaluation of transport nodes is believed to be one of the most effective ways to overcome these barriers. Based on an accurate literature review, chapter 2 delineates the main research question, and the geographic context of application of this research.

Chapter 3 illustrates the adopted methodology, highlighting its innovative characters in comparison to other methodologies, the possible implementation and the limitations.

Chapter 4 reports the results of the application of the methodology to the North Holland study case, clarifying the rationale behind the choice, the outcomes and the possible policy implications.

Chapter 5 is about the implementation of methodology to the Campania study case, showing how the shift from the Dutch context required an inevitable adjustment of the procedure and indicators. This study case has been chosen due to the issue of accessibility of education facilities, particularly relevant in this case. Chapter 5 also underlines outcomes and policy implications.

Chapter 6 describes the application of the methodology to the Central Italy study case, hit by a disastrous earthquake in August 2016 and now involved by a reconstruction plan. This study case aims to include, in the planning principles behind the reconstruction plan, also considerations referred to accessibility by public or 'sustainable' transport.

The conclusive paragraph highlights what was learned from the elaboration and application of methodology, what are the limitations, which could be the directions for further research.

Research background

One of the most visible effects of the industrial revolution was the huge urban growth that involved several cities of Western Europe and United States since the first half of eighteenth century. Numerous urban centres have seen a sudden increase of their population, at previously unknown rates, giving birth to increasingly large, populous and crowded cities. The rise of new lifestyles, with more needs and necessities, led to the increase of mobility demand and, together with the high population density of urban centres, determined the explosion of urban congestion. As reported by many witnesses of the nineteenth-century London, thousands of people and coaches flocked into narrow streets, heritage of the previous centuries, inappropriate to sustain a population that, in the case of the British capital city, had grown from one million at the beginning of the century to more than six million at its end.

It is probably in those years that transport issues become central in order to ensure the functionality of urban systems, and maybe it is not perchance that, during the nineteenth century, can be observed substantial improvements, if not real revolutions, in the field of transport, both for goods and for passengers. The invention of steam locomotive and the establishment of the first railway links gave the possibility to move huge amounts of goods and great numbers of passengers at unimaginable speed, if compared to coaches or river transports. In 1825, the first public steam railway was opened between Stockton-on-Tees and Darlington, in north-east England, and only twenty-five years later, in 1850, Great Britain's rail network counted more than 11,000 kilometres of railways. These figures prove the stunning success achieved by rail transport in a very brief lapse of time. In the same decades, many European countries, together with USA, experienced a fast growth of this new mode of transport (Wolmar, 2009).

The revolutionary innovations brought by the railway soon regarded the fast-growing cities, as the new mode of transport offered a tangible alternative to crowded, murky streets and slow coaches. Probably, the city of London has been the first worldwide to be involved by these events. In the British capital city, several railways termini were built, transforming urban landscape and providing fast connections to every corner of the nation. In 1863, the first underground railway opened in London between Paddington and Farrington, achieving a great success, and thus giving the spur to the realisation of new lines (Wolmar, 2004). The development of rail transport improved the connections between London and the surrounding areas and, at the same time, eased mobility within the city centre. These developments in the transport field, greatly shortening travel time between the city centre and the suburbs, allowed many people to move to satellite towns, where they could find a more pleasant residential environment, far from the overcrowded city centre where they continued to work.

In Italy, the opening of the first railway predated proclamation of Italy as unified State, occurred in 1861. In fact, the first railway was the Naples-Portici, a 7 kilometres-long railway opened in 1839 in the former Kingdom of the Two Sicilies. The political subdivision of the Italian peninsula resulted in the realisation of many separated railway networks; however, at the beginning of the 20th century the *Ferrovie dello Stato* – the national railways company – was founded, aiming to nationalise local railways and to build a national railway network (Castronovo, 2005).

Starting from this period, transport infrastructures assumed a central role in urban development, due to the constant urban growth, in terms of population and urbanisation, and due to the rise of more complex lifestyles. People started to express more desires, thus increasing the demand of transport, not more limited to house-to-work commuting, but including travels to schools, education centres, leisure activities, etc. (Moccia, 2012).

Some authors, recognizing the increasing relevance of transport infrastructures, elaborated urban models, sometimes defined 'utopic', based on the integration between mobility and urban planning, in order to reduce the huge congestion problems that afflicted the cities of the second half of 19th century (Choay, 1965). The first ones, following a chronological order, are the designs of 'garden cities' and 'linear cities'. Garden cities represent, between the end of 19th and the end of 20th century, a forerunner example of metropolitan decentralization, offering healthily and comfortable accommodations to wealthily families, sustained by the development of a metropolitan railway network (Hall, 2014; Moccia, 2012). The hypothesised *ciudad lineal*, elaborated at the end of 19th century for the city of Madrid by Soria y Mata, is more deeply focussed on transport. The original idea corresponded to the realisation of a ring-shaped urban settlement around the Spanish capital city, isolated from the urban core by parks and agricultural lands, with a total length of 48 kilometres and a width of 400 metres. In the half of the ring, an infrastructural corridor for public and private transport provided accessibility (Priemus, & Zonneveld, 2003). Even though this idea remained largely unrealised, it had a remarkable impact, at least from a theoretical point of view, in other countries. In France, in 1904, the *Association Internationale des Cités Linéaires* was established, while in the Soviet Union the linear city has been seen as a possible implementation of the socialist egalitarian doctrine. According to Hall (2014), the city of Brasilia was conceived as the intersection of two linear cities, one mostly residential and the other mostly designed for tertiary activities.

During the 1920s, the German urban planner Fritz Schumacher proposed, for the cities of Cologne and Hamburg, the development of urban centres along railways, a strategy resumed, after the Second World War, by some European cities, like Copenhagen, Stockholm, Helsinki (Wegener & Fürst, 1999). The Danish capital city, already in 1947, elaborated the well-known 'Finger Plan', which channelled urban growth along five 'fingers', i.e. five existing or planned railway corridors converging in city centre and separated by 'green wedges' (Knowles, 2012).

On the other hand, there are several 'utopic' urban models deeply 'car-based'. Among them, we can cite Broadacre City by F. L. Wright, the *Siedlung* experimentation by German architects in the first decades of the 20th century; but the most famous is probably Le Corbusier's *Ville Radieuse*. This model, elaborated during the 1930s, partly anticipates the shift from public transport to car transport that later happened. The *Ville Radieuse* model, in fact, is based on car transport, with the connections guaranteed by urban motorways, while very little attention is put on other mobility systems (Benevolo, 1985; Moccia, 2012b).

The rise of automobile and the decline of public transport

The rise of car transport produced remarkable consequences on mobility habits and modalities, on city's fruition times, on urban morphology and use of public spaces. It can be said that its impact has been stronger than the effects of rail transport. Car has become, over time, a real 'status symbol' of twentieth century and the main consumption good after the private house

(Banister, 2005). From a quantitative point of view, the success of car is undeniable, as suggested by figures about car ownership: in fact, it is esteemed that in 1960 less than 4% of world population owned a car, while in 1980 this figure had increased to 9% and today the share is assessed around 12%. Continuing with the actual growth rate, by 2020 15% of world population is expected to own a car and, given that in the next 15 years world population will probably reach 7.5 billion, the total number of vehicles will rise from 850 million to the staggering figure of 1.1 billion (Crea, 2010).

The automobile, due to the undeniable advantages offered in terms of flexibility and speed represents the main concurrent of public transport. From 1950s, the share of trips made by public transport has decreased steadily, in western countries, in favour of private motorized transport. In Europe, during the period 1970 – 2000, this rate reduced from 22% to 14%, going hand in hand the sub-urbanisation of numerous cities (WBCSD, 2001).

Consequently, from the 1950s to the 1980s, the infrastructures devoted to public transport lost their primary role, also because of urban plans aiming at the maximisation of car accessibility. Several cities experienced total or partial closures of tram, trolleybus and urban railway networks, which represented an obstacle to the increasingly intense circulation of private cars. Moreover, public transport agencies suffered a period of financial crisis, leading to the reduction of transport offer. However, the harmful impacts of car transport's hypertrophy rapidly appeared, spanning from congestion, to air and noise pollution, accidents, occupation of urban spaces, etc. Soon many local authorities realised that measures able to control car transport were necessary, therefore, after decades of stasis, they undertook policies aimed to improve public transport, with the goal of offering a real alternative to private car transport.

In some cases, the transformation or the re-arrangement of public transport infrastructures or nodes represented the opportunity to restore broad urban areas. This typology of plans, spread out during the last decades of the 20th century, deal with disused or underused infrastructural areas and design new services, offices, retails, residences. The new activities benefit from high accessibility provided by public transport services, while the convenient location guaranteed the financial balance, linked to the predictable high demand and high real estate values (Moccia, 2011b).

The revamp of public transport

During the 1980s, starting from the United States of America, public authorities started encouraging the use of public transport, spurred by the issues related to the intensive use of car transport. Public administrators, experts and academics realised, however, that the improvement of existing public transport services and infrastructures, or the opening of new lines, proved to be not sufficient for this purpose, but a global reform of the urban organism was necessary (Cervero, 1998). American cities have grown, since the 1950s, following a common pattern, with a small, central area, reserved to tertiary activities and characterised by high-rise office buildings, corresponding to the so-called Central Business District or CBD, and broad peripheries, made up by low-density residential neighbourhoods, with thousands of single-family houses with private yards and parking spaces. This kind of urban structure is made possible only by private car mobility, and discourages the realization of high-capacity public transport services, since the low residential density does not provide enough potential passengers, that are required, for example, by rail transport to be financially sustainable (Marique & Reiter, 2011). This is one of the reasons why the suburban low-density development, despite its appearance of quiet neighbourhoods and wide green spaces, is believed to be one of the most unsustainable type of urban settlement.

The need of re-thinking urban form has emerged more vigorously in the United States of America, which probably represent the country where the detrimental effects of suburban growth, together with the intense use of car, are more evident. Scholars and public administrators, especially from that country, have started to develop plans aiming to concentrate urban development in the areas close to public transport's stations and stops. This relatively recent approach is defined Transit Oriented Development, often shortened by the acronym TOD, and its first formulation dates to the 1990s, with the works of authors like Calthorpe (1993) and Cervero (1998). It can be said that TOD acronym has become a 'label' representing the most common approach to land use and sustainable transport integration.

In Europe, differently from what happened in the United States, the pre-existence of historical urban cores, with their peculiar spatial arrangement hampering car mobility, partially limited the explosive growth of car mobility and suburban development, although today European cities and regions face problems that are largely comparable to the ones experienced by American cities. For these reasons, European authorities and public administrators consider TOD principles as valuable tenets, in order to reduce the environmental impact of urban settlements (Bertolini, Curtis & Renne, 2012; Moccia, 2011b).

Sustainability, safety and transport

Before exploring the consequences of TOD's spread, a digression is needed to highlight how the concept of 'sustainability' deeply transformed the way of looking at and framing the issues related to transport. During the 1990s, the awareness of the negative impacts of transportation emerged, especially from the environmental point of view. The concept of sustainable development, carried out by the Brundtland Report in 1987, has influenced the way of looking at transport sector (Langhelle, 1999). Many local public authorities have started plans and policies aimed to boost transport modalities with lower impacts, sometimes reaching incomplete and unsatisfying results (Cartenì, 2014); anyway, these actions increased the consciousness about transportation's 'side' effects (Banister, 2005), leading to the emergence of a 'sustainable mobility model' (Banister, 2008). This approach aims to satisfy mobility needs and, at the same time, to reduce negative impacts of mobility itself. However, it is not devoid of contradictions, and the real implementation of sustainable mobility's principles has highlighted, in many cases, several obstacles and barriers (May & Marsden, 2010).

According to European Environmental Agency (2015), in the 28 countries of European Union, transport sector is the only one, among main economic sectors, that did not reduce its greenhouse gases' emissions during the period 1990-2013. Conversely, they increased by 19.4%, despite the economic downturn of 2008.

According to Intergovernmental Panel on Climate Change (2007), private motorised vehicles represent around 23 per cent of global greenhouse gas emissions. Thus, operating on emissions caused by transport would represent a fundamental action in order to reach the objectives of sustainability and reduction of polluting emissions, also ratified by international agreements. These figures lead to meditate on the effects that transports have on air and urban environment quality.

It is worth remembering transport's socio-economic effects. In fact, passenger transport shows levels of risk linked to accidents, noticeably different according to transport modalities. The comparison between different transport modes from the perspective of safety is not an easy task, the few studies in this branch refer to the entirety of passenger transport modes, without distinction between urban and extra urban trips (Evans & Addison, 2009). However, some differences are clearly underlined: railway and bus transport usually obtain the lowest values in terms of deadly accidents (Rumar, 1999)

Mode		per 100 million person kilometres	per 100 million person/hours
Road	Total	1.1	33
	Bus	0.08	2
	Car	0.8	30
	Foot	7.5	30
	Cycle	6.3	90
	Motorcycle/moped	16.0	500
Others	Train	0.04	2
	Ferry	0.33	10.5
	Air	0.08	36.5

Table 2. Estimates fatality risks per person kilometres and hours for each transport mode in EU. Source: Rumar (1999).

In the light of these figures, the fatality risk can be considered an additional factor of distinction between public and private transport, inasmuch it shows very low values in the case of public transport and higher values in the case of private motorized transport.

The polluting emissions linked to transport activities indirectly affect global climate (Unger et al., 2010), but also have direct effects on human health. Almost all the motorized transport modes produce, with their functioning, a certain quantity of gases and particulates potentially harmful for human health. However, also in this case, remarkable differences exist among the different transport modes, in terms of not only energetic efficiency, but also regarding the localisation of polluting emissions. Transport modes that use electric traction – electrified railways, trams, trolleybuses, electric cars – can concentrate energy production in efficient power plants located outside urban areas, separating emission sources from densely populated centres. Moreover, technological evolution could improve the usage of energy coming from renewable and low-impact sources, as it is happening in the case of car transport (Romm, 2006).

Nitrogen oxides, sulphur oxides and micro-particulates, produced by combustion processes, are the main responsible for the harms to the human respiratory system; it is esteemed that the polluting emissions, of which a substantial proportion comes from transports, provoke more than 400,000 premature deaths each year in Europe (European Environmental Agency, 2015).

Acoustic pollution represents an additional threat to human health. According to European Environment Agency (2014), 125 million European citizens suffer a potentially damaging level of acoustic pollution produced by road traffic. The quantity of people affected considerably decreases if other sources of acoustic pollution are considered: in fact, about 10 million people are exposed to noise coming from railways and about 5 are exposed to noise produced by air traffic. Such pronounced differences can be explained by the different locations of the cited transport modalities, with road transport noise that, due to its capillarity, inevitably affects a higher rate of population. Those considerations, regarding polluting gases emissions and acoustic pollution, seem to be a further factor in support of policies and actions aimed to limit the growth of individual motorized mobility and foster, at the same time, public and non-motorised transport.

Many scholars highlight that not all transport modes have the same impact, in particular from the point of view of polluting emissions and energy consumption. From the energetic point of view, rail-based modes are the most efficient ones, due to their physic characteristics, that entail, for example, a minor friction opposed to motion. It has been calculated that lorry transport shows a specific energy consumption fifteen times higher than railway transport; about passenger transportation, according to mobility measure criterion, car transport is two to three times less efficient than railway transport (Usón, Capilla, Bribián, Scarpellini, & Sastresa, 2011).

Due to the reasons linked to energy consumption and safety, a rough distinction can be sketched between urban transport modes with higher rates of consumption and less safety – like car, motorbike – and, on the other side, transport modes with better performances in terms of efficiency end safety – bus, train, metro, tram, and collective transport in general.

It can be argued that, when discourses about sustainability in transport are made, they should encourage the shift from individual motorised transport – car and motorbike – to collective and public transport, and to increase safety of individual non-motorised transport, – walking and cycling. In this thesis, the aforementioned distinction will be used in order to distinguish 'unsustainable transport modes', i.e. individual motorised modes, from 'sustainable transport modes', i.e. public transport, walking and cycling. However, the aim of this research is not 'to fight against cars', but is to help in shaping an integrated framework between transport and the localisation of activities and population, where different transport modes should work in cooperation rather than in competition.

Urban system and transport system in the age of urban transformation

As recently highlighted by Bertolini et al. (2012), starting from the 1980s, in Europe, several urban redevelopment plans have been produced, regarding areas close to railway nodes. These plans principally involved the main railway stations of the bigger European cities. Some examples are Liverpool Street Station and King's Cross Station in London, Gare de Montparnasse and Gare de Lyon in Paris, Euralille in Lille, Stuttgart 21 in Stuttgart and the central station of Utrecht. In other cases, urban redevelopment came together with new public transport infrastructures. It is the case of the well-known London Docklands, whose urban transformation into a financial district entailed the realisation of the Dockland Light Railway and the Jubilee Line (Moccia, 2012b), or the new financial district of Zuidas in Amsterdam, built around the railway node of Amsterdam Zuid station (Jacob Trip, 2008).

Bertolini et al. (2012) provide an excursus of the operations of urban re-development occurred, in the last three decades, around railway nodes of European cities. They identify six 'guiding forces' that act as catalysts: the technological innovation of railway infrastructure, the technological innovation of industrial sites, the privatization of railway companies, public policies increasingly directed to boost the attractiveness of neighbourhoods and cities, the struggle for sustainable development patterns, the spatial dynamics of contemporary cities, with more complex demands expressed by citizens, city users and firms. According to them, the interventions realised in Europe in the last three decades can be classified into three categories, differentiated on the basis of dimension, typology of city involved, promoters of the initiative, predominance of one or more abovementioned 'guiding forces'. The categories are private investments, urban mega-projects, Transit Oriented Development. The interventions belonging to the first category reply to the demand, expressed by railway companies, of maximising the profits coming from urban re-development of brownfields located in the surroundings of stations. This approach had its maximum spread in United Kingdom during the 1980s, when railway companies had to cope with a drastic reduction of national funds devoted to public transport, and the privatisation of many public transport companies. An emblematic example of this strategy is Broadgate, the urban district developed around Liverpool Street station in London, which took advantage of its central location and of the favourable conditions of real estate market. Similar projects, as King's Cross in London, Gare de Montparnasse and Gare de Lyon in Paris, have not been able to repeat the success obtained by the urban re-development of Broadgate. In Italy, a policy of refurbishment of main stations can be recognised, whose distinctive aspect corresponds to the insertion of shopping facilities inside railway terminals with the aim of reducing conflicts linked to redevelopment projects (Moccia, 2011a).

The second typology of interventions, common during the 1990s, corresponds to the category of 'Urban mega-projects'. It differs from the earliest since it is founded on the improvement of railway infrastructure, e.g. the inauguration of high-speed lines, on the strategies pursued by public local authorities aimed to increase urban attractiveness, and on new lifestyles. This typology of interventions struggle to take advantage of the high-speed railway nodes in order to localise, in their surroundings, new facilities and services. In this case, national and local public authorities act as promoters, while private developers have a secondary role. As emblematic example Bertolini et al. (2012) cite Euralille station in Lille, France, which success is partly due to the favourable position of the city of Lille, easily accessible from Paris, London and Bruxelles.

The third category defined by the authors is Transit Orieted Development. This approach is focused on environmental sustainability as 'guiding force'; moreover, it is boosted by the infrastructural improvement of metropolitan mobility systems. The intervention scale changes, embracing entire urban and metropolitan systems rather than single transport nodes. From a chronological point of view, this approach has started to spread at the beginning of this millennium, preventing an exhaustive evaluation of its implementation's effects. Among the examples reported, can be cited the *Stedenbaan* Plan, involving the south wing of the Randstad Conurbation, in the Netherlands, and the 'Regional Metro' Plan in Campania Region, Italy. As already sketched, the attempt to integrate urban planning and transport is not a European prerogative, but can be found in many countries, from North America to Far East countries and Australia (Cervero, 1998; Dittmar & Ohland, 2004). In each context, the guiding principles are very similar: on one side, the goal is to concentrate urban development – i.e. residences, jobs and facilities – around public transport nodes, preferably railway transport, in order to promote the ridership of transport modalities with lower environmental impact. On the other side, it is necessary to improve public transport networks to reach existing urban settlements and connect them with planned and new urban developments, aiming to provide good accessibility by public transport.

Land use and public transport integration

As explained in the previous paragraphs, the relationships between public transport and urban spaces is attracting increasingly attention. Scholars, public authorities and planners are becoming aware that transport systems and land use are deeply intertwined, though transport choices and spatial planning strategies are often un-coordinated. Therefore, the harmonisation of transport and land use planning is becoming one of the most recurrent approaches, aiming to reduce the environmental impact of human settlements, to provide better accessibility, encourage the shift towards more sustainable transport choices.

TOD

As already sketched, some authors elaborated the concept of Transit Oriented Development, which has become a 'label' embracing the concept of land use and public transport integration. Even though does not exit a univocal definition of TOD, it can be said that its main goal is the integration between public transport and urban settlements (Knowles, 2012). Through the management of land-use, it encourages urban development around transport nodes – railway and metro station, tram and bus stops – and suggests adopting medium or high-density urban structure.

Among TOD's goals, we can recall the creation of liveable, walking/cycling friendly urban spaces and the reduction of car usage that has proved to have several negative effects. Even if a unique definition of TOD cannot be declared, we can sketch its main aspects, that stem from the studies of Calthorpe (1993), Cervero et al. (2004), Dittmar & Ohland (2004). These authors, recognizing the environmental and social unsustainability of the actual urban and transport pattern in North American cities, elaborated an alternative model that aims to integrate land use planning and public transport management. The main goal of TOD is to build liveable neighbourhoods, i.e. urban areas in with adequate pedestrian and cycling paths, a relevant mix of functions and a sufficient density of residences and jobs. These neighbourhoods should be connected to high-quality public transport network, firstly rail transport. Thus, according to TOD principles, urban development should be focussed around transport stations and stops in order to offer a relevant substitute to car transport and to maximise the ridership of existing public transport services (TransLink, 2012). The supporters of TOD imagine, therefore, to build high density, pedestrian/cycling friendly, functionally diversified urban districts within 'walking distance' from rail stations or bus stops. They oppose this concept to the typical residential suburban areas, dominated by single-family houses, only accessible by car, without basic services, like small stores or facilities, thus forcing people to an intensive use of car. This pattern of suburban development has been highly criticised by numerous American scholars, like Jackson (1985), Duany, Plater-Zyberk & Speck (2001).

Some authors underline that development around railway nodes is preferable to development around bus station or other public transport modalities, because of the greater environmental efficiency of railway transport. Therefore, TOD is considered a viable strategy against suburban growth, but it could also have positive effects on the financial wealth of transport agencies, due to higher transport ridership. The areas closer to stations, defined 'station areas', become prime location for urban development. TOD aims to realise a medium-to-high urban density, compact urban areas with an adequate level of functional mix, designed to maximise accessibility by public and non-motorised transports.

The following list summarises the main characteristics of an urban settlement oriented to public transport, according to Victoria Transport Policy Institute[2].

- Presence of a public transport's station or stop, with a good safety level, pleasant waiting spaces, small retail activities.
- Roads and blocks designed to encourage walking and cycling.
- Roads with traffic-calming systems.
- Functional mix, embracing retails, schools and other public services, residences differentiated by typology and size.
- Parking management, in order to reduce the quantity of parking areas.

Medium to high urban density values are needed in order to provide a sufficient number of passengers, able to sustain a high-frequency service (Suzuki, Cervero, & Iuchi, 2013); moreover, urban density itself reduces distances between residences, jobs, retails, facilities, thus making them reachable by walking or by bike. Not all transport modalities have the same effects in terms of attractiveness: it has been observed that passengers using railway transport are willing to walk much longer distances to reach the station in comparison, for example, to bus passengers. This is explained by the greater speed of railway transport, by the fact that stations are usually more comfortable than bus stops, etc. (Daniels & Mulley, 2013).

The concept of TOD, early formulated in the United States of America, rapidly spread across Europe, Far East countries and Australia. Its first form, initially developed by American scholars and mostly focussed on urban scale, has been extended to urban and regional contexts. In Europe, the TOD approach has met some eminent examples, which date back to the first half of the past century, like the Copenhagen's 'Finger Plan' (Knowles, 2012) or the Stockholm's network of satellite cities (Stojanovski, Lundström, & Haas, 2012). These cities planned their expansion along transport corridors, in particular along railways, foreseeing the importance of providing an adequate level of public transport accessibility.

In the Netherlands, some public authorities started policies and projects aimed to implement TOD principles. Among them, one the most frequently reported is the so-called *Stedenbaan* plan, implemented in the Randstad's south wing, a polycentric urban area embracing

[2] Definition by Victoria Transport Policy Institute – http://www.vtpi.org/tdm/

Rotterdam, The Hague, Dordrecht, and Gouda. *Stedenbaan* does not plan to build new rail or metro links, but takes advantage of the realisation of a new high-speed railway, opened in 2008, running from Amsterdam to the Belgian border, which allows to improve frequency of intercity and 'sprinter' trains along the existing regional railways, relieved from international and high-speed train traffic. The objective is to provide a metro-like service in 34 existing stations and 13 planned ones along the railway links Schipol-Dordrecht, The Hague-Gouda and Rotterdam-Gouda, while regional and provincial authorities are pursuing an urban development strategy aimed to intensify urban development around railway stations (Balz & Schrijnen, 2009).

In Italy, even though a real TOD strategy cannot be recognised, the most populous metropolitan areas have tried – or are trying – to focus urban transformations on railway infrastructures. The cities of Rome and Naples, for example, have started in the 1990s a period of urban planning reform, explicitly considering accessibility by public transport in their planning strategies[3] (Cerrone, 2013; Comune di Napoli, 2003), with only partial achievements. More recently, the city of Milan has elaborated a strategy aiming to transform dismissed rail yards into parks and public spaces[4], while the city of Turin is realising the 'Spina project' a urban redevelopment project linked to the transformation of a long section of railway running in the central area of the city into an underground by-pass, obtaining new urban spaces and reconnecting the neighbourhoods once split by the railway line (Comune di Torino, 2017).

A wide literature exists about the advantages of Transit Oriented Development. Some scholars underline that people living in transit oriented urban areas, in comparison to people living in conventional, car oriented, districts, own less cars, travel less by car, use more public transport, prefer alternative transport modes – walking, cycling, taxi services, car-sharing, car-pooling, etc. Urban areas oriented to public transport, if compared to conventional urban areas, can halve the quantity of trips made by car (Cervero & Arrington, 2008).

Studies led in the Region of Portland, capital city of Oregon, USA, have shown that areas served by high-quality public transport, with a good degree of functional mix, obtain the highest rates in terms of public transport ridership and, at the same time, lowest rates of car usage, number of cars per household and vehicle miles travelled or VMT (Portland Bureau of Transportation, 2009). A study published by the Center for Transit-Oriented Development (2010), referred to Chicago Region, have pointed out that households dwelling in neighbourhoods oriented to public transport produce 43% less greenhouse gases. According to these studies, policies in sustain of public transport oriented development could led to a reduction of greenhouse gases' emission by 36% across the entire region.

[3] In the city of Rome this approach was summarised by the motto *La cura del ferro* (The iron therapy); while in Naples the new urban plan was accompanied by the '100-stations plan'.

[4] Blog post: Milano | Scali Ferroviari: Stefano Boeri ci racconta "Un fiume verde per Milano" Retrieved from http://blog.urbanfile.org/2017/04/12/milano-scali-ferroviari-stefano-boeri-ci-racconta-un-fiume-verde-milano/

Land use type	Mode Split: Auto	Mode Split: Walk	Mode Split: Transit	Mode Split: Bike	Mode Split: Other	Daily Vehicle Miles per Capita	Auto Ownership per Household
High Freq. Tr./Mixed Use	58.1%	27.0%	11.5%	1.9%	1.5%	9.8	0.9
High Frequency Transit Only	74.4%	15.2%	7.9%	1.4%	1.1%	12.4	1.5
Remainder of Multnomah Co.	81.5%	9.7%	3.5%	1.6%	3.7%	17.3	1.7
Remainder of Region	87.3%	6.1%	1.2%	0.8%	4.5%	21.8	1.9

Table 3. Effects of public transport and land use mix on modal split. Source: Portland Bureau of Transportation (2009).

Kimball, Chester, Gino & Reyna (2013) esteem the effects of public transport oriented development, using the Life Cycle Assessment approach in order to evaluate the environmental impacts of products, processes, services and activities, including the impacts caused by the realisation and maintenance of buildings and transport systems. This study analyses the urban re-development program carried out by the city of Phoenix, in the USA, where the administrative board has decided to develop the areas close to suburban railway's stops. The results show that the city of Phoenix, through the building of 200,000 residential units in stations' catchment areas, can contribute by 7% to the objective of Arizona's overall greenhouse gases reduction, in addition to obtain advantages in terms of air quality improvement and reduction of energy consumption.

These figures help giving an overview of expected advantages of land use and public transport integration. In the following paragraphs, some terminological and methodological aspects of this field of study are clarified, also illustrating the node place model, an assessment tool used to evaluate transport nodes performances.

Catchment area

The distance that people are willing to travel to reach transport nodes[5] is a fundamental parameter in studies about land use and public transport integration, in fact this value is used as basis in order to define stations' 'catchment area'. Usually, it is assumed that passengers of railway transport are willing to walk half mile – about 800 metres – while for bus lines' passengers this value decreases to a quarter mile – about 400 metres. Such distances are obtained on the basis of walking speed, evaluated between 1 and 1.5 m/s (respectively 3.6 and 5.4 km/h): therefore travel time for 400 metres falls between 7 and 4.5 minutes, while 800 metres are covered in a time between 13 and 9 minutes. Longer times, and distances, are considered not convenient and discouraging the use of public transport (Calthorpe, 1993); nevertheless, there is not unanimous consensus on the correct value (Guerra, Cervero, & Tischler, 2012).

[5] Distance between the origin/end of travel – e.g. home, school, workplace, etc. – and transport node – railway or metro station, bus or tram stop, etc.

Therefore, in TOD studies, stations' catchment areas correspond to a circle with their centre on the transport node and a radius of a measure between 400 and 800 metres, sometimes reaching 1000 or 1200 metres. Beyond the debate around the value of circle's radius, it must be reported the dispute about the shape itself of stations' catchment area. The circular shape is believed, by most of the authors, to be a good approximation of the 'real' catchment area, due to the thick road network that can be found in urban areas; furthermore, it represents a simple and direct way to define catchment areas. However, some authors note that stations' catchment areas are influenced by the design of road network, by the quality of pedestrian paths, etc., arguing that these factors cannot be ignored. In sustain of these statements, they cite or develop studies aimed to re-design catchment areas based on the quality of road and pedestrian network, using an approach that has been defined 'network distance' approach (Gutiérrez & García-Palomares, 2008), or 'isochrone' approach (O'Sullivan, Morrison, & Shearer, 2000). The comparison between circular catchment areas and areas obtained with isochrones shows remarkable variations (Walker, 2012).

The relevance of the debate around the shape and the extension of catchment area can be explained by the fact that, in many cases, the delimitation of these areas is crucial to individuate which residents, workplaces, activities are considered part of the 'place' around transport nodes, participating to the evaluation of transport nodes' performances. Therefore, the adoption of the 'Euclidean' approach or 'isochrone' approach in delimitating catchment area is not a secondary choice, and the researcher should ponder about it on the basis of the context of implementation.

The node place model

In the branch of land use and public transport integration, the node place model introduced by Bertolini (1999), is often used to assess the degree of integration between transport and land use. The node place model describes public transport's stations and stops on the basis of transport service's quality and land use density of the areas located close to stations themselves. According to Bertolini (1999), in fact, each station or stop can be defined, at the same time, as a 'node' within transport network and a 'place' within urban context. It is a node because people use it to physically access to transport, and it is a place because people carry out several activities in the 'catchment' areas (Bertolini, 1999).

Each node is different: within a transport network there are hierarchies, sometimes very pronounced, regarding nodes' accessibility. As intuition suggests, a metro stop, with frequent trains, is much more accessible than a small railway station placed along a secondary railway line, where only few trains call. Also from the point of view of the 'place', remarkable differences can occur: a station located in the city centre, with high levels of urban density and functional mix, offers many more opportunities in comparison to a station located in a rural area with low residential and functional density. Each station is, thus, classifiable on the basis of node's degree of accessibility and residential and functional density and mix of station's catchment area; this twofold classification is translated into two indexes: 'node' index and 'place' index. A xy diagram is used to display the results, in which the x axis represents the place value, while the y axis represents the node value.

Each station, once classified, is represented by points on the xy diagram. The points located close to the bisector line, in the central sector of the diagram[6], are those that show an equilibrium between node and place indexes. This means that transport service matches the quantity of residents and activities located within station's catchment area. Points located close to the bisector line, but placed in the top-right and bottom-left sections of the diagram[7] respectively represent 'stress' and 'dependence' situation. In the first case – 'stress' – high level of accessibility is registered together with high urban density, while in the second case – 'dependence' – low accessibility is matched with little urban density. Stations that fall outside the 'balance sector' of the diagram could show a disequilibrium in the sense of node or place. A prevailing node index means that, despite good accessibility, the areas surrounding the node are characterised by low urban density (unbalanced node). Conversely, if place index outreaches node index, the station area shows an intense land use patters, while transport service is insufficient (unbalanced place).

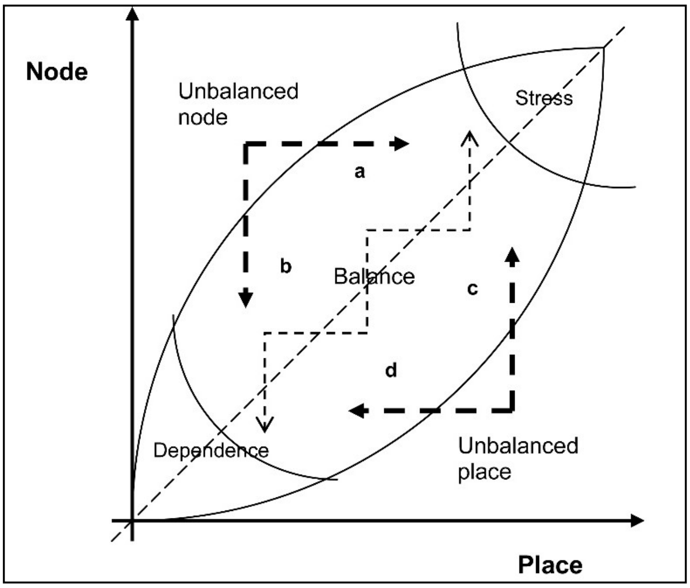

Figure 1. The node place model. Source: Bertolini (2005).

This way of classifying transport nodes can be the basis on which elaborate suggestions to policy makers, like transport companies and urban planners, and sketch integrated land use and transport planning strategies. Looking at figure 1, dashed lines represent the possible directions that a transport node could follow in order to move close to the bisector line, i.e. a situation in which transport offer and land use intensity are more in balance. In the case of unbalanced node, where high accessibility meets low urban density, the policy could correspond to an increase of 'place', in order to increase the quantity of people, jobs and activities in the catchment area (arrow a). Otherwise, if particular constraints impede urban transformations, the alternative option could be (arrow b) the decrease of 'node', i.e. transport offer represented by number of trains per day, service time, etc. The reasons beyond the last choice can be financial or environmental: in fact, to provide a very frequent service in a node where transport demand is not so high, could represent a

[6] In Figure 1 these areas are indicated as 'balance'.
[7] In Figure 1 these areas are indicated as 'dependence' and 'stress'.

waste of financial resources – that should be destined to more urgent purposes – fostering a useless consumption of energy.

In the case of unbalanced place, e.g. represented by small stations serving dense and fast-growing cities, the balance can be reached by increasing node index, i.e. service speed, frequency, reliability (arrow c) or by operating on land use regulations in order to decrease urban pressure, reducing the value of place index (arrow d).

The described strategies are referred to transport or land use aspects but, in reality, policies and decisions often embrace these two aspects, or they consider different temporal steps, as can happen in urban development plans where transport infrastructures have to be realised first. It is important to underline that, sometimes, peculiar conditions lead to accept an 'unbalanced' situation, like in the case of railway stations serving airports where, despite the low residential density of the catchment area, a very frequent service is needed in order to ensure an adequate accessibility level. For these reasons, the classification of transport nodes should be considered a tool that has to be used carefully, since its outcomes cannot be translated automatically into transport or land use planning choices.

Chapter 2

Research framework

This research is part of the wide debate about the integration of land use planning and public transport management. In the last twenty years, in many countries over the world, concerns have grown about the increasing mobility demand linked to economic and demographic growth, concentrated in the urban areas (Castells, 1996; Sheller & Urry, 2006). At the European scale, even if the urban population is substantially steady, there is an increasing mobility demand, which cannot be satisfied only by private mobility. This, in fact, has several negative consequences in terms of greenhouse gases emissions, accidents, acoustic pollution, congestion, etc. The contribution of private motor vehicle to the total amount of emissions represents, according to Intergovernmental Panel on Climate Change (2007), 44% of transport sector emissions and roughly 23% of overall greenhouse gas emissions.

For these reasons, many European municipalities, in particular governing bodies of metropolitan areas, are undertaking efforts directed to enhance public transport and offer a viable alternative to car transport. This approach is part of a wider strategy, which aims to increase the sustainability of human settlements. The reduction of transportation impact, in fact, can play a key role in the reduction of the impact of human settlements.

Over time, has become clear that the policies directed to improve the public transport offer – i.e. new infrastructures, frequency increases, new and more comfortable vehicles – had only limited effects on public transport ridership. Mainly for these reasons, several authors claimed the necessity of a better integration between public transport and urban areas. In the first half of the 1990s, Peter Calthorpe (1993) coined the acronym TOD – Transit Oriented Development – to identify a different approach to urban development, which aims to build more liveable – e.g. pedestrian and cyclist friendly – urban communities around transport nodes. The main issue faced by Calthorpe is the dominant role that car has in American cities from the end of World War II. The high rate of motorization that characterizes American society is tightly linked to the suburban sprawl, an urban morphology that has high environmental impact, frustrates social life, and limits the development of public transport.

Many cities in the USA, Europe and Australia experimented a suburban growth, with issues largely comparable to the ones criticized by Calthorpe and the supporters of TOD. For these reasons, several municipal boards started TOD programmes to increase public transportation ridership and limit car mobility.

Encouraged by the perspective of a radical solution to problems like congestion and pollution, and by the possibility to offer attractive places for real estate investments, several cities and metropolitan areas around the world have started to implement land use and public transport integration programmes and plans (Bertolni et al., 2012; Cervero, 1998; Cervero et al., 2004). The shift from theory to practical application has highlighted the existence of many barriers and obstacles that can prevent the realization of the principles of integration. Some scholars focus on the institutional or communication obstacles, other underline the advantages of the assessment of actual and potential performances of transport nodes.

Some authors underline that the classification of transport nodes can be an effective tool to overcome implementation barriers. As highlighted by Kamruzzaman, Baker, Washington, & Turrell

(2014), TOD typologies have several advantages, for example help policy makers and stakeholders to create common sets of strategies, enable comparisons between nodes, allow assessing an acceptable balance between uses, density and transport service against a pre-determined set of objectives. These evaluations are based on the concepts of 'node' and 'place' performances, introduced by Bertolini (1999) respectively measuring transport quality and land use intensity.

As will be clarified in this chapter, the literature review underlined that several studies apply TOD typologies to metropolitan areas and densely populated contexts. The aim of this research is to extend the implementation of TOD typologies to 'non-metropolitan areas' that often show unsustainable transport pattern and low levels of accessibility by public transport, with many negative consequences from the environmental, social and economic point of view.

Barriers to TOD

Some authors recognise that there are many barriers that impede the realization of TOD principles (Bertolini et al., 2012). Van Vliet (2000) and Banister (2005), underline that the obstacles can be identified with conflicting interests and complexities that are common in the branches of land use and transport. The obstacles can be institutional, political, financial, legislative, or they can involve skills and information (May & Marsden, 2010). Curtis (2008) reports the study case of 'Network City' in Perth, Australia, as an example of the challenges linked to the implementation of a TOD spatial framework. Curtis lists the barriers that had to be overcome in that specific case: the absence of a national policy framework supporting TOD, the weakness of regional planning system, the little awareness shown by transport agencies of their role, the inadequate approach to planning practice, the conflicts with communities and stakeholders. Thomas & Bertolini (2014) bring out sixteen 'Critical Success Factors', whose deficiency can affect the implementation of TOD programmes, as shown by the analysis of eleven study cases among European, North American and Australian cities. The Critical Success Factors can be grouped into three categories: plans and policies, actors, implementation. They are: policy consistency, policy stability, government support, national political stability, local political stability, actor relationships, regional land use-transportation body, inter-municipal competition, multidisciplinary implementation teams, public participation, public acceptance, key visionaries, site-specific planning tools, regional level TOD planning, certainty for developers, willingness to experiment.

Some authors focus on institutional barriers as the major impediment in turning TOD tenets into practice (Rietveld & Stough, 2005). These include, for instance, the lack of coordination between zoning policies and transport strategies that prevent mixed and dense developments along railway corridors (Leinberger, 2009), even though the demand for walkable and well-connected neighbourhoods is growing (Broberg, 2010). Te Brömmelstroet and Bertolini (2010) underline the wide differences existing between the branches of land use and transport, which impede an easy communication. These differences refer to planning objects (places vs. networks/flows); tools (spatial GIS vs. mathematical transport models); operational modes (holistic visioning vs. optimizing problem solving).

As claimed by Bertolini et al. (2012), the integration between land use and transport planning is a complex challenge, since it involves many different actors and stakeholders – public transport agencies, local and regional government boards, public transport passengers, developers and investors, private citizens in general – whose goals are often divergent when not conflicting. For these reasons, they cite some strategies that are considered exemplar in the implementation of TOD principles. On the basis of some practices led by Australian cities, Newman (2005) lists among the characteristics for a successful planning strategy the 'existence of a strategic planning framework that asserts where centres need to occur, in what density and mix, and links these centres with a rapid transit base, almost inevitably with electric rail'. The practical experiences reviewed by Bertolini et al. (2012), confirm this statement: in the cases of most successful TOD implementation, such as Singapore and Tokyo, a strategic planning framework is necessary to achieve a sufficient level of coordination among the station areas involved into the development process.

Evaluation of transport nodes

Some authors individuate the evaluation and classification of transport nodes as an effective tool in order to shape scenarios of land use and public transport alignment, often referred to a study case. The classification leads to the building of typologies, which have several advantages, as underlined by Kamruzzaman et al. (2014).

Categorisation of TODs into typologies enhances their planning, design, and operational activities in many ways. For example, the similarities within a type allow policy makers and stakeholders to create common sets of strategies to plan or to improve performance.

As a result, the typology helps answer questions such as "what mixtures of uses will optimize effective mixed-use development?" and support location efficiency or "what densities and level of transit service are necessary?".

Classification also reduces management complexity for infrastructure companies by enabling the application of standards in operations and development.

Classification enables comparisons and performance assessments within the station classes, identifying successful benchmarks or highlighting needs for action.

Moreover, the classification allows to analyse the existing built environment and to define what type of policy is suitable for each node – or group of them – and not only if a site is eligible for urban development. The results of classification can be used by public administrative boards in the definition of development strategies at the urban, metropolitan and regional scale.

The classification of transport nodes is considered a field of study in which there is a great potential for further in-depth analysis. The application of land use and public transport integration to non-metropolitan contexts underlines issues that do not receive enough attention. For example, accessibility of main transport nodes, relationships between transport nodes and origins/destinations of trips placed beyond the 'walkable' area, the potential of transport as a network, i.e. not just the accessibility guaranteed by main transport but the connection between different transport modes. All these factors, in fact, have a decisive role in low-density contexts and should be analysed deeply in order to apply integration's principles within these geographical contexts.

The core question

The following question summarizes the central aim of this research:

How can a transport node evaluation help in improving accessibility by public transport and non-motorized modes within non-metropolitan areas?

The basic factors of this question are listed as follows.

Transport node evaluation: is the methodology used to reach the research's goal. As already outlined, transport node evaluation is believed to be an effective tool to overcome implementation barriers in the field of land use and transport integration.

Help in improving accessibility: is the main objective of the research, sustained by a wide set of studies regarding the impact of mobility and accessibility on social inclusion (Gray, 2004; Preston & Rajé, 2007), social justice (Farrington & Farrington, 2005), economic development (Vickerman, Spiekermann & Wegener, 1999).

Public transport and non-motorised modes: as already mentioned, a rough distinction can be made between 'sustainable' transport modes – public transport, walking and cycling – and transport modes with higher environmental impact – car, motorbikes. The aim of this research is to support the use of 'sustainable' modes, while private motorised modes can, in some cases, work in cooperation with public transport.

Non-metropolitan areas: the innovative aspect of this research is the integration of land use and 'sustainable' transport within non-metropolitan areas, which actually receive little consideration by academic literature and planning practices. This goal requires a clearer definition of the geographical context to which the methodology will be applied, therefore a statistical transnational classification of municipalities has been used (Djikstra & Poelman, 2014), as will be explained later in this chapter.

The expected result is a methodology applicable to several different contexts, but specifically tailored to non-metropolitan contexts, able to describe the actual degree of land use and 'sustainable' transport alignment and to sketch future integrated scenarios. The methodology, resulting into an evaluation of transport nodes' performances, is expected to suggest actions and policies able to improve integration and, not secondarily, to trigger the debate between actors and stakeholders – municipal and regional planning offices, transport authorities and companies, public transport passengers, citizens.

Innovative characters of the research

A broad literature exists about the environmental, social and economic impacts of low-density urban morphology. These correspond to transportation and travel costs, social concerns and poor quality of life, high rates of natural and agricultural soil consumption (Altshuler, 1997; Burchell et al., 2002; TCRP, 1998). Even if the impacts on transport seem to be the most problematic among the cited ones, low urban densities have proved to be a key factor in increasing the need to travel (Ewing, Pendall, & Chen, 2003; Steiner, 1994). Moreover, sprawling cities are dominated by individual motorized transport (European Environmental Agency, 2006); for a review about the topic of suburban development and mobility see also García-Palomares (2010). Rural areas and regions with low residential density often present an insufficient level of accessibility by public transport, and are much more car-dependent than medium or high-density urban areas, an issue that affects rural areas throughout western countries (Velaga, Beecroft, Nelson, Corsar, & Edwards, 2012).

Many Nations, across Europe and North America, face the duality between metropolitan, well-connected regions and, on the other side, constellations of suburbs, towns and villages that are scarcely accessible. This condition has been long studied especially by Anglophone scholars: among them Moseley (1979), Nutley (1999), Weir & McCabe (2009); for a review see also Farrington & Farrington (2005). They underline how the lack of accessibility affects the social sphere, producing social exclusion and isolation (Gray, Shaw, & Farrington, 2006). Other scholars base their studies on the analysis of specific geographic context, as made by some studies about mobility in the Alpine region (Tischler & Mailer, 2014), Australia (Nutley, 2003), Ireland (McDonagh, 2006), Scotland (Gray, Farrington, Shaw, Martin, & Roberts, 2001), rural areas of USA (Nutley, 1996).

As this thesis will outline, almost all the documented studies about land use and public transport integration refer to metropolitan areas, characterised by high residential and employment density, presence of amenities and facilities, and served by mass transport modes, such as railways, metros, tram, and bus rapid transit. The cited transport modes require a remarkable passenger flow to be financially sustainable, as summarized by the motto 'mass transit needs mass' (Suzuki et al., 2013). However, the areas with lower population density and a more dispersed urban pattern often show an unsustainable transport pattern, with the majority of travels relying on private car[8]. This relationship has been analysed through the lens of urban density by the well-known study of Newman and Kenworthy (2006), which demonstrates how high urban density is linked to lower use of car transport, representing a milestone in the studies about land use and transport interaction. More recently some authors underlined that the mainstream vision of 'higher density = less car use' is not supported by evidence. Particularly Mees (2010), referring to data about urban density and modal split in different cities around the world, proves that some of them, despite low density values, have been able to realise effective public and/or sustainable transport networks.

[8] As example, the study led by Tischler & Mailer (2014) referred to the Alpine Region, underlines that 'Periurban areas' and 'Rural areas' show a travel pattern in which car transport represents more than half of modal split, while this ratio decreases to 26% in the case of 'Urban area'. Conversely, public transport, walking and cycling reach their highest point in urban centres.

It can be said that, the absence of high urban density is not necessarily an obstacle to the realisation of an effective 'sustainable' transport network, able to curb car transport and encourage modal shift to public and non-motorised transport.

As Mees (2010) highlights, urban and transport planners should focus their attention on the effectiveness of public and sustainable transport network, before sketching unrealistic scenarios of urban density's increases. This approach opens new perspectives for land use and transport integration, i.e. the application of its principles within geographic contexts that, for their characteristics – low urban density, low development expectation – have been ignored by TOD academic literature and practice. By focussing on 'Transit' rather than 'Development' qualities, this research aims to extend the application of land use and transport integration to those areas where intense urban development is unrealistic, or is not desired, or where car-oriented urban development has already occurred.

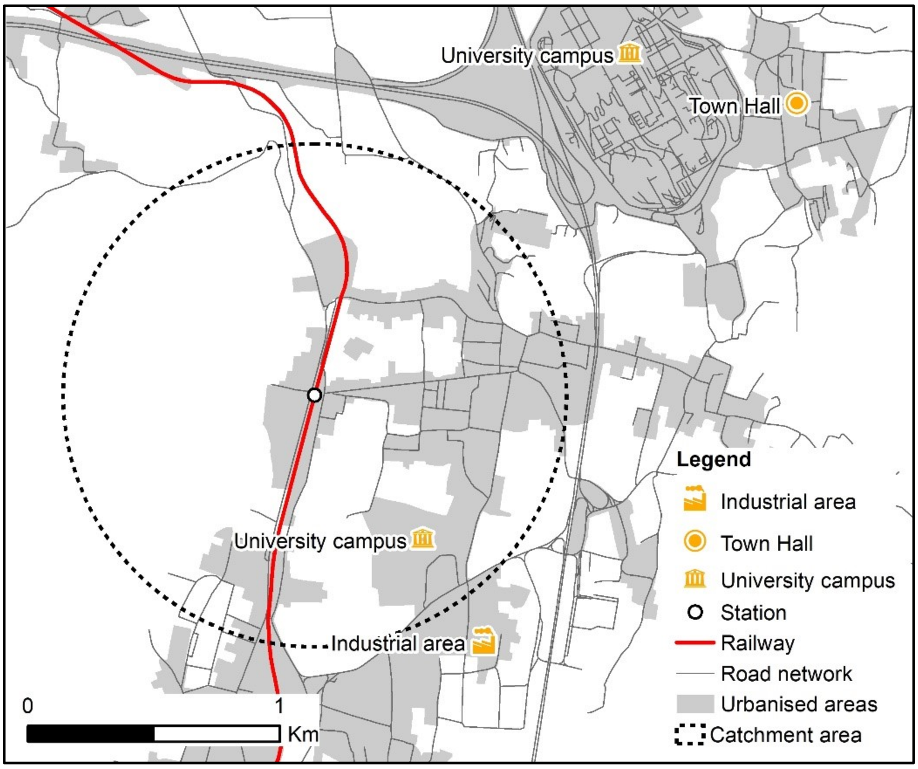

Figure 2. Example of missed integration between land use and railway accessibility. Source: author's elaboration.

Figure 2 gives an example of missed integration between land use and sustainable transport integration, referred to the small railway station of Fisciano, in southern Italy, which belongs to one of the study cases of this research. As can be observed, the circular catchment area of 1-kilometer radius, does not embrace many of the most relevant facilities of the area: in this case, we cannot imagine demolishing and rebuilding them within catchment area. Moreover, the modification of railway network, with the aim of put in contact railway node with facilities and activities, is expensive and cannot be achieved in short time. In cases like this, the unsolved question – to which this research aims to answer – is about the connection between transport infrastructures and attractors, which can be guaranteed by 'feeder' transport, like cycling, local bus lines, etc.

Context definition

This research refers to the context of 'small cities and towns' or 'non-metropolitan areas'. This statement needs a clearer definition, given from the point of view of this research's purposes.

- The definition of the geographic and social context – what is the meaning of 'non-metropolitan' areas.
- The definition of aspects related to accessibility and transport – what is meant by 'transport node' and which transport modalities are considered.

A digression is needed in order to sketch what is the meaning of 'non-metropolitan areas', in the light of this research's purpose. It is important to note that, while several studies have struggled to define a metropolitan area, very few authors tried to define 'non-metropolitan area'. Thus, we can refer to the broad field of studies related to the definition of 'metropolis', 'metropolitan city', 'metropolitan area' or, on the opposite side, studies that relate with rural areas.

The definition of metropolis and metropolitan areas is one of the most debated and long lasting issues among urban planners, and it is deeply rooted in the founding studies about urban and regional planning. Several authors pointed their attention on what discriminates a 'metropolis' from a common city or a small town. A first group of scholars, that includes the famous works of Geddes (1915), Mumford (1961), Gottmann (1964), Hall (1966), underline the exceptional role that metropolises play on the global stage. Some authors use the quantity of population to give an idea of the importance of a city, however it is not the only one taken into account. Hall (1966) underlines the relevance of the demographic factor, in fact, he considers the twenty-four cities with a population greater than three million – in 1964 – and selects among them the ones that really have a global relevance, due to their economic, political, trade and transport primary role. Hall indicates New York, London, Paris, the Randstad conurbation in the Netherlands, the Ruhr conurbation in North-West Germany, Moscow and Tokyo,

As reported by Véron (2006), many different statistical definitions exist, among the different countries of the world, of 'metropolitan area', 'metropolitan city', etc. He underlines how the urban expansion is a global phenomenon, even though huge differences occur between metropolitan areas in terms, for example, of population density. Véron compares Los Angeles and Mexico City, two metropolises with a similar population in 1990 – about 15 million – but allocated on an area of 8,000 km^2 in the first case and 4,600 km^2 in the latter. Census departments in different countries around the world have elaborated more or less refined definitions of metropolitan areas. Based on demographic data, they often add considerations on the prevalent employment sectors, commuting flows, as done in the method developed by OECD (Brezzi, 2012).

Geddes and Hall reflect on the term 'world cities', identifying with it the cities that spread cultural and political innovations, where are defined the prices and the circulation of goods on the planetary scale. Based on this approach, more recent authors like Castells (1989), Soja (2000), Sassen (2001) underline the economic and sociologic issues linked to the emergence of a network of 'global cities'. According to Sassen, the phenomenon of financial integration, typical of the globalization, led to the birth of a group of 'global cities'. In these cities are gathered command centres of world economy, headquarters of financial societies – banks, insurance services, advanced finance. The same cities are markets for the commerce of the cited products. Additionally, cities and metropolitan areas have been analysed from the point of view of social sciences. Already in the first decades of the past century, the sociologists belonging to the so-called 'Chicago School' described metropolitan areas from the point of view of social behaviour using the principles of the ecological sciences (Park, Burgess, & McKenzie, 1925). Those studies have started the branch of urban sociology that has been enriched by many authors, and nowadays represents one of the most used lens through which the cities are studied (Sassen, 2000). Different aspects can be recognised as the ones that distinguish metropolitan and non-metropolitan areas, and they can be summarized as follows.

- Demographic and statistical figures, such as number of inhabitants, residential density, demographic dynamic, employment typology, commuting flows.
- Economic facts, according to which the 'global cities' are the only ones that host advanced financial services, represent transport and communication hubs, and in which are taken decisions regarding economic matters.
- Sociologic issues, that focuses on the differences between urban and non-urban societies.

National definitions

In some European nations, public authorities developed classifications of territories according to their degree of 'urbanity'. Bibby & Shepherd (2004) illustrate the methodology, still valid today, adopted by Census Authorities of England.

England's rural-urban classification

Local Authorities are classified in six categories: 'Urban with Major Conurbation', 'Urban with Minor Conurbation', 'Urban with City and Town', Urban with Significant Rural', 'Largely Rural', 'Mainly Rural' (UK Government, 2017).

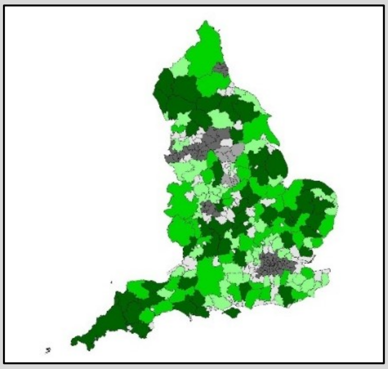

Figure 3. Rural-Urban classification of Local Authorities in England. Source: UK Government (2017).

In Italy, many areas demographically 'weak' are undergoing a process of de-population that finds one of its reasons in the lack of basic services and accessibility. Many medium and small towns are losing their elementary services, while population and activities tend to concentrate in the metropolitan and well-connected areas (Calafati, 2009). The raising awareness of this problem, already highlighted by some Italian geographers during the last decades of the 20th century (Becchi Collidà, Cicciotti, & Mela, 1989; Cencini, Dematteis, & Menegatti, 1983), recently led the Italian Government to arrange policies to contrast it, and to prevent the dereliction of small towns and rural territories.

The Italian definition of 'Disadvantaged areas'

The *Atlante Nazionale del Territorio Rurale*[9] - National Atlas of Rural Territory - whose latest edition has been issued by the Italian Minister of Agriculture in 2010, provides a definition of 'Disadvantaged areas' partly based on accessibility indexes (Rete Rurale Nazionale, 2010). In the following picture, darker areas correspond to the territories with better accessibility. This map shows the great differences existing within the Italian national territory.

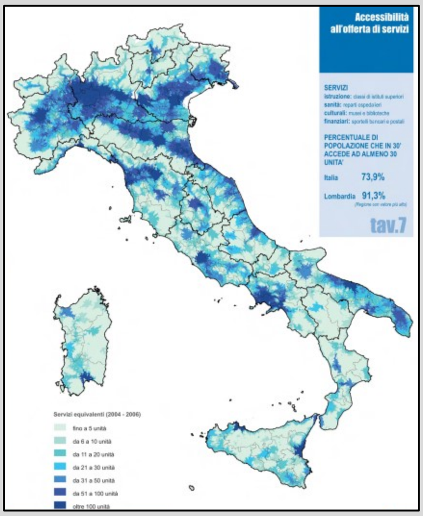

Figure 4. Accessibility to education, health, culture, finance services. Source: Rete Rurale Nazionale (2010).

More recently, the Italian Department for the Cohesion policies of Presidency of the Council of Ministers carried out a study that classifies municipal territories based on the accessibility of basic services[10]. This study found that a relevant extent of the National territory suffers a condition of marginality, summarized by the expression 'inner areas', i.e. municipalities that are distant more than 40 minutes from urban centres with a complete equipment of basic services. These services correspond to health care, schools and public transport (Dipartimento per le politiche di Coesione della Presidenza del Consiglio dei Ministri, 2015).

[9] Available at http://www.reterurale.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/3567 . Retrieved on 26/06/2017.

[10] Available at http://www.agenziacoesione.gov.it/it/arint/index.html . Retrieved on 26/06/2017.

Even though the study does not differentiate public and private transport, it can be said that a relevant percentage of Italian national territory faces a condition of poor accessibility, which could be at least mitigated by policies of land use and transport integration aimed to provide a higher level of accessibility and a better equipment of services.

The existence of different studies, analyses and definitions of 'disadvantaged areas', 'inner areas', etc., witnesses the relevance of these issues for the Italian government.

The Italian debate on 'Inner areas'

The analysis led by the Department highlighted that 30.6 % of Italian Territory is classified as 'inner area', with a total population of 4.5 million, the 7.6 % of the national total. One of the key aspects of the 'inner areas' is thus the poor accessibility, that makes trips inconvenient in terms of travel length and cost.

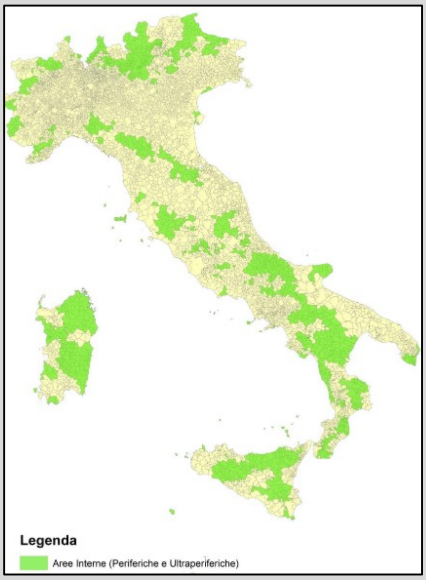

Figure 5. Municipalities classified as 'marginal' and 'ultra-marginal'. Source: Dipartimento per le politiche di Coesione della Presidenza del Consiglio dei Ministri (2015).

A European definition[11]

As briefly illustrated in the previous paragraphs, some European countries have elaborated specific definitions of 'rural areas', or 'inner areas'; however, they greatly differ from many points of view, like classification's purposes, methods, etc. For these reasons, it seems convenient to use a classification based on a wider geographic scale. Some international institutions developed all-inclusive methods able to classify territories according to their characteristics of 'urbanity'. OECD has individuated the categories of 'Predominantly urban', 'Intermediate', and 'Predominantly rural' across OECD countries (Brezzi, 2012; Brezzi, Dijkstra, & Ruiz, 2011). In the light of this research's purposes, the definition produced by European Community has been adopted, partly based on the

[11] All maps in this paragraph are based upon vector data freely available at http://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/population-distribution-demography/degurba . Retrieved on 07/07/2017.

OECD concepts, which classifies local administrative units into three categories: 'Densely populated areas – cities', 'Intermediate densely areas – towns and suburbs', 'Thinly populated areas – rural areas' (Dijkstra & Poelman, 2014).

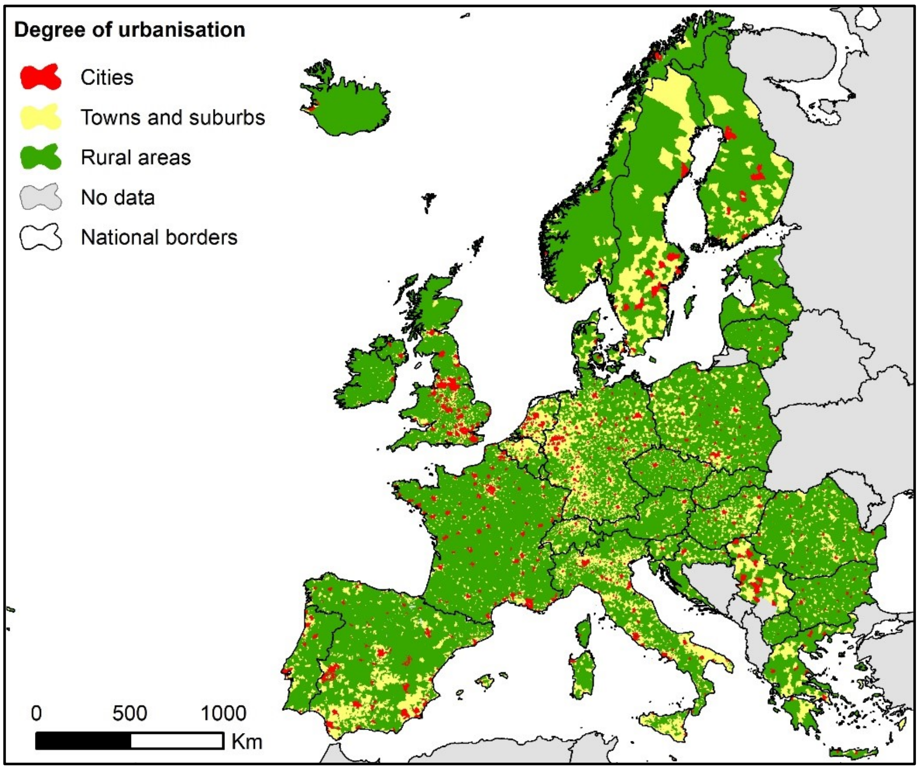

Figure 6. EU countries – Degree of urbanisation. Source: author's elaboration based on Eurostat data.

The following images show the national detail of the map, referred to the Netherlands and Italy, the countries where are located the study cases of this research.

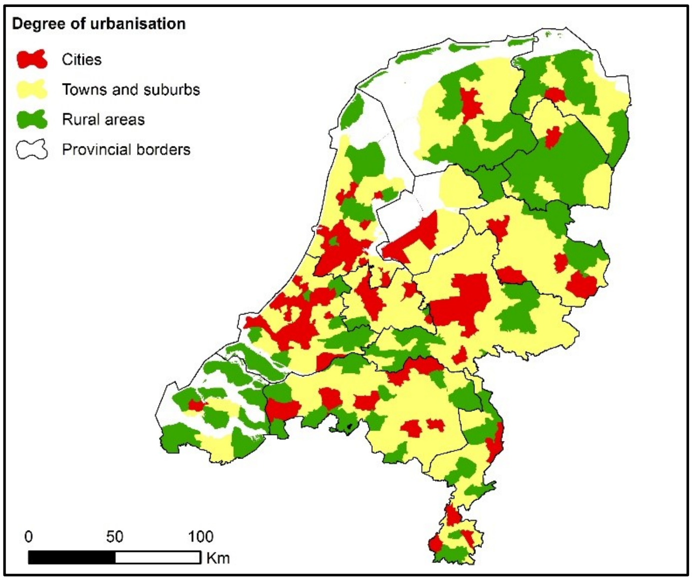

Figure 7. The Netherlands – Degree of urbanisation. Source: author's elaboration based on Eurostat data.

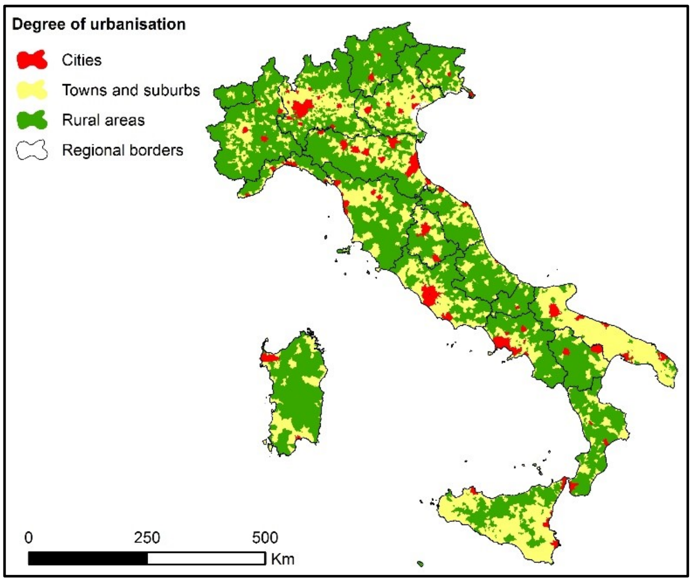

Figure 8. Italy - Degree of urbanisation. Source: author's elaboration based on Eurostat data.

The main advantage linked to the use of a supranational definition corresponds to the possible comparison between study cases locate in different national contexts, in this case the Netherlands and Italy.

Terminology

In the branch of land use and transport integration, the expression 'transport node' usually describes stations and stops belonging to railway or bus network, while 'catchment area' or 'station area' is the area that can be reached from the station in a short time – usually not more than ten minutes – by walking. Catchment areas are usually drawn as a circle with its centre on the station, or on its main access, and a radius between 400 and 1,000 metres, although there is not unanimous consensus on these values (Guerra et al., 2012).

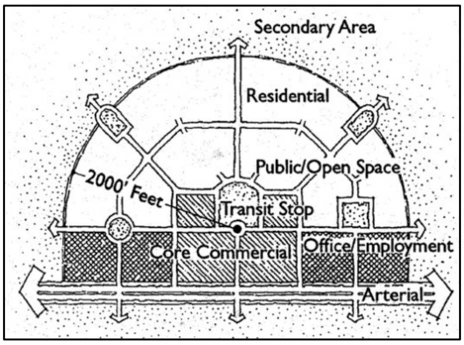

Figure 9. Calthorpe's model of catchment area. Source: Calthorpe (1993).

For this research's purposes, a broader definition of 'transport node' is needed, based on the characteristics of transport modes considered[12]. In order to do this, a rough distinction can be sketched between 'main public transport' – railway, tram, bus rapid transit, etc. – and 'secondary public transport' modes – bus, mini bus, collective cars, etc. Moreover, a broader definition of

[12] In this research are only considered the most common terrestrial transport modes.

public transport has to be adopted. With the expression 'public transport' in fact, is meant a wide range of transport modes, also encompassing alternative modes, shared transport, demand-responsive transport (Ellis & McCollom, 2009; Jäppinen, Toivonen, & Salonen, 2013; Thogersen, 2007).

For their characteristics, main transport modes usually represent the backbone of transport infrastructure. Built on separated tracks, they usually provide connection to the regional/national public transport network. They need a consistent passenger flow to be financially sustainable, due to the high costs of realization and maintenance of dedicated infrastructures. Moreover, their transport supply is often rigid, with fixed stops and timetables that are hardly adaptable to the fluctuations of transport demand. Their main advantages correspond to high transport capacity, low rates of polluting emissions, higher degree of safety (Rumar, 1999), low or null interferences with congestion caused by road traffic, higher energetic efficiency, especially in the case of rail transport (Usón et al, 2011).

Secondary public transport, like local buses, are cheaper in the phases of design and realization, because they do not require separate tracks and use the existing infrastructures. On the other hand, they have limited transport capacity, they usually entail higher environmental impacts, and are subject to road congestion, since they share their space with many other vehicles; they often serve local commuting and connect to main transport nodes – railway hubs, airports, etc.

Halfway between these two categories there are modes that, even if use fixed tracks, do not present very high capacity of transport, for example trolleybus, cable railways, cable cars, elevators, etc.; water public transport modes are by many ways comparable to this category. At this stage, the analysis relates with the first two categories, which do not aim to be exhaustive, but only useful in the light of the research's purposes. The following table summarizes the characteristics of 'main' and 'secondary' public transport modes.

-	'Main public transport'	'Secondary public transport'
Example list	Railway Tram-train Bus Rapid Transit (BRT) / Intercity bus	Local bus Tram Shared/pooled cars Demand-responsive modes
Strengths	High capacity High efficiency Low environmental impact Speed / Not influenced by road congestion High safety	Cheapness Flexibility
Weaknesses	Expensiveness of the design and realisation phases Low flexibility Fixed routes Huge passengers flow needed	Low capacity Subject to road congestion High environmental impact
Routes served	Regional + connection with national networks	Local, adduction to main transport nodes

Table 4. Proposed distinction of 'Main public transport' and 'Secondary public transport'. Source: author's elaboration.

Based on this distinction, some considerations follow about transport in non-metropolitan areas. The absence of huge demand undermines the financial wealth of transport companies, leading them to serve only the very essential routes in limited times of the day, e.g. in relation to 'home to school' and 'home to work' commuting flows. In addition, transport companies often do not coordinate their services, acting in a competitive scenario rather than in cooperation. This results in doubling transport services, absence of integration, and a transport offer that can reach only few areas and small rates of population (Mees, 2000; Weir & McCabe, 2008).

For these reasons, public transport in rural areas often shows low usage rates, and transport relies on car or individual motorized modes much more in these contexts than in metropolitan areas. Discourses about mobility in non-metropolitan areas cannot be focussed on a single or few nodes, but should be set up to a regional scale, comprising entire transport networks and different modes, which serve systems of towns and villages. Within the transport network can be identified usually few main transport corridors, corresponding to the already cited 'main public transport' and several secondary corridors served by 'secondary public transport'.

Moreover, in those areas, many people do not live or work within 'walkable' distance from main transport nodes, which are often scarcely accessible by other transport modes. This factor suggests taking into account an 'extended catchment area' beyond the 'Euclidean' catchment area usually considered in studies about land use and public transport integration. In the following figure is represented an example of area of application of 'extended catchment area'. In a hilly or mountainous territory, main public transport corridors often run in valley floors, while towns and hamlets are located far from stations and outside Euclidean catchment areas. Thus, they can be only reached by 'secondary transport corridors', able to connect urban areas to main transport. The areas accessible by secondary corridors make up the 'Extended catchment areas'.

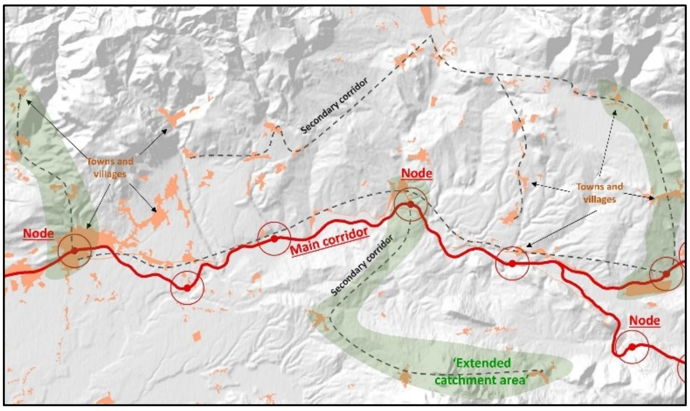

Figure 10. Example of a possible area of application. Source: author's elaboration.

However, the distinction between main and secondary transport nodes is useful, also, to determine their ability to support urban development. Main transport catchment areas – rail stations, tram and BRT stops – seem the most suitable for urban development, while secondary corridors have to be evaluated on the basis of their ability to serve existing settlements, and to put them in contact with other destinations and with the main nodes. In fact, some scholars underline how transport modes with fixed tracks are more attractive for real estate investments, due to their stability, ensuring the existence of a long-term transport service (Dittmar & Ohland, 2004).

Disused transport infrastructures

Italy, as many western countries, experienced a decrease of ridership along secondary railways during the second half of the past century, leading rail transport agencies to hasty closures of many of them. Today, according to the Italian Database of disused railways, more than 6,500 km of abandoned tracks spread out along the national territory, of which about 3,800 km were part of the State Rail network (Database delle ferrovie non più utilizzate, 2016). Many of these railways pass through rural areas.

The United Kingdom also experienced a relevant loss of minor railways, accelerated during the 1960s, with the so-called 'Beeching cuts'. Between 1963 and 1973, more than 6,500 km of railways closed, despite the protests of local communities, and rail services substituted with bus lines, which proved to have lower attractiveness, leaving large parts of British territory substantially without public transport (Wolmar, 2005).

The closure of huge extents of public transport infrastructures is, in great part, due to the changes occurred in economic and transport patterns among western countries, with the rise of car and lorry transport and the subsequent decrease of public transport business, which made economically unprofitable their management (Tomes, 2008). Those services and infrastructures were often located within suburban or rural areas; therefore, their closure worsened public transport accessibility in those zones. Today the awareness of environmental and social impacts of transport highlights the advantages of good public transport accessibility, also in low-densely populated areas, despite the financial burden that it entails, as proved by some successful reopening of disused railways.

In the United Kingdom, appears relevant the recent case of the Edinburgh – Tweedbank railway, closed in 1969 after having been included into the 'Beeching I report', and reopened in September 2015 with a remarkable ridership success (Dalton, 2015). In the same way, In Italy some of local railways have been reopened in the last years. Among them, the most known case is probably the Merano – Malles railway, located in Sud Tirol. Closed in 1989, the Province of Bolzano acquired it in the 1990s and, after a deep refurbishment, the railway reopened in 2005. The figures show that the rail service passengers are more than double of bus service passengers that previously covered the same route (Gandini, 2014).

These experiences show that an efficient public transport system – also rail-based – is not a prerogative of metropolitan, densely populated areas only, but can be also implemented in small towns and rural areas.

Theoretical framework

Since the first statement of TOD (Calthorpe, 1993) the node-place model as a tool to classify transport nodes (Bertolini, 1999) and the station typologies proposed by Dittmar & Poticha (2004), a great number of studies enriched the original findings, considering new indicators to define transport nodes typologies, or using the classification to address specific goals, etc.

Discourses and applications of land use and public transport integration usually focus on metropolitan areas, characterised by high or very high intensity of land use. On the other hand, some studies aim to classify numerous transport nodes throughout entire regions or countries (Austin et al., 2010; Reusser, Loukopoulos, Stauffacher, & Scholz, 2008), in so including nodes located both in urban and in rural contexts. However, they only consider the station area precinct, without paying attention to the context. Other studies adapt TOD typologies to specific goals, as boosting the development of not-rail transport (Rodriguez & Vergel, 2013; Stojanovski, 2013); some authors aim to implement TOD in low-densely populated areas (Curtis, 2008; Larose, 2010). Anyway, a specific evaluation of transport nodes shaped on non-metropolitan contexts seems to lack.

Belzer and Autler (2002) draft the advantages of creating TOD projects typologies, to fit development projects into different contexts, from large cities to small towns. As recently highlighted by Kamruzzaman et al. (2014), transport nodes typologies are a branch that is little explored and, at the same time, seems to be one of the most promising ways to overcome the barriers that impede the realisation of land use and public transport integration.

As already explained, the aim of this research is to explore the topic of accessibility in non-metropolitan areas, using the assessment of transport nodes as a tool. The research's objective is to build a methodology relevant for non-metropolitan areas. Moreover, the goal is also to provide an effective tool to stakeholders and public decision makers, sketching an integrated land use - public transport framework for regional and municipal land use plans.

Search methodology

Before sketching the main theoretical approaches, this paragraph reports the method used to search among the academic literature and the main sources on which the search is based on. As first step, the contributions of Kamruzzaman et al. (2014) and Lyu, Bertolini & Pfeffer (2016) were considered as basis.

Title	Author(s)	Year
Comparing transit-oriented development sites by walkability indicators	Schlossberg & Brown	2004
Classifying railway stations for sustainable transitions–balancing node and place functions	Reusser, Loukopoulos, Stauffacher, & Scholz	2008
Performance-Based Transit-Oriented Development Typology Guidebook	Austin, Belzer, Benedict, Esling, Haas, Miknaitis, & Zimbabwe	2010
The geography of advance transit-oriented development in metropolitan Phoenix, Arizona, 2000–2007	Atkinson-Palombo & Kuby	2011

Portland Metro TOD Program and TOD Strategic Plan case study	Center for Transit-Oriented Development	2011
An application of the node place model to explore the spatial development dynamics of station areas in Tokyo	Chorus & Bertolini	2011
Classifying railway stations for strategic transport and land use planning: context matters!	Zemp, Stauffacher, Lang, & Scholz	2011
Evaluation of railway surrounding areas: the case of Ostrava city	Ivan, Boruta, & Horák	2011
Transit-Oriented Development Typology for Allegheny County	Center for Transit-Oriented Development	2013
Advance transit oriented development typology: Case study in Brisbane, Australia	Kamruzzaman, Baker, Washington, & Turrel	2014
The evaluation of the spatial integration of station areas via the node place model; an application to subway station areas in Tehran	Monajem & Nosratian	2015
TOD, integration of land use and transport, and pedestrian accessibility: […] evaluate and classify station areas in Lisbon	Vale	2015
Developing a TOD typology for Beijing metro station areas	Lyu, Bertolini & Pfeffer	2016

Table 5. Initial group of sources. Source: author's elaboration.

The cited publications provided a consistent number of references about transport nodes typologies. In table 5 are listed the sources reported by them, with title, authors and year of publication. In addition, three more sources not contained in the cited articles were considered, listed in table 6.

Title	Author(s)	Year
Spatial Development Patterns and Public Transport: The Application of an analytical model in the Netherlands	Bertolini	1999
Defining transit-oriented development: the new regional building block	Dittmar & Poticha	2004
Gaining insight in the development potential of station areas: A decade of node-place modelling in The Netherlands	Peek, Bertolini & De Jonge	2006
An accessibility planning tool for Network Transit Oriented Development: SNAP	Papa, Moccia, Angiello, Inglese	2013
Breaking barriers to transit-oriented development: insights from the serious game SPRINTCITY	Duffuhes, Mayer, Nefs & Van der Vliet	2014

Table 6. Additional references, listed by year of publication. Source: author's elaboration.

As a second step, a deeper search has been done. The main web search engines were used to seek the keywords 'TOD typology' and 'TOD typologies'. The search regarded the entire text and not only on the title.

The web search engines used are listed as follows.

- Google scholar[13].
- Catalogue plus (UvA)[14].
- Scopus[15].
- Web of Science / Web of knowledge[16].

From a quantitative point of view, Google scholar gave the greatest result, as reported in the following table.

Exact keywords*	Web Search Engines			
	Google scholar**	Catalogue plus	Scopus	Web of Science
'TOD typology'	53	10	3	3
'TOD typologies'	38	10	3	2
* search made on the entire text and not only in the title ** the search results did not include citations and patents				

Table 7. Quantitative results of the search about the keywords 'TOD typology' and 'TOD typologies'. Source: author's elaboration.

The results found with Catalogue plus, Scopus and Web of Science were already contained in the list obtained with Google scholar. The found sources are mostly academic articles, with a little number of books, book chapters, dissertations and reports. The results were selected in order to exclude the already known and the not relevant sources. Finally, an additional set of articles has been considered (table 8).

Source	Why is it relevant?
Zhang & Yi, 2006	Reference to Austin TOD typology
Larose, 2010	Implementation of TOD in small towns
O'Kefee, 2011	Review of cities TOD typologies; reference to Denver TOD typology
Dwarka, Kooris, Nelson &Twining, 2012	Reference to Winnipeg TOD typology
Atkinson-Palombo & Marshall, 2013	Reference to Denver TOD typology
City of Denver, 2014	Implementation of TOD typology
Higgins, 2015	Reference to Denver TOD typology
Dorsey, 2016	Reference to Denver TOD typology
Higgins, 2016	TOD typology review; quantitative method to build TOD typologies
Higgins & Kanaroglou, 2016	TOD typology review; quantitative method to build TOD typologies

Table 8. Additional sources considered after the keywords search. Source: author's elaboration.

[13] https://scholar.google.it/
[14] http://lib.uva.nl/primo_library/libweb/action/search.do?vid=UVA
[15] https://www.scopus.com/home.uri
[16] https://apps.webofknowledge.com/UA_GeneralSearch_input.do?product=UA&SID=W2uJGs71zFZfAPfkaud&search_mode=GeneralSearch

Many sources refer to the typology developed by the City of Denver (2014) as best practice and exemplification of the several TOD typologies used by American and Canadian cities. The attention put on transport node typology, and on land use and public transport integration in general by North American institutions, is also proved by the existence of the non-profit institution Reconnecting America, that provides a 'Typology guidebook' (Austin et al., 2010). For these reasons, it seemed correct to consider these sources as cases of implementation of TOD typologies, beyond academic researches.

A first list, made up of 20 sources, has been obtained (table 9); this list is composed by the contributions just found (18) and the two articles of Kamruzzaman et al. (2014) and Lyu et al. (2016). These sources have been analysed from the point of view of keywords, in order to find out the most recurrent and significant ones and use them to repeat the search and possibly find new sources. In the case of articles or documents that do not have keywords, some of them have been assigned in relation to the content.

Sources	Keywords
Bertolini, 1999	Decentralization / TOD / Node-place model / Accessibility / Deconcentrating clustering
Dittmar & Poticha, 2004	TOD typology / Performance-based TOD definition / Community
Schlossberg & Brown, 2004	Walkability / Urban form / Pedestrian catchment area
Peek, Bertolini, & De Jonge, 2006	Urban development / Stakeholders / Station areas / Real estate value / Accessibility
Reusser, Loukopoulos, Stauffacher, & Scholz, 2008	Accessibility / Mobility / Railway stations / Sustainable development
Austin, et al., 2010	Performance-based typology / Auto ownership / Travel behaviour / Urban density
Atkinson-Palombo & Kuby, 2011	TOD / Overlay zoning patterns / Light-rail transit / Urban investment patterns / Uneven development
Center for Transit-Oriented Development, 2011	Urban investment guide/ Urban development
Chorus & Bertolini, 2011	Transport / Land use / Node-place model / Tokyo
Zemp, Stauffacher, Lang, & Scholz, 2011	Railway station / Comparability / Classification / Functional requirements / Context / Environment
Ivan, Boruta, & Horák, 2011	Railway station / Place index / Node index / Ostrava City
Papa, Moccia, Angiello, & Inglese, 2013	TOD / Accessibility planning / Network analysis
Center for Transit-Oriented Development, 2013	Investments guide / Urban development

City of Denver, 2014	Urban development / Strategic plan
Duffhues, Mayer, Nefs, & Van der Vliet, 2014	TOD / Serious gaming / Policy learning / Multiactor modelling
Kamruzzaman, Baker, Washington, & Turrell, 2014	TOD / TOD typology / Advanced TOD planning / Mode choice behaviour/ Public tr. accessibility level / Brisbane
Monajem & Nosratian, 2015	Station area / Node place model / Spatial integration
Vale, 2015	Transit-oriented development / Node-place model / Walkability / Pedestrian connectivity / Lisbon
Higgins & Kanaroglou, 2016	TOD / TOD typology / Transportation and land use planning / Latent class analysis / Model-based clustering
Lyu, Bertolini, & Pfeffer, 2016	TOD Typology / Metro station areas / Node-place model / Beijing

Table 9. First group of sources, listed by year of publication, with related keywords. Source: author's elaboration.

On the basis of this analysis, a list of the most recurrent keywords was drawn up. In table 10 are reported only the keywords, or the group of them, found at least two times.

Keywords	Frequency
Accessibility / Accessibility Mobility / Accessibility planning	4
Node-place model	5
Railway station /Railway station	3
Station area / Station areas	2
TOD / Transit Oriented Development	8
TOD typology	3
Urban development	4
Walkability	2

Table 10. Found keywords or group of them and frequency. Source: author's elaboration.

The found keywords are quite general, and appear not useful for a new search, since they would give too numerous results. The only exception is 'node place model'[17], that has been used for a new search through the main web search engines, i.e. Google Scholar, Catalogue Plus, Scopus and Web of Science, following the already explained methodology.

Exact keywords*	Web Search Engines			
	Google scholar**	Catalogue plus	Scopus	Web of Science
'node place model'	124	28	21	5
* search made on the entire text and not only in the title ** the search results did not include citations and patents				

Table 11. Quantitative results of the search about the keyword 'Node-place model'. Source: author's elaboration.

[17] In the search through the web search engines, the typing 'node place model' has been preferred to 'node-place model', used by some authors. Anyway, the used web search engines gave the same results in both cases.

As reported by table 11, the search with 'node place model' as keyword gave 124 results from Scholar, 28 from Catalogue, 21 from Scopus and 5 from Web of Science. Among these articles, the ones that discuss nodes classification and TOD typologies were selected, detailed in table 12.

Title	Author(s)	Year
Identifying Areas for Transit-Oriented Development in Vancouver	Ngo	2012
The performance and potential of rail stations in and outside freeway medians: the application of a node/place model to Perth	Babb et al.	2015
Shanghai Hongqiao air-rail hub	Chen & Lin	2015
Classifying railway passenger stations for use transport planning - Application to Bulgarian railway network	Stoilova & Nikolova	2016

Table 12. Results of the second keywords search, listed by year of publication. Source: author's elaboration.

List of sources

Figure 11 summarises and clarifies the methodology used in the literature review.

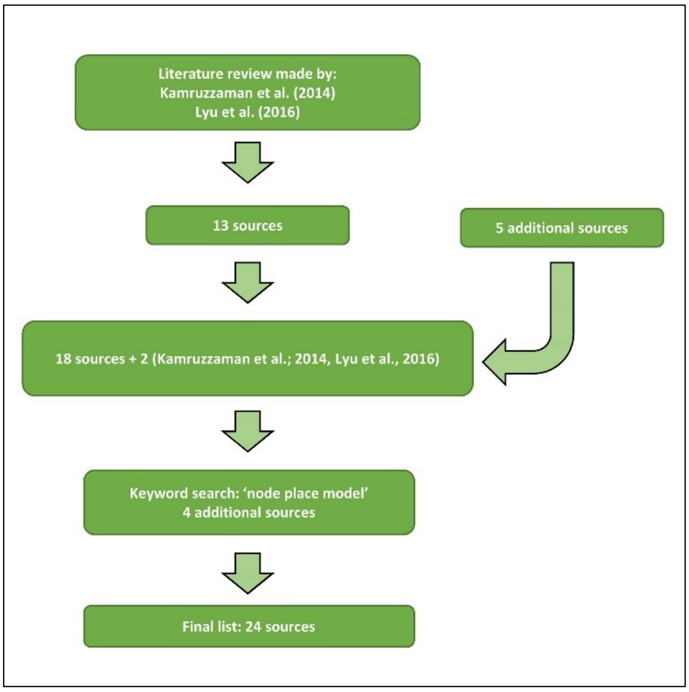

Figure 11. Search methodology. Source: author's elaboration.

The following table lists the articles and documents found that relate with transport node typologies. They amount to 24 sources, covering a period of almost twenty years, from 1999 to nowadays, reporting about implementations in North American, European, Australian, Chinese and Japanese cities.

n.	Title	Author(s)	Year
1	Spatial Development Patterns and Public Transport: The Application of an analytical model in the Netherlands	Bertolini	1999
2	Defining transit-oriented development: the new regional building block	Dittmar & Poticha	2004
3	Comparing transit-oriented development sites by walkability indicators	Schlossberg & Brown	2004
4	Gaining insight in the development potential of station areas: A decade of node-place modelling in The Netherlands	Peek, Bertolini & De Jonge	2006
5	Classifying railway stations for sustainable transitions–balancing node and place functions	Reusser, Loukopoulos, Stauffacher, & Scholz	2008
6	Performance-Based Transit-Oriented Development Typology Guidebook	Austin, Belzer, Benedict, Esling, Haas, Miknaitis, & Zimbabwe	2010
7	The geography of advance transit-oriented development in metropolitan Phoenix, Arizona, 2000–2007	Atkinson-Palombo & Kuby	2011
8	Portland Metro TOD Program and TOD Strategic Plan case study	Center for Transit-Oriented Development	2011
9	An application of the node place model to explore the spatial development dynamics of station areas in Tokyo	Chorus & Bertolini	2011
10	Classifying railway stations for strategic transport and land use planning: context matters!	Zemp, Stauffacher, Lang, & Scholz	2011
11	Evaluation of railway surrounding areas: the case of Ostrava city	Ivan, Boruta, & Horák	2011
12	Identifying Areas for Transit-Oriented Development in Vancouver	Ngo	2012
13	An accessibility planning tool for Network Transit Oriented Development: SNAP	Papa, Moccia, Angiello, Inglese	2013
14	Transit-Oriented Development Typology for Allegheny County	Center for Transit-Oriented Development	2013
15	Transit Oriented Denver: Transit Oriented Development Strategic Plan	City of Denver	2014
16	Breaking barriers to transit-oriented development: insights from the serious game SPRINTCITY	Duffuhes, Mayer, Nefs & Van der Vliet	2014
17	Advance transit oriented development typology: Case study in Brisbane, Australia	Kamruzzaman, Baker, Washington, & Turrel	2014
18	The performance and potential of rail stations in and outside freeway medians: the application of a node/place model to	Babb et al.	2015
19	Shanghai Hongqiao air-rail hub	Chen & Lin	2015
20	The evaluation of the spatial integration of station areas via the node place model; an application to subway station areas in	Monajem & Nosratian	2015
21	TOD, integration of land use and transport, and pedestrian accessibility: […] evaluate and classify station areas in Lisbon	Vale	2015
22	A latent class method for classifying and evaluating the performance of station area transit-oriented development in	Higgins & Kanaroglou	2016
23	Developing a TOD typology for Beijing metro station areas	Lyu, Bertolini & Pfeffer	2016
24	Classifying railway passenger stations for use transport planning - Application to Bulgarian railway network	Stoilova & Nikolova	2016

Table 13. Final list of sources, listed by year of publication. Source: author's elaboration.

n.	Peer rev. Y/N	Name and /or geographic context	Geographic scale	N. of nodes analysed	N. of indicators used	N. of typologies found	Positive/ normative P/N[18]
1	Y	Amsterdam – Utrecht, NL	Metropolitan	31	15	7	P
2	N	-	-	-	7	6	N
3	Y	Portland, OR, USA	Metropolitan	11	12	-	P
4	Y	Delta Metropolis	Regional	96	-	-	N
		NOVEM [19]	National	-	-	-	P
		Buck Consultants International	-	-	-	-	P
		Goudappel[20]	National	92	-	-	N
		NS[21]	National	-	13 'criteria'	9	N
		Hourglass model/Zutphen, The Hague	Local	2	-	-	N
		Concern synergy model/Amsterdam	Regional	-	-	-	N
5	Y	Switzerland	National	1684	21	2 to 5	P
6	N	USA	National	app. 3760	20	15	P
7	Y	Phoenix, AZ, USA	Metropolitan	27	12	5	P
8	N	Portland, OR, USA	Metropolitan	app. 35		9	N
9	Y	Tokyo, Japan	Metropolitan	99	10 'criteria'	7	P
10	Y	Switzerland	National	app. 1700	10	7	P
11	Y	Ostrava, Czech Republic	Metropolitan	11	11	-	P
12	Y	Vancouver, Canada	Metropolitan	20	6 'criteria'	-	P
13	Y	Naples, Italy	Metropolitan	212	-	7	P
14	N	Pittsburgh, USA	Metropolitan	app. 75	9	5	N
15	N	Denver, CO, USA	Metropolitan	21	5 'groups'	5	N
16	Y	The Netherlands	Various	-	6 'families'	12	N
17	Y	Brisbane, Australia	Metropolitan	note[22]	6	4	P
18	N	Perth, Australia	Metropolitan	13	43	5	P
19	Y	Shanghai, China	Metropolitan	1	17	-	P
20	Y	Tehran, Iran	Metropolitan	79	10	7	P
21	Y	Lisbon, Portugal	Metropolitan	83	13	7	P
22	Y	Toronto, Canada	Metropolitan	372	12	10	P
23	Y	Beijing, China	Metropolitan	268	18	6	P
24	Y	Bulgaria	National	98	18	6	P

Table 14. List of sources, analysis. Source: author's elaboration.

In table 14, the found sources are analysed according to the parameters of the geographic context and scale of implementation, number of nodes analysed, number of indicators used, number of typologies found, affinity with the 'positive' or 'normative' typologies[23].

[18] Higgins & Kanaroglou (2016).
[19] NOVEM, an agency of the Dutch Ministry of Economic Affairs.
[20] Consultancy firm Goudappel Coffeng asked by the Dutch Ministry of Transport, Public Works and Water Management.
[21] Nederlandse Spoorwegen (Dutch Railways).
[22] Classification referred to Census Tracts, not only to station areas.

In conclusion, the classification of transport nodes is based on the node place model defined by Bertolini (1999, 2005), which looks to stations as transport nodes and places of social interaction. Bertolini suggests considering indicators referred to accessibility - by train, bus, tram, underground, car, bicycle - and intensity of use, i.e. the density and mix degree of residents, jobs, activities and facilities within the 'walkable radius' of 700 metres from the main entrance of the station.

This methodology has been enriched, taking into account several indicators, of which an exhaustive overview is made by Lyu et al. (2016). According to Higgins & Kanaroglou (2016), the existing node typologies can be grouped in two main families: 'positive' TOD typologies and 'normative' TOD typologies. It can be said that these two families respectively aim to measure the actual performance of station areas and to sketch a future development framework of the network of station areas. Positive typologies classify huge sets of stations, from a single metropolitan area to national rail networks, involving hundreds or thousands of nodes. The classifications belonging to this group aim to scale and fit land use and transport integration into specific contexts. Calthorpe himself (1993) identified two different scales of implementation: 'urban' and 'neighbourhood', differentiated on the basis of the distance from transport node. Dittmar & Poticha (2004) further developed the classification, reaching six different typologies based on hypothetical urban contexts: urban downtown, urban neighbourhood, suburban centre, suburban neighbourhood, neighbourhood transit zone, and commuter town centre. Several cities have carried out a classification of their own public transport nodes, assessing the existing conditions, as a necessary step before arranging TOD plans and policies. The classification allows to sketch development policies fitted into the context, as in the case of the City of Denver (2014), that individuated five typologies among the stations placed along the city's LRT and CRT lines: downtown, urban centre, general urban, urban, suburban.

Normative TOD typologies, recognizing that a 'one-size-fits-all' TOD cannot be used, aim to adopt a more complex method, firstly directed to consider the context in which transport nodes are located. Secondly, normative typologies aim to shape policies and context-sensitive solutions able to turn integration design into reality. However, a preliminary positive evaluation of existing conditions seems necessary, therefore it can be said that also normative typologies are based upon positive assessment. Normative typologies are referred to urban contexts, while the academic literature about typologies of transport nodes has paid little attention to non-metropolitan areas.

In order to define the most relevant scholars, the group of sources contained in table 14 has been re-analysed in the light of this research's question, context of application and purposes.

Re-analysis of the literature

The objective of this research is to build an assessment tool of transport nodes able to explicitly take into account the quality of access and egress transport to nodes, thus considering several feeder transport modes beyond 'walk transport'. Moreover, also destinations reachable by these modes should be accounted when assessing the 'place' performance of transport nodes.

[23] As defined by defined by Higgins & Kanaroglou (2016).

The task is to classify station areas considering factors related not only to walkable area, but also to 'extended station areas', defined by the network of feeder transport modes. To do this, the methodology needs to answer to questions like:

- How many people/jobs/facilities are located in the 'extended' station area?
- How are connections between them and the transport node?

The classification of nodes could highlight a lack of public transport accessibility and/or an inefficient transport pattern. If this happens, the methodology will suggest policies and actions able to fill this gap, such as service improvement along some routes, identification of places suitable for urban development, etc.

In the branch of transport nodes evaluation, station areas are classified on the basis of the quality of transport service and the density/mix of use of urban areas close to transport nodes. The node place model, as defined by Bertolini (1999), uses in order to quantify node and place indexes, a defined set of indicators related to specific features, summarized in the following table.

Node/place indexes	Indicators related to:
Node index	Rail transport
	Other public transport
	Car transport
	Bike transport
Place index	Number of residents
	Number of workers
	Functional mix

Table 15. Indicators and their relationship with topics. Source: author's elaboration based on Bertolini (1999).

As already outlined, non-metropolitan areas show, if compared to metropolitan areas, a more dispersed urban pattern, which entails longer distances between stations and houses, jobs, facilities. Urban cores are sometimes located far from transport nodes, so that they require an additional travel to cover the node-core distance. This issue is partially comparable to the 'last mile problem' that has been long studied from the logistic point of view (Song, Cherrett, McLeod, & Guan, 2009). However, in this case, the question seems to be more complex, as the distance to be covered is widely variable, requiring different transport modes, and passengers express much more demands than goods. For these reasons, it seems reasonable an adjustment of the model elaborated by Bertolini, as reported by table 16.

Node/place indexes	Indicators related to:
Node index	Quality of rail transport / main transport
Place index	Number of residents
	Number of workers
	Functional mix
Feeder transport index	Quality of walk / bike environment / public feeder transport / car accessibility

Table 16. Possible adjustment of the set of indicators used by Bertolini (1999) for his node place model. Source: author's elaboration.

After having defined the geographical context of implementation, new typology's tasks and a possible set of indicators, the mentioned sources have been re-analysed in the light of these considerations (table 17). In the following table are highlighted the goals of each typology, the methodological aspects of interest, the geographic area involved by the study, the 'matching degree' in comparison to the abovementioned tasks, and the indicators that can be of some interest.

n.	Name and/or geo. context	Classification goal	Potentially interesting / useful features			
			Methodological aspects	C / T / R[24]	Match with task[25]	Indicators
1	Amsterdam – Utrecht, NL	Highlight 'balanced' and 'unbalanced' nodes.		C	M	
2	-	Adapt TOD to context.		C T	H	
3	Portland, OR, US	Evaluate pedestrian friendliness.	Use of pedestrian catchment area to obtain a re-shape of station areas.	C	M	
	Delta Metropolis	Select the most promising locations for urban development aimed at exploiting up-and-coming investments in		C T	L	
	NOVEM	Provide recommendations for a national policy on transportation nodes, with a focus on sustainable mobility impacts.	Evaluation of 'Interaction' value of station areas.	C T R	L	interaction value rail-urban core
	Buck Consultants Int.	Predict effects on real estate values (offices).	Identification of an optimal line between place and node.	-	L	
4	Goudappel	Support development strategies.	Six spatial scales are distinguished.	C T R	M	
	NS	Support to strategy making.	Evaluation of micro and macro accessibility. Distinction between urban and	C T R	M	
	Hourglass model	Comparison between station areas Facilitation of stakeholders' interactions.	Distinction of micro and macro station areas.	C T	M	
	Concern synergy model	Develop a regional placement strategy.		C T R	L	
5	Switzerland	Evaluate the potential of urban development.	Addition of new indicators to node-place. Cluster analysis.	C T R	L	Indicators about the context.
6	US	Assess performance / Evaluate potential of development.	Performance-based typology (estimates effects on VMT).	C T R	L	
7	Phoenix, AZ, US	Evaluate the potential of urban development.	Use of 'real' walking distance.	C T	L	
8	Portland, OR, US	Evaluate the potential of urban development.		C T	L	
9	Tokyo, Japan	Understand which transport and land use factors are responsible for structuring station area	Account of number of feeder bus lines per station.	C	M	n. of feeder bus lines per station

[24] Implementation context. C=cities; T=towns; R=rural.
[25] L=low; M=medium; H=high

10	Switzerland	Evaluate the potential of urban development.	Identification of context factors and indicators (by interviews).	C T R	H	
11	Ostrava, Czech Republic	Evaluate the potential of urban development.	Account of closeness to other transport modes.	C T	M	closeness of rail to other transport modes
12	Vancouver, Canada	Evaluate the TOD potential.	Differentiated station area radius 400 / 600 / 800 m.	C	L	
13	Naples, Italy	Evaluate the potential of urban development.		C T	L	
14	Pittsburgh, US	Define priority areas for investments (focussed on place).		C T	L	
15	Denver, CO, US	Define the possible urban development (focussed on place).		C	L	
16	NL, different places	Evaluate the potential of urban development.		C T R	L	
17	Brisbane, Australia	Evaluate people's ridership behaviour.		C T	L	
18	Perth, Australia	Evaluate the potential of urban development, focus on stations located in freeway medians.		C T	L	
19	Shanghai, China	Implementation of the node-place model.	Station area: Three-zone modelling. Accessibility analysis on bus transport network.	C	M	
20	Tehran, Iran	Evaluate the quality of street connections.	Evaluate the impact of street configuration on transportation and land use dynamics.	C	L	
21	Lisbon, Portugal	Evaluate pedestrian friendliness.	Use of 'pedshed' ratio.	C T	L	
22	Toronto, Canada	Build an empirical tool for policy evaluation and prescription.	Focus on a model-based latent class method classification.	C T	L	
23	Beijing, China	Context based typology able to help planners and policy makers, in Beijing metropolitan area.	TOD indicators list.	C	L	TOD indicators list.
24	Bulgaria	Evaluate the potential of urban and transport development.	TOD indicators list	C T R	M	potential of the town where the station is located

Table 17. Re-analysis of the literature on the basis of this research's objectives. Source: author's elaboration.

The 'Methodological aspects' field contains the aspects relative to the specific typology, that can be used for this research's purposes. The 'Cities/towns/rural' field expresses the category that better describes the geographic context, according to the already cited Eurostat 'Degree of urbanisation' (Dijkstra & Poelman, 2014). The field 'Match with task' states the extent to which the typology's goal are comparable to the new typology's task. The field 'Indicators' reports what indicators used by the analysed typology can be used for this research's purposes.

The results of the literature's re-analysis can be briefly summarised as follows: some typologies pay attention to the shape of station areas, and define methods to re-shape them, usually based on pedestrian accessibility, in order to consider the areas really located within walking distance from station's exit. Ngo (2012) reports the use, made by the City of Vancouver, of circular areas with different radiuses of 400, 600 and 800 meters around stations. Anyway, these differentiated station areas are focussed on pedestrian and bike accessibility to stations, since the typology is referred to an urban context.

Another notable feature is related to geographic context, mostly cities and suburban areas. In addition, the ones focussed on towns and rural areas always deal with an all-embracing regional scale, in so including cities and core areas. Although the match with the three categories is based roughly on the EU classification (Dijkstra & Poelman, 2014) and not founded upon an exact assessment, it gives an idea of the prevailing geographic context of the cited typologies. Some authors use indicators about feeder transport modes; some analyse the 'relevance' of the destination reachable with feeder modes. In fact, feeder modes can connect transport nodes with towns, villages, touristic places, or specialised areas like industrial sites, healthcare centres, university campuses, etc. Each of these destinations has different transport demands, for example, bigger towns and specialised areas can be connected to transport nodes with a frequent bus service, while small villages and touristic places can rely on alternative and demand-sensitive transport modes.

In conclusion, no one of the analysed sources is explicitly referred to 'extended station areas', or considers destinations beyond 'walkable catchment area' in its assessments, or systematically evaluates the quality of different feeder transport modes. Therefore, a methodology able to reach all these goals would fill this gap in the academic literature and, not secondarily, would provide a tool for planners and public decision-makers.

Chapter 3

The role of transport integration

The connection between transport nodes and destinations reachable with feeder modes receives, at the actual state of the art, little attention. The new typology has to focus on this aspect in order to produce an evolution of knowledge in this branch. In sutain of this vision, some authors underline the relevance of accessibility to public transport as an element able to increase overall accessibility by public transport (Keijer & Rietveld, 2000; Murray, 2003; Redman, Friman, Garling, & Hartig, 2013).

As extensively and passionately sustained by Paul Mees in his book 'Transport for Suburbia' (2010), high-quality public transport should not be considered a privilege of densely populated areas. He refers to some successful cases of integration between railway transport and feeder modes – especially in the Zurich Canton, Switzerland – as iconic examples.

Public transport authorities and municipal governing boards often cite low population density as the key factor preventing the implementation of public transport services. Mees cites some cases – Zurich, Toronto, etc. – as concrete examples that invalidate this assumption. The cited cases show that, leveraging on transport integration, is possible to provide high-quality public transport services despite medium or low population density.

The urban density of Zurich City is 67 per hectare, but the average for the middle and outer suburbs is 32 per hectare, 12 much lower than the equivalent parts of London, similar to or lower than in other English cities, and only about 20 per cent higher than the figures for the equivalent parts of Toronto and Los Angeles […]. In fact, the overall urban density of the City of the Angels is closer to Zurich than it is to Boston or Portland, Oregon.

Mees highlights that the 'compact city' model does not significantly encourage a shift from private car to 'sustainable transport'. He notices, at the same time, that urban transformation aimed to increase density within areas surrounding the stations are difficult to achieve. He summarizes these statements as 'good news':

The good news is that we don't need impossible increases in density to provide viable alternatives to the car. The relative attractiveness of competing urban transport modes seems to influence mode choice much more than differences in density, and the notion that 400 or even 30 residents per hectare is a minimum density below which public transport cannot be provided is completely unsupported by evidence.

The successful cases reported by Mees show that, within contexts with low population density and with low development expectations, the integration between modes becomes the key element that encourages people to choose more sustainable ways of transport instead of individual motorised transport. Integration can be achieved through many ways, like coordination of time schedules, regular-interval and mnemonic timetables, fare integration, easy transfers. The coordination of transport services, in fact, provides the flexibility needed to compete with private car, as experienced in the Zurich Canton, which implemented a strong transport integration starting from the 1970s:

> *A group of young SBB engineers […] argued that the main factor attracting passengers to the car was not high top speeds, but the freedom to travel when, where and as often as desired. […] All rail lines would be provided with regular-interval services at the same frequency, with schedules arranged so that different routes converged on key interchange stations at the same time. Passengers could then transfer in any direction, allowing 'anywhere to anywhere' travel all day long.*

Zurich authorities improved this system over time. In 1990, the *Zürcher Verkehrsverbund* (ZVV), a new monopolistic public transport organisation, commenced its operations, providing high-quality public transport throughout the entire Canton, linking main towns - Zurich, Winterthur – to suburbs and rural areas.

> *An illustration of the system in operation can be had by travelling to Hinwil, a town of around 5000 residents in the Zurich Oberland, the mountainous region in the far east of the canton. S-Bahn line 14 leaves Hinwil station at 8 and 38 minutes past the hour, from 5:38 am to 11:38 pm every day of the year; longer trains run at busy times. Five minutes down the line, each train arrives at the regional junction of Wetzikon, which has two 'island' platforms. A minute later, the S5 express service from* Rapperswil *pulls in on the opposite side of the platform. After passengers are exchanged, the express departs for Zurich, followed by the stopping-all-stations S14. A minute later, a third service departs: the S3, which uses the platform vacated by the express but follows a different route to Zurich, via the sub-regional centre of Pfaffikon. On the opposite island platform, the same procedure occurs in reverse, allowing transfers in all directions. In the station forecourt, half a dozen bus routes perform a similar manoeuvre. Some of these service the town of Wetzikon, while others fan out across the countryside to neighbouring rail corridors. Connections are possible between all three train lines and all six bus routes, in all directions. Once the last bus has left, Wetzikon station is quiet until the cycle begins again.*

The application of ZVV led to a steady increase of ridership, witnessing an undeniable success.

> *Daily patronage on the Zurich S-Bahn has risen from 159,000 in 1989, the year before the ZVV began, to 356,000 in 2007 – an increase of 124 per cent.*

Methodology

Since this research refers to non-metropolitan areas, by many ways similar to the ones described by Mees, it is crucial to identify a consistent method able to define the 'extended station area'.

The attention has to be pointed on: (1) feeder transport, since in these contexts residences, jobs and facilities are often located outside the 'classic' station catchment area used in TOD studies, based on walking distance. Moreover, (2) street network is not homogeneous as in dense urban areas, for this reason station area design has to be based on the 'network distance' rather than 'Euclidean distance'. In order to define the breadth of 'extended station area', two elements should be considered.

1. It is necessary to define how much time people are willing to spend to reach a main transport node – usually a railway station – rather than define a distance, since travel time seems to have a greater value than travel distance (Vale, 2013). This objective relies on data about travel time and the 'interconnectivity ratio' concept (Krygsman, Dijst, & Arentze, 2004).
2. Adopt the principle of 'network distance' instead of the 'Euclidean distance' often used in TOD studies (Gutiérrez & García-Palomares, 2008).

The first point, recognizing the importance of feeder transport, marks a difference between this research and the 'classic' TOD studies, regarding the sequence of transport modes that make up a travel, from its origin to the destination. With the expressions 'multimodal chain' (Rietveld, 2000), 'multimodal passenger transport' (Bokstael-Blok, 2002), 'multimodal public transport' (Krygsman et al., 2004) are often identified travels made up of multiple sub-trips, summarized by the sequence 'access trip – main mode trip – egress trip'. Seen from the 'transport chain' point of view, it can be said that, usually, land use and public transport integration studies are based upon the sequence 'walking – public transport – walking', where walking is considered the only access and egress mode to main transport. Main transport corresponds to train, metro and, less frequently, tram and bus rapid transit. These modes own the characteristics of main modes: high transport capacity and energy efficiency, they are not influenced by road congestion, few access and egress points, they provide fast connection.

In the light of the context and objectives of this research, the transport chain should include, for access and egress trips, also feeder mechanised transport, i.e. bike, public transport, car-based transport[26].

In fact, access and egress trips can rely on walking, bike, public feeder transport, car-based transport. The simple transport chain 'walking – main mode – walking' becomes thus more complex, turning into the chain 'mixed – main mode – mixed', in which access and egress trips can correspond to several different transport modes – i.e. walking, bike, public transport, car-based transport) as shown by figure 12.

[26] Is here considered car-based transport, which embraces modes like car-sharing, carpooling, car rental, taxi, park-and-ride, kiss-and-ride.

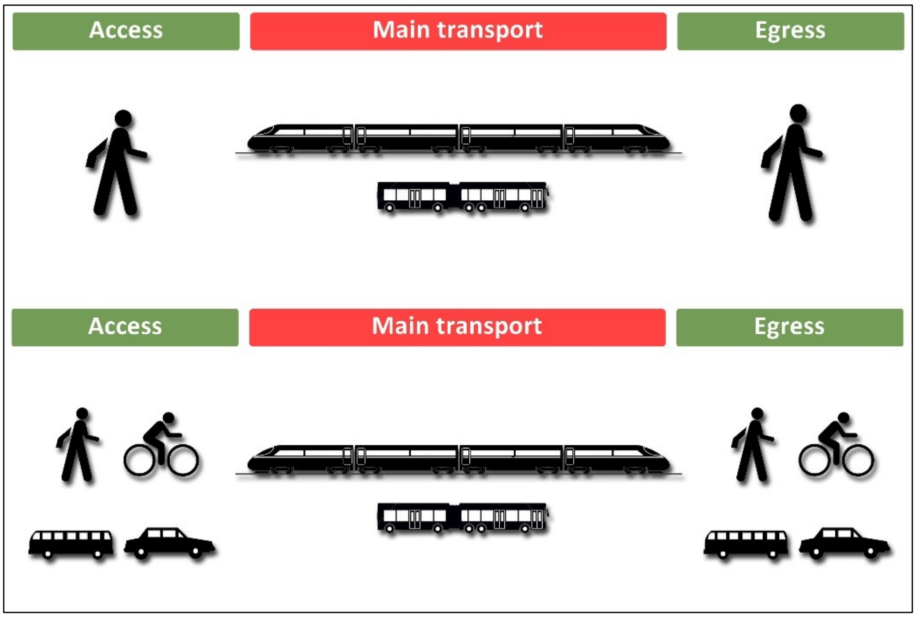

Figure 12. Multimodal transport chain and proposed innovation. Source: author's elaboration.

In the next figure is represented the conceptual diagram of the extended station area. Beyond the 'walkable' area, are sketched the areas reachable by bike, public transport and car-based transport, assuming that these modes allow to reach increasingly longer distances (Walker, 2012).

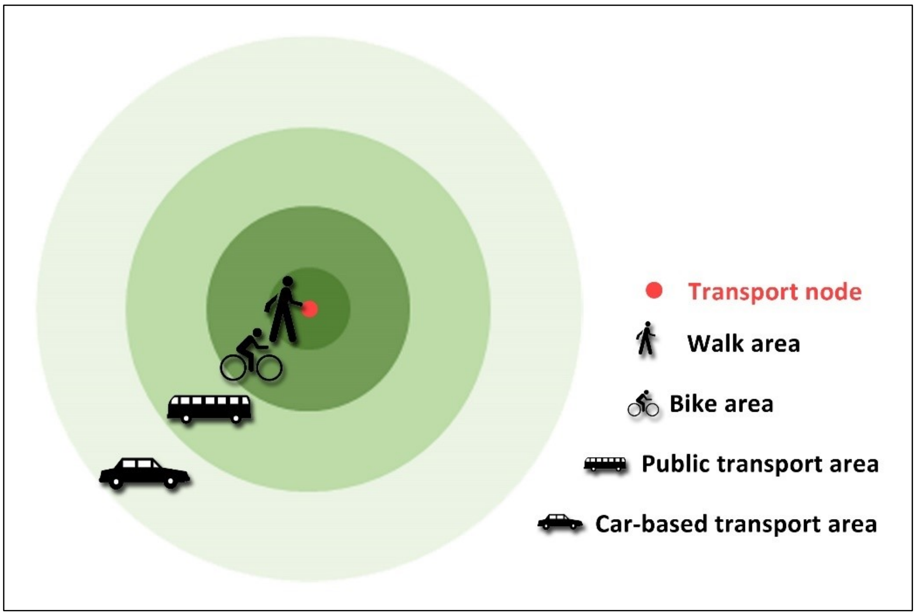

Figure 13. Conceptual diagram of the extended station area. Source: author's elaboration.

However, a fundamental difference exists between the 'classical' station area and the 'extended' station area. In fact, the circular walkable area can be used in urban contexts with a thick road network, thus representing an acceptable approximation of reality. Instead, in 'non-metropolitan' areas, to which this research refers, urban and road pattern is often highly irregular. For this reason, instead of 'Euclidean distance', seems more adequate the 'network distance' approach (Gutiérrez & García-Palomares, 2008). A GIS software can help in defining 'isochrone' areas (O'Sullivan, Morrison, & Shearer, 2000).

The 'network distance' approach corresponds to the design of isochrones based on the existing network of pedestrian paths (walk), bike lanes (bike), feeder transport lines (public transport), roads (car transport). In the next figure is sketched a possible transformation of the conceptual diagram into network distance areas, designed on the basis of isochrones.

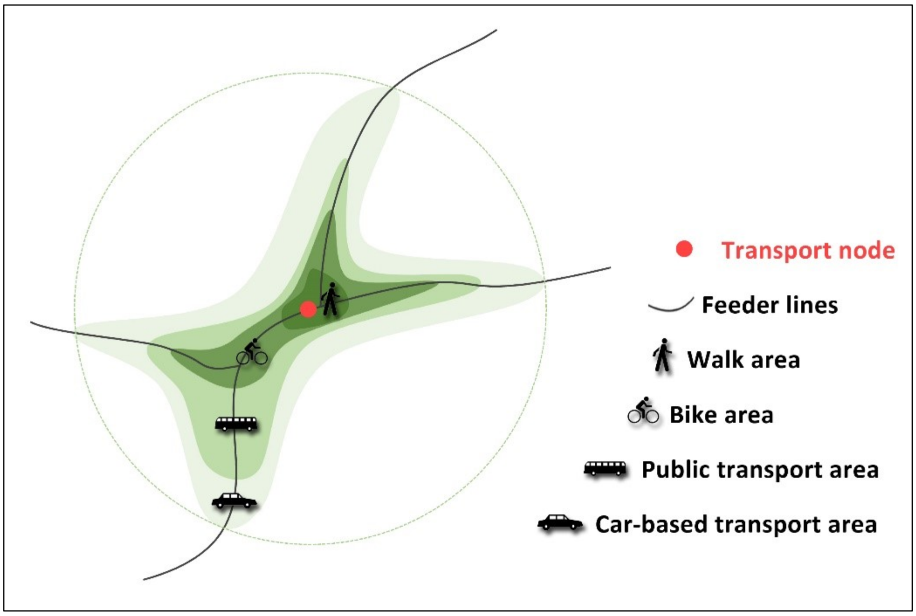

Figure 14. Conceptual diagram of 'network distance' station area. Source: author's elaboration.

Indicators

This paragraph reports the choice of indicators and gives some technical insights on how values are transformed into normalised scores. Differently from the usual node place analysis, in this methodology are considered some indicators explicitly aiming to assess the quality of feeder transport. The used indicators belong to three families.

- Main transport indicators.
- Place indicators, differentiated by catchment areas.
- Feeder transport indicators, differentiated by transport modes.

Some of the indicators have been individuated by the author, while many others can be found in previous studies on TOD typologies[27]. Place indicators are referred to catchment area; the value of each indicator is compared to the maximum value found among the analysed transport nodes, so obtaining a score between 0 (minimum) and 1 (maximum).

The choice of indicators is based upon the most recent orientations of academic literature and is influenced by data availability. In the case of main transport indicators, some authors

[27] For an extensive review, see Lyu et al., 2016.

highlight that frequency of service and 'span'[28], represent the most important qualities of public transport (Walker, 2012). The factors connected to of reliability, even if relevant (Monchambert & De Palma, 2014), are much harder to investigate due to lack or unavailability of data, so they have been excluded.

Main transport indicators:

- Number of directions served.
- Number of arrivals/departures per day (workdays and holidays).
- 'Span' (workdays and holidays).
- Ticketing services.

How many arrivals/departures?

The accessibility of a transport node is decisively influenced by the number of arrivals and departures per day. However, some issues can be related to the assessment of this figure, especially when the evaluation includes stops placed at the terminus of a transport line, or where services end, as sketched in figure 15.

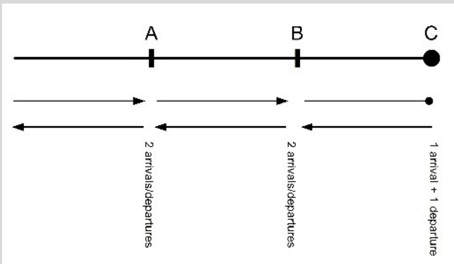

Figure 15. Arrival/departures diagram. Source: author's elaboration.

In this hypothetical case, every service calls at all stops (A, B, C), providing equal accessibility to each node. The counting solution adopted is differentiated according to the characteristics of nodes: in the case of non-terminal nodes, every arrival/departure is counted just once, while in the case of terminal stations, arrivals are counted separately from departures. In this example, this methodology gives the same result for each node, reflecting the real service pattern.

As suggested by Bertolini (1999), residential density, job density and functional mix constitute the indicators representing 'place' performance. However, in this research, data about functional mix have not been considered due to unavailability of data about workplaces in different economic sectors. The indicators of residential and job density have been calculated for each catchment area separately, meaning that each node will be linked to a fourfold analysis of 'place' performances. Occasionally, indicators about the amount of students have been added, in the cases in which the accessibility of education places represented an issue, as will be shown in chapter 5 about Campania study case.

[28] According to Walker (2012), 'span' is 'indicated by the scheduled time of first and the last trip in each direction'.

Place indicators:

- Residential density.
- Job density.
- Number of students.

Beyond 'urban density', it is necessary to find indicators able to assess the accessibility of each isochrone area. For this reason, Feeder transport indicators have been elaborated, and they are described in detail in the following paragraph.

Regarding walk transport, qualitative indicators referred to the quality of walking environment have been used, since this factor decisively affects walking safety, while the presence of pedestrian streets can result in shorter distances to potential destinations (Ewing & Handy, 2009; Saelens & Handy, 2008). Even though a quantitative study, e.g. based on the length of sidewalks and pedestrian streets would be more accurate, the unavailability of this kind of data suggested to use a qualitative approach, helped by field trips.

Walk transport indicators:

- Quality of sidewalks.
- Presence and quality of pedestrian streets.

Similarly, in the case of bike transport, an indicator related to the quality of bike environment has been included, since the quality of physical environment plays a key role in promoting transport bicycling (Buehler & Pucher, 2012; Xing, Handy & Moktarian, 2010). If available, also binary indicators referred to the presence of bike facilities at the transport node, like bike parking, bike lockers, bike repair, have been included.

Bike transport indicators:

- Presence and quality of bike lanes.
- Presence of bike facilities.

Regarding public feeder transport, the used set of indicators roughly corresponds to the list referred to main transport, with the addition of indicators related to the degree of fare integration, which has a strong influence on public transport attractiveness (Mees, 2010; Walker, 2012) and the quality of waiting places. This group of indicators is decisively influenced by the presence of at least one public transport line: in fact, differently from all other feeder transports, public transport inevitably needs fixed lines and scheduled services. Therefore, it can occur that a railway station has no public feeder transport, making also impossible to determine the extension of catchment area.

Public transport indicators:

- Presence of at least one line.
- Number of lines.
- Number of departures/arrivals per day (workdays and holidays).
- 'Span' (workdays and holidays).

- Degree of fare integration[29].
- Passenger services, like good-quality waiting places and kiosks/restaurants.

Car-based feeder transport embraces different transport modes, with diverse requirements. While we can say that kiss-and-ride is always possible, park-and-ride, car rental, car-sharing, carpooling and taxi service, necessitate specific infrastructures, like car parking, taxi rank, etc. For this reason, indicators referred to car facilities have been included.

Car-based transport indicators:

- Car-based transport facilities.
- Extension of car parking.

The choice of including car-based transport could appear contradictory in comparison to the claimed objective of improving accessibility by public transport and non-motorised modes. However, in low-density contexts, to which this study refers, car-based transport can be considered a plausible access/egress mode, working in cooperation with public transport rather than compete with it.

The cited families of indicators have been transformed into indexes, using simple arithmetical operations. It can be argued that different indicators could have different relevance, e.g. in the case of main transport, frequency can be considered more or less relevant than span or ticket services. A way to account for these differences would have considered 'weights' for each indicator proportioned to their relevance. However, the impossibility to define exact weights suggested to calculate a simple average rather than a weighted average. In conclusion, each catchment area will be described on the basis of:

- Accessibility by main transport (Node index).
- Intensity of land use (Place 'average values' differentiated by catchment area).
- Quality of feeder transport (Feeder transport 'average values' differentiated by transport).

Since the great number of indicators and indexes involved, it is useful to associate a code to each index, as done by the following table.

[29] This indicator answers to the questions: is it possible to buy integrated tickets? And how many, among the transport companies operating in this transport nodes, issue integrated tickets? E.g., in a transport node served by one train company and two bus companies, can occur that every company participates to fare integration – i.e. is possible to buy tickets valid for train and bus – or can happen that only two of them issue integrated tickets; in the worst case, there is no fare integration. The indicator will assume value 1 – maximum – in the first case and 0 – minimum – in the last.

Subject	Index	Area / transport	Code
Accessibility by main transport	Node index	-	N
Intensity of land use	Place average values	Walk area average value	Pw
		Bike area average value	Pb
		Public tr. average value	Pp
		Car-based average value	Pc
Quality of feeder transport	Feeder transport average values	Walk transport average value	Tw
		Bike transport average value	Tb
		Public transport average value	Tp
		Car-based tr. average value	Tc

Table 18. Indexes and codes. Source: author's elaboration.

Therefore, each transport node is described by the listed values, repeating the analysis four times, every time targeting one of the four catchment areas and the linked transport mode, as reported in the following table.

	Catchment areas/feeder transport			
	Walk area and transport	Bike area and transport	Public transport area and transport	Car-based area and transport
Accessibility by main transport	N	N	N	N
Intensity of land use	Pw	Pb	Pp	Pc
Quality of feeder transport	Tw	Tb	Tp	Tc

Table 19. Performances of transport nodes and indexes. Source: author's elaboration.

In order to obtain the General Place index (P), Place average values have been multiplied in pairwise by Feeder transport average values, thus obtaining four Place indexes per each node. Then, through the operation of average, General Place index has been obtained; this procedure is summarised and clarified by the following figure.

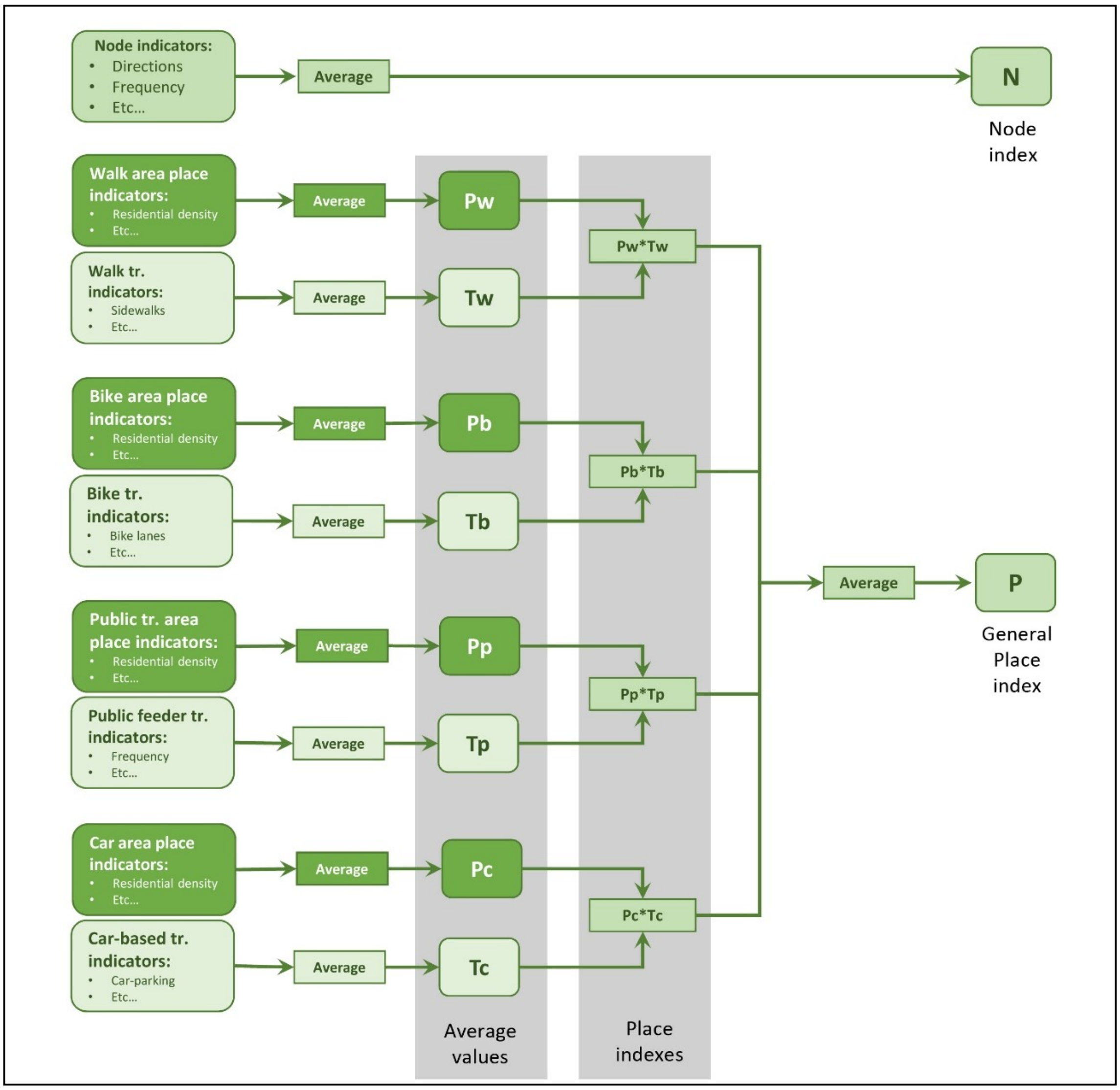

Figure 16. Connection between indicators and indexes. Source: author's elaboration.

'Three-step' node place analysis

Since the huge number of information involved, the methodology relies on a 'three-step' node place analysis, in which each step gives different insights, summarized as follows:

- A 'general' node place analysis giving a general description of the accessibility in the study area in comparison to intensity of land use.
- A 'detailed' node place analysis, differentiated by transport mode.
- A 'radar diagram' analysis, able to display which catchment area could host urban development, and whether an improvement of main or feeder transport is needed.

General node place analysis

The general node place analysis is based on the Node index (N) and the General Place index (P), coming from the combination of indicators.

Name	Formula
Node index (N)	Average of main transport indicators
General Place index (P)	$\frac{(Pw*Tw) + (Pb*Tb) + (Pp*Tp) + (Pc*Tc)}{4}$

Table 20. Operation linked to Node and General place indexes. Source: author's elaboration.

The results are displayed by a xy diagram, which reports on the vertical axis the values of Node index, and on the horizontal axis reports the values of General Place index, as done by Bertolini (1999). In this way, each transport node is represented by a point, which position underlines 'unbalances', e.g. cases in which urban density is not sustained by adequate accessibility or when high accessibility suggests increasing land use intensity. However, General Place index, although based upon values of residential and job density, is decisively influenced by the quality of feeder transport modes – walking, bike, public transport and car-based transport. At this stage of the study, the differences between accessibility by feeder transport and land use intensity are still not visible, in fact it can occur that a high value of General Place index is determined by high urban density in some catchment areas or, conversely, high accessibility provided by some feeder transport. This analysis does not clarify yet those aspects, thus a deeper study is needed, as explained in the following paragraphs.

It is important to underline that, in the case of the analysis based on the General Place index, residents and jobs belonging to the walking catchment area have a higher 'weight', because they are also included into bike and car catchment area, while very often they belong to public transport catchment area too. While we can say that, as example, jobs and residents placed within walking area belong to bike and car-based transport areas too, is not always true that they always belong to public transport catchment area. This means that jobs and residents located within walking area are will be surely counted in bike and car-based transport areas, but it is not possible to know a priori if they will be counted in public transport area. For these reasons, the 'detailed' node-place analysis is believed to be more insightful than the 'general' one.

Detailed node place analysis

The second step corresponds to a fourfold node place analysis detailed by feeder transport and the relative catchment areas, represented by four xy diagrams. In this case, the horizontal axes of the diagram report the Place indexes, obtained multiplying place average values (Pw, Pb, Pp and Pc) referred to catchment areas and feeder transport average values (Tw, Tb, Tp and Tc) referred to single transport mode, as shown by figure 17.

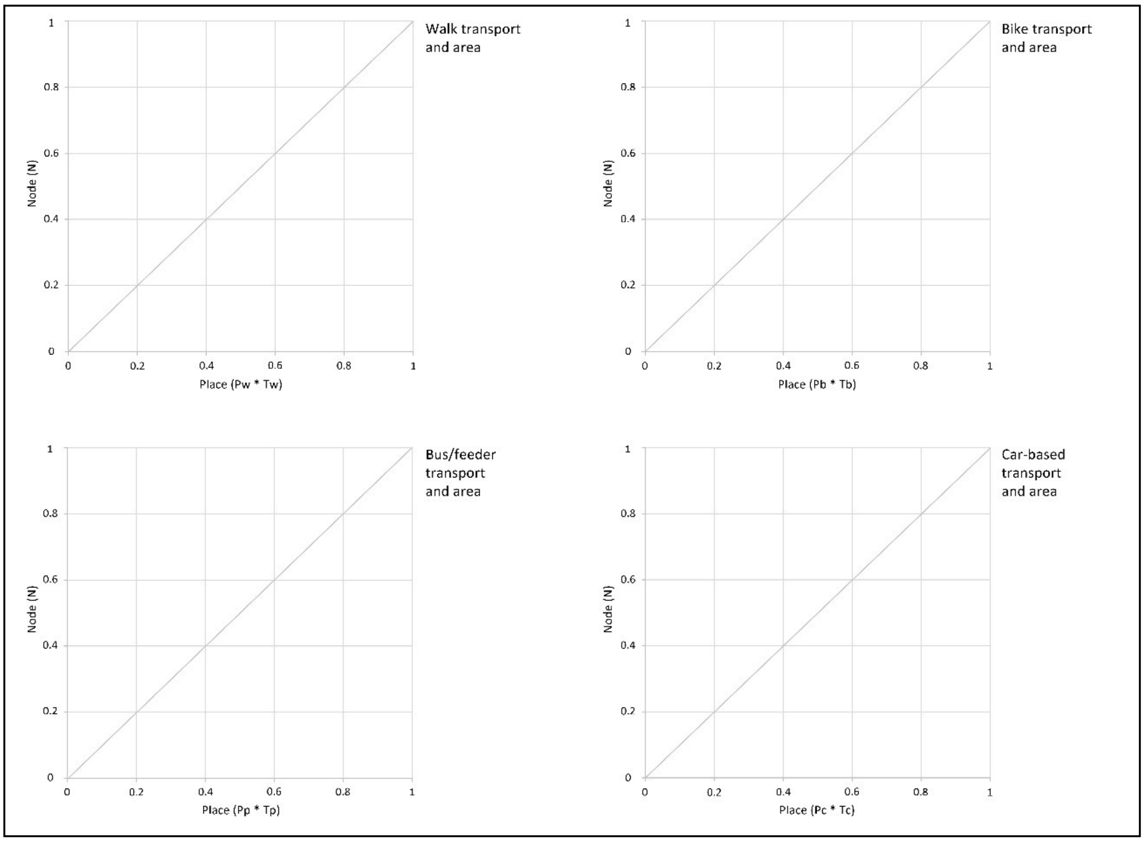

Figure 17. Example of diagrams representing the detailed node place analysis. Source: author's elaboration.

The detailed node place analysis helps to understand better, in relation to a transport node, the differences existing between the four catchment areas in terms of 'Place' performances. However, a deeper study able to treat separately Place and Feeder transport qualities is necessary, with the aim of highlight possible differences between these factors. This is represented by the 'radar charts' analysis, illustrated in the next paragraph.

Radar diagram analysis

The third step is lead through triangular radar diagrams[30] representing single catchment areas. On each axis are reported the scores of Node index (N), Place average values (Pw, Pb, Pp, Pc), Feeder transport average values (Tw, Tb, Tp, Tc), as shown by the following figures.

This step aims to highlight the – potential – situation of 'unbalance' and to suggest policies able to consider, at the same time, aspects referred to land use, accessibility by main transport and quality of feeder transport.

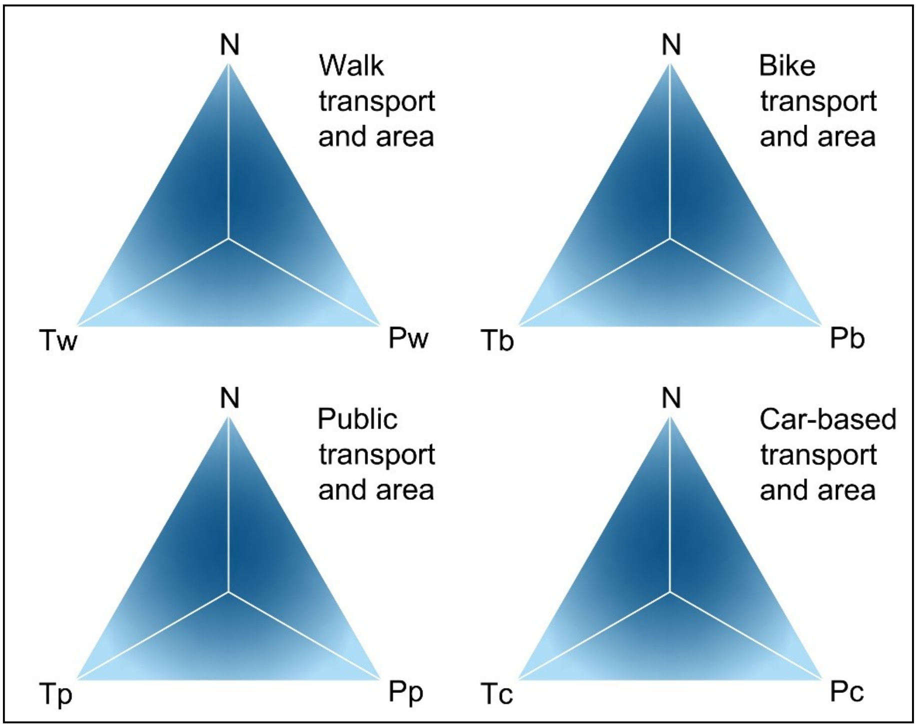

Figure 18. Set of four radar diagrams describing transport nodes' performances. Source: author's elaboration.

The diagrams reported in figure 18 can be 'translated' into a four-fold map, representing a transport node and its catchment areas, referred to different feeder transport modes, as displayed by figure 19. As can be observed, the extension of catchment areas is influenced by the shape of road network, except for public transport catchment area, whose depends on the pattern of lines – in this case bus lines – linked to the considered transport node. In fact, the shape of public transport catchment area is much more irregular in comparison to other catchment areas. In order to define the extension of public transport catchment area, information about public transport lines are needed; in the case of unavailability or incompleteness of these information, also public transport catchment areas will be determined on the basis of road network[31].

[30] A radar diagram, also known as spider chart or star chart or Kiviat diagram is a diagram able to show multivariate data of three or more variables by using a bi-dimensional representation (Chen, Härdle, & Unwin, 2007).

[31] In this research, as will be shown in Chapters 4, 5 and 6, a different approach has been followed according to the used study cases: in the cases of North Holland and Campania Region information about

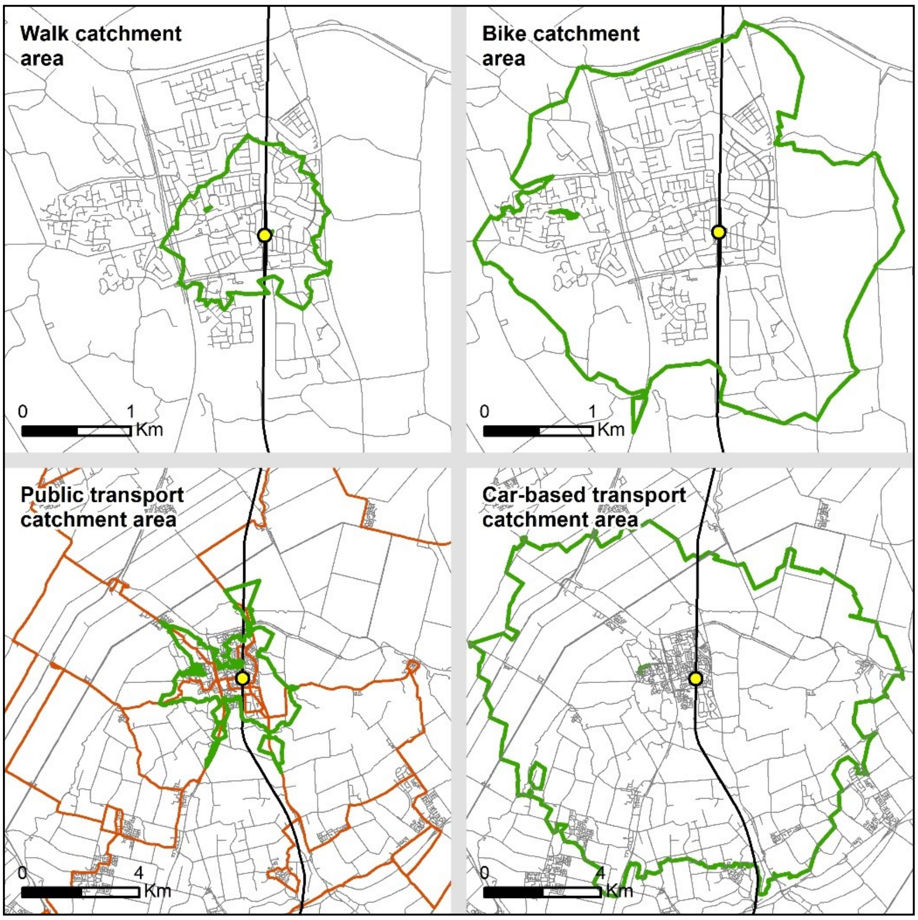

Figure 19. Example of four-fold catchment area. Source: author's elaboration.

Figure 19 displays the possible configuration of a four-fold catchment area, referred to a transport node – the yellow dot. The areas reachable by walking and bike include zones placed on both sides of transport node, meaning that pedestrians and cyclists have easy access to it. In the case of public transport catchment area, feeder transport is represented by the lines in light brown; as can be observed, in this case many lines are linked to the transport node, signalling a good integration between main and feeder transport.

It is important to underline that radar analysis has to be seen as a tool aiming to 'take a picture' of the actual state and suggest possible integrated land use – transport strategies. Therefore, irregular triangles do not automatically mean that a deep transformation is inevitable or the actual situation is unsustainable, but they highlight areas in which there could be the possibility of increasing the quantity of population and jobs, and where the actual transport offer is insufficient. However, a more detailed study focussed on those areas is necessary. In fact this analysis does not consider peculiar factors that can occur locally, i.e. the presence of constraints to urban or transport development – natural protected areas, archaeological sites, etc. – the existence of special

feeder public transport were available, thus public transport catchment areas have been designed on the basis of this network. Conversely, in Central Italy case study, it was not possible to obtain information about feeder public transport, so an approach based on standard road network was adopted.

destinations – touristic attractions, sport or amusement facilities – that justify a high accessibility level despite a medium or low density.

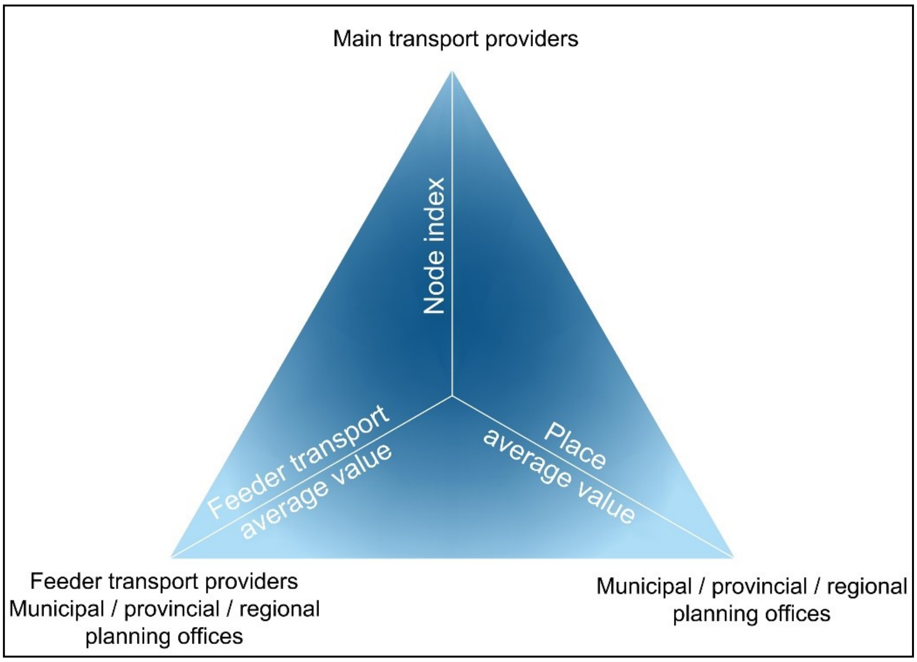

Figure 20. Radar diagram with linked stakeholders and public decision-makers. Source: author's elaboration.

As reported by figure 20, each axis can be linked to stakeholders and public decision-makers that directly influence, with their choices, the parameters represented by the chart. 'Node index' is decided by main transport company or companies, 'Place average value' is influenced by planning strategies of Municipal and Provincial planning offices, 'Feeder transport average value' is determined by the decisions of transport providers, as in the case of bus transport, while this aspect can be conditioned by municipal or provincial planning offices, as occurs when decisions regarding bike lanes, bus lanes, pedestrian areas, etc. have to be taken.

One of the goals of this analysis is, thus, to help urban and regional planners in defining their planning strategies, not only to underline 'mismatches' between land use and transport, but also highlighting possible solutions to reach a better integration. On the other side, transport authorities and companies can use it to adjust their transport offer on the basis of the potential demand. The next chapters report the application of this methodology to three study cases referred to 'non-metropolitan areas' located in the Netherlands and Italy. The implementation phase required to adjust the set of indicators used, while differences regarding travel habits influenced the definition of station catchment areas.

Chapter 4

North Holland study case

The province of North Holland shows a noticeable variety in terms of urban density. The southernmost area is part of the so-called Randstad, the horseshoe-shaped conurbation that occupies the central part of the Netherlands, spanning from Rotterdam to Utrecht and embracing many large and medium cities like The Hague, Amsterdam, Leiden, Haarlem, etc. The northern sector of the province is characterised by much sparser urban centres, and a lower urban and infrastructural density. For these reasons, some areas of the North Holland province seem adequate to implement the proposed typology[32].

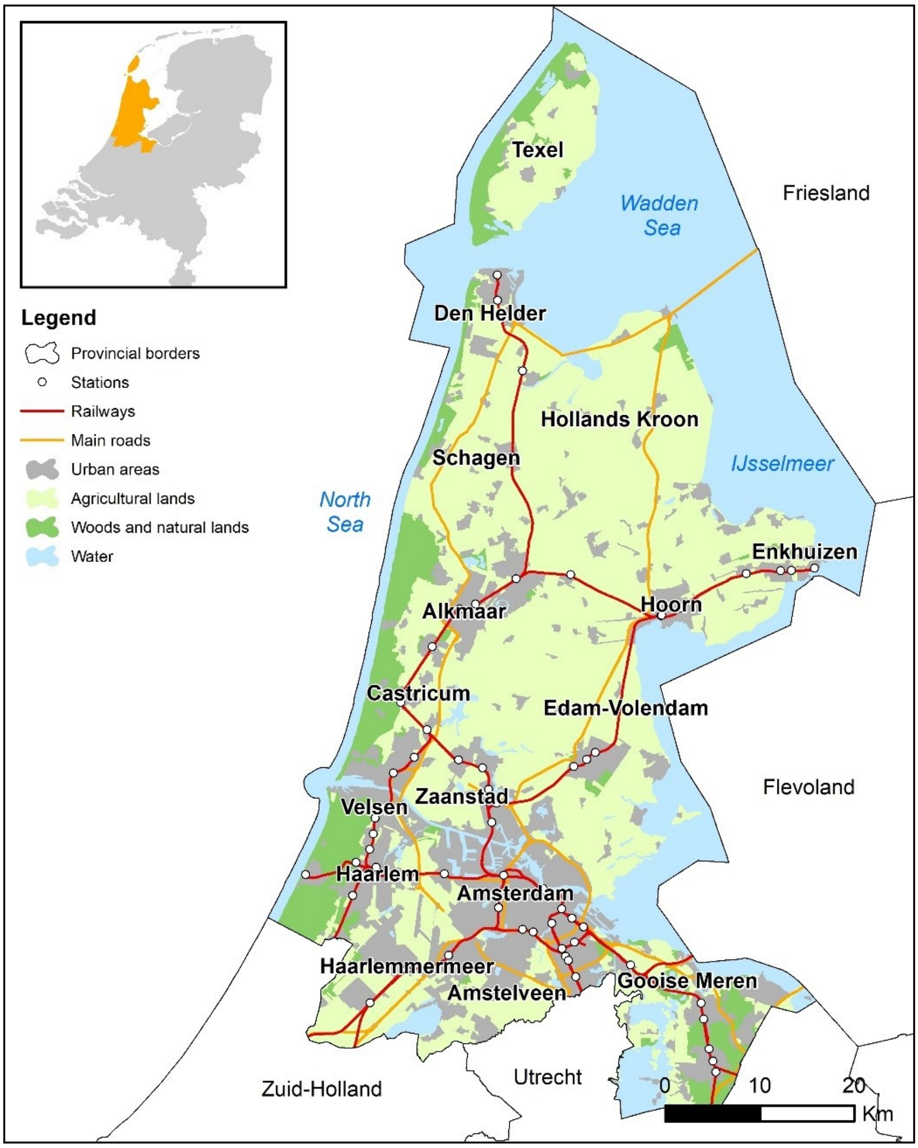

Figure 21. Province of North Holland, urban and infrastructural pattern. Source: author's elaboration.

32 All the maps in this chapter are based upon geographic data freely available at https://www.openstreetmap.org/ , http://www.imergis.nl/asp/47.asp , and http://land.copernicus.eu/pan-european/corine-land-cover/clc-2012 . Retrieved on 15/03/2017.

As already shown in the previous chapters, European Community authorities carried out a statistical classification, regarding all EU municipalities, aimed to categorise them into three typologies: 'Cities', 'Towns and suburbs', and 'Rural areas' (Dijkstra & Poelman, 2014).

In the following image, the railway map of North Holland is overlaid with the Eurostat classification of municipalities, in order to highlight those stations that can be used as study cases.

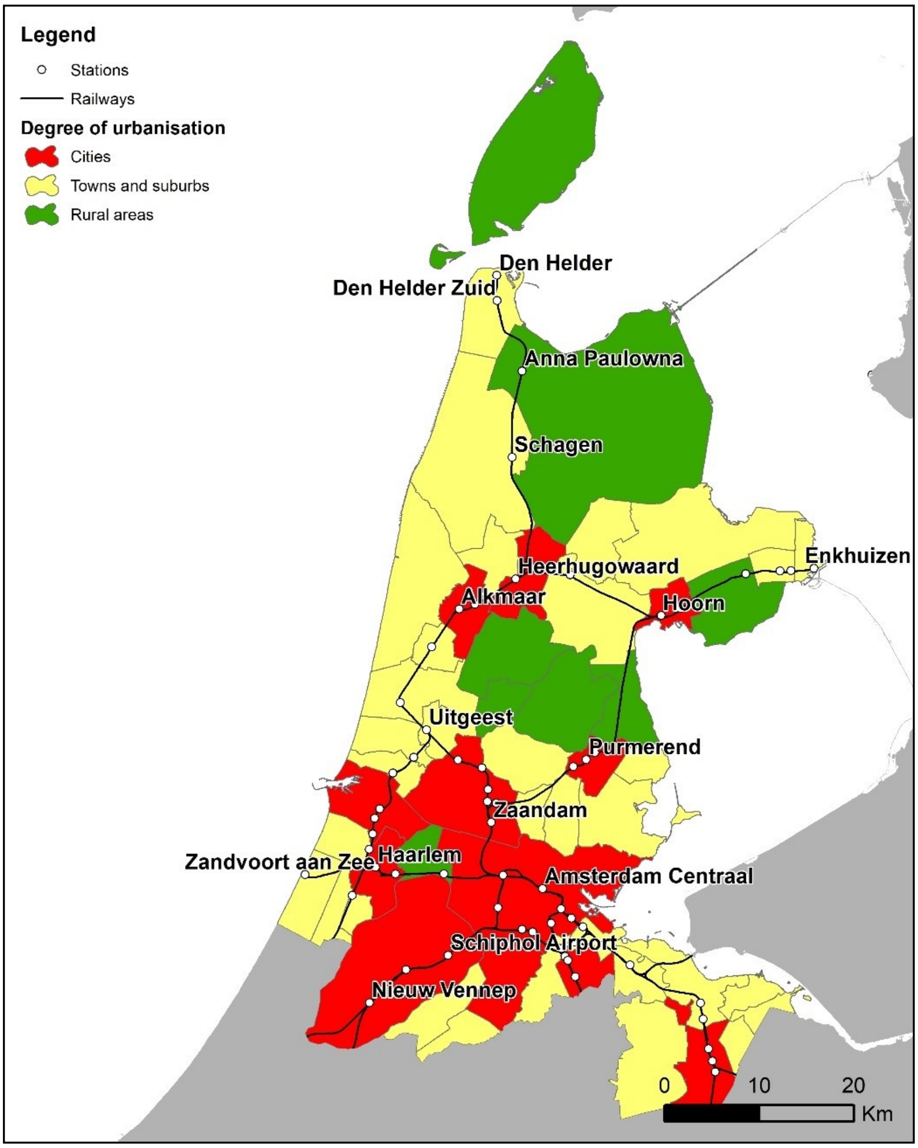

Figure 22. Province of North Holland. Urban degree of municipalities, and railway infrastructures. Source: author's elaboration based on Dijkstra & Poelman (2014).

The selected railway corridor involves nine stations, placed along the railway line Haarlem – Den Helder. Not all the stations found along the cited line have been included into the analysis, but only the ones located into municipalities classified as 'Towns and suburbs' and 'Rural areas'. The following list contains the studied stations.

- Den Helder

- Den Helder Zuid
- Anna Paulowna
- Schagen
- Heiloo
- Castricum
- Uitgeest
- Heemskerk
- Beverwijk

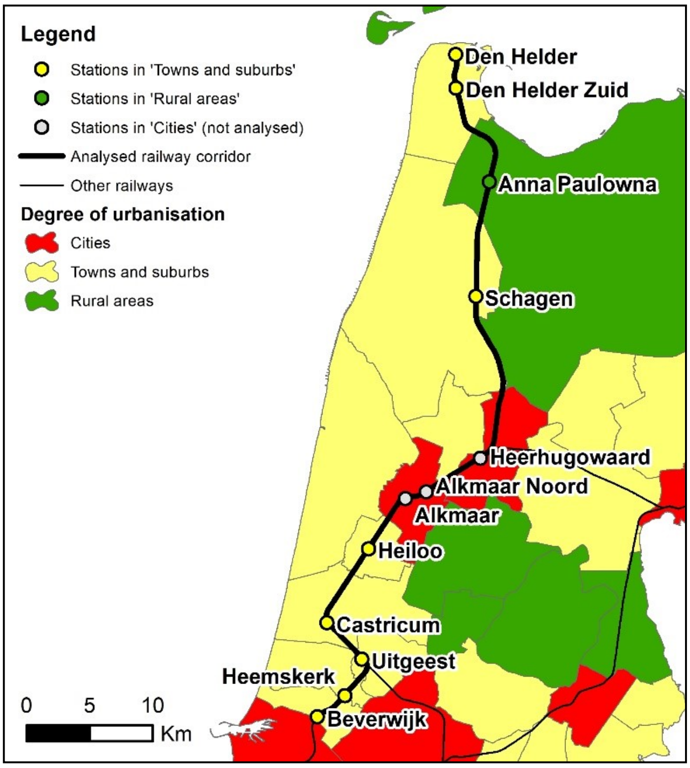

Figure 23. Analysed railway corridor. Source: author's elaboration.

It has been necessary to analyse the relationship between stations, road network and bus lines. In the following pictures (from 24 to 27), are reported the analysed stations, their position within road network and feeder bus lines. All stations, except Heemskerk, are connected to local bus network.

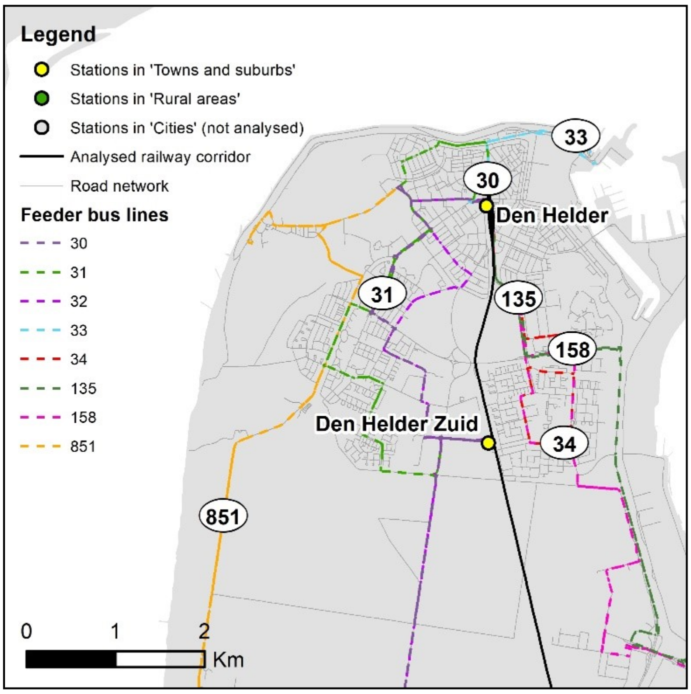

Figure 24. Transport nodes and relation with road network and bus lines: Den Helder and Den Helder Zuid. Source: author's elaboration.

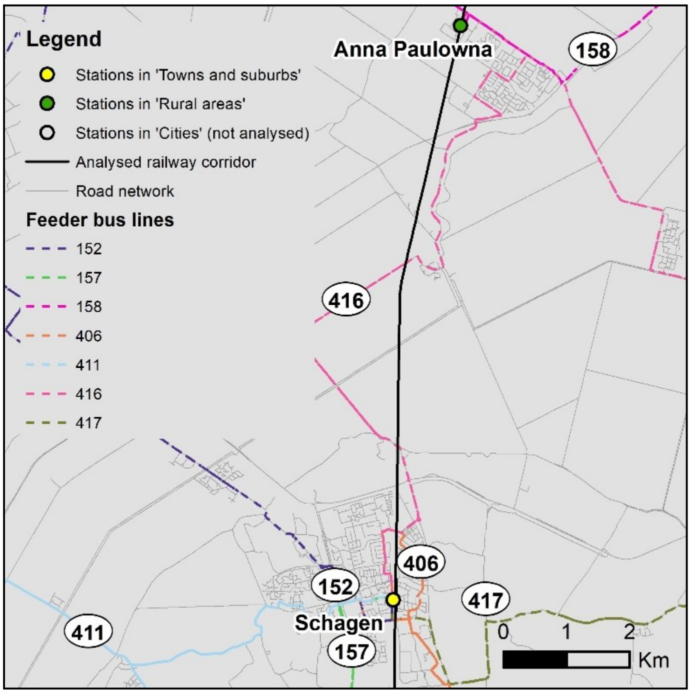

Figure 25. Transport nodes and relation with road network and bus lines: Anna Paulowna and Schagen. Source: author's elaboration.

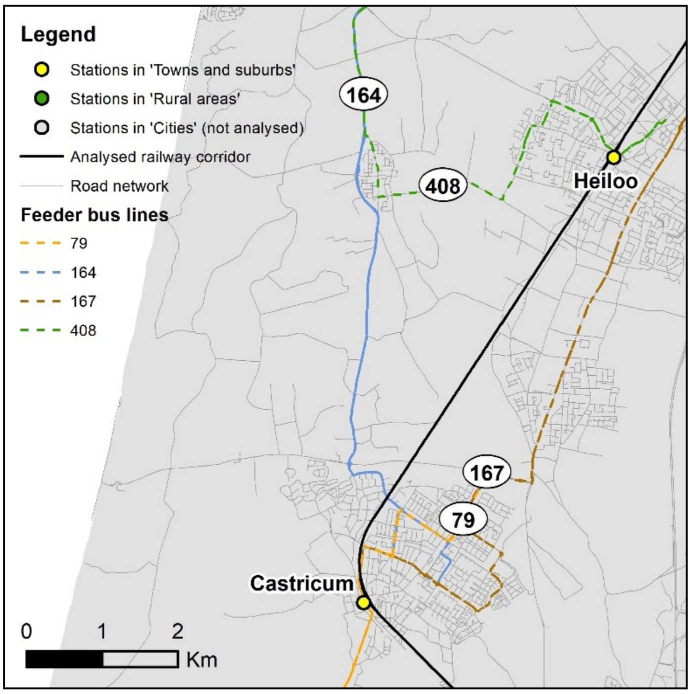

Figure 26. Transport nodes and relation with road network and bus lines: Heiloo and Castricum. Source: author's elaboration.

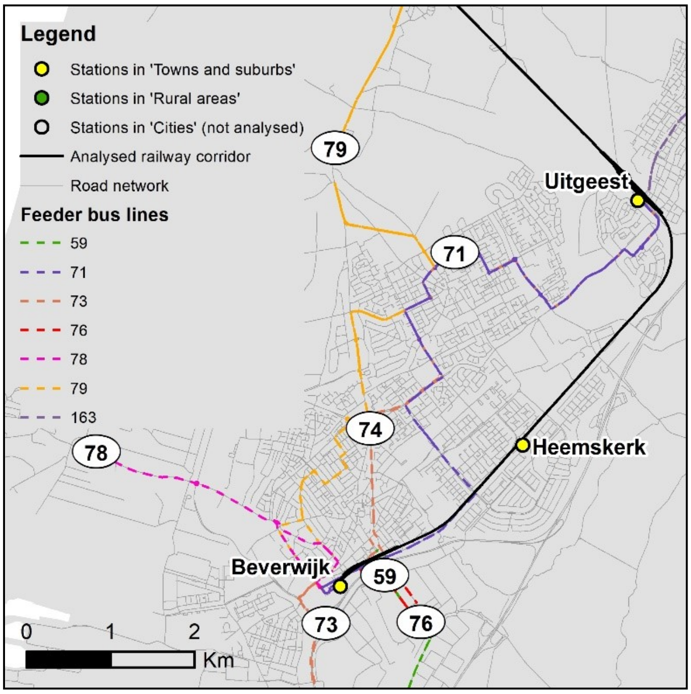

Figure 27. Transport nodes and relation with road network and bus lines: Uitgeest, Heemskerk and Beverwijk. Source: author's elaboration.

In the following table are summarised the feeder bus lines linked to the studied railway stations, with their characteristics in terms of frequency and service time.

Station	Feeder bus lines[33]	Workdays		Holydays	
		Frequency (departures/day)	Span (hours)	Frequency (departures/day)	Span (hours)
Den Helder	30	30	17	24	13
	31	29	16	21	13
	32	31	18	22	15
	34	29	16	14	14
	135	18	17	15	15
	158	16	13	-	-
	851[34]	-	-	-	-
Dep. total / max span	-	**153**	**18**	**96**	**15**
Den Helder Zuid	30	30	17	24	13
	31	29	16	21	13
	32	31	18	22	15
Dep. total / max span	-	**90**	**18**	**67**	**15**
Anna Paulowna	158	8	10	-	-
	708	5	5	5	15
	709[35]	5	5	5	15
Dep. total / max span	-	**18**	**10**	**10**	**15**
Schagen	150	13	13	-	-
	152	16	16	12	12
	157	14	14	-	-
	406	12	12	-	-
	411	12	12	-	-
	416	11	11	-	-
	417	13	13	-	-
Dep. total / max span	-	**91**	**16**	**12**	**12**
Heiloo	408	9	9	-	-
Castricum	79	30	17	14	14
	164	17	17	15	15
	167	26	18	15	15
Dep. total / max span	-	**73**	**18**	**44**	**15**
Uitgeest	73	38	19	33	17
	163	20	15	13	13
	N69[36]	-	-	-	-
Dep. total / max span	-	**58**	**19**	**46**	**17**

[33] All bus lines are managed by Connexxion. Information available at: https://www.connexxion.nl/ . Retrieved on 08/05/2017.
[34] Line 851 runs only in summer months, so it has been excluded.
[35] Lines 708 and 709 are 'overstapper' lines (service has to be reserved).
[36] Night line.

Heemskerk	-	-	-	-	-
Beverwijk	59	30	15	14	14
	71[37]	-	-	18	9
	72	17	17	14	14
	73	38	19	33	17
	74	32	18	15	15
	76[38]	-	-	18	18
	78	35	17	32	16
	79	30	17	14	14
Dep. total / max span	-	**182**	**19**	**158**	**18**

Table 21. Transport nodes and features of feeder bus lines. Source: author's elaboration.

The following figure describes the 'extended station areas' linked to analysed stations. The extended station areas relative to stations located in 'Cities' are reported in grey.

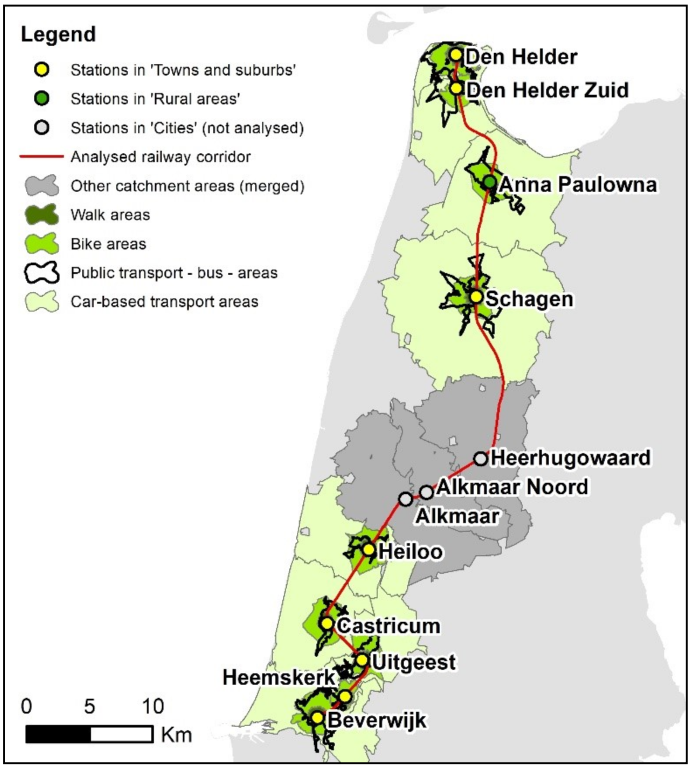

Figure 28. Isochrone catchment areas. Source: author's elaboration.

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[39], on the basis of the closest station, also including catchment areas linked to stations located in 'Cities'. This kind of situation can be observed, in figure 28, in the south-western sector of North Holland territory, where many stations are located very short distance.

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[37] Line 71 runs only on Saturdays.
[38] Line 76 runs only on Saturdays.
[39] A GIS software has been used to elaborate maps.

Data sources

Data about travel behaviour are issued by the Dutch *Centraal Bureau voor de Statistiek* – CBS. CBS leads a yearly survey specifically focussed on travel habits across the Netherlands. The latest available information date back to 2015, representing the most complete and appropriate data sources. The statistics provided by CBS are differentiated on the basis of transport modes. CBS[40] differentiates trip modes as follows.

- Train.
- Bus/tram/metro.
- Bike/motorbike.
- Walking.
- Car (driver).
- Car (passenger).
- Other.

It is important to note that trips made, e.g. by train, correspond to the travels for which the train is the prevalent transport mode. This means that the voice 'train' embraces trips made of multiple sub-trips, relying on different transport modes, such as bike-train-walk or car-train-walk or bus-train-bus, etc. This value of time corresponds to the 'time travel for displacement' voice (*Reisduur per verplaatsing*). Considering trip's purposes[41], the Dutch statistical database makes the following distinction.

- Work.
- Business trip.
- Medical care.
- Shopping.
- Education / classes and childcare.
- Make visits / stay over.
- Sport, hobby, hospitality visit.
- Travel / hike.
- Other.

In this study case, railway transport can play the role of main transport, since it is the main public transport infrastructure of the region. Thus, average commuting time referred to trips with railway transport as main mode, seems to approximate well the average commuting time for this study case.

[40] http://statline.cbs.nl/Statweb/selection/?DM=SLNL&PA=83499NED&VW=T . Retrieved on 13/3/2017.

[41] http://statline.cbs.nl/Statweb/selection/?DM=SLNL&PA=83494NED&VW=T . Retrieved on 13/3/2017.

Travel time

It is essential to quantify the average commuting time by train. According to some national statistics, average commuting time varies from nation to nation and within national borders, as it is influenced by transport modes, transport's purposes, land use pattern, personal preferences, etc. CBS also provides data differentiated by 'urban degree' (*Stedelijkheidsgraad*). The following table reports commuting time in the Netherlands – by train and all modes – and differentiated by urban contexts.

Average travel time per urban degree and transport mode, year 2016		
Area, urban degree	Transport modes	Average travel time (minutes)
The Netherlands - total	All modes	23.02
	Train	75.95
Very strong urban	All modes	25.19
	Train	74.58
Strong urban	All modes	22.77
	Train	72.56
Moderate urban	All modes	21.68
	Train	80.44
Little urban	All modes	22.41
	Train	81.64
Not urban	All modes	22.80
	Train	77.49

Table 22. Travel time in the Netherlands. Source: author's elaboration based on CBS data.

Average commuting time does not show great variations among the different contexts. In the following table, travel duration is analysed for travels made by train and all travels[42].

[42] http://statline.cbs.nl/Statweb/publication/?DM=SLNL&PA=83500NED&D1=4&D2=0&D3=0%2c3&D4=a&D5=0&D6=l&VW=T Retrieved on 13/03/2017.

The Netherlands, average travel time per mode and trip's purposes, year 2016		
Transport mode	Travel's purpose	Travel time (minutes)
All modes	Total	23.02
	Work	28.25
	Business trip in working atmosphere	45.10
	Services / medical care	21.09
	Shopping	13.78
	Education / classes and childcare	21.54
	Make visits / stay over	24.41
	Sport, hobby, hospitality visit	24.65
	Travel / hike	42.65
	Others	15.12
Train as main mode	Total	75.95
	Work	64.86
	Business trip in working atmosphere	-
	Services / medical care	-
	Shopping	59.55
	Education / classes and childcare	71.01
	Make visits / stay over	100.09
	Sport, hobby, hospitality visit	88.93
	Travel / hike	-
	Others	-

Table 23. Average travel time in the Netherlands. Source: author's elaboration based on CBS data.

According to these numbers, the average travel time by train shows, at national level, some variations related to the purpose of travel. In particular, travels by train towards workplaces, shops and schools register the lowest values (respectively 64.86, 59.55 and 71.01 minutes), though much higher than the corresponding values referred to all modes.

Access and egress times

Once obtained reliable values of travel time, is necessary to esteem how much time people are willing to spend in order to cover the distance between the point of origin of their journey and the departure station (access trip), and between the arrival station and the final destination (egress trip). Krygsman, Dijst & Arentze (2004) define the 'interconnectivity ratio' of multimodal chains as the proportion of access and egress time to total trip travel time.

Although individual access and egress times show significant individual variability, the interconnectivity ratio shows less variation falling mainly in the range of 0.2–0.5 for most multimodal public transport chains. With increasing trip time, the ratio shows a continuously decreasing trend. This decreasing trend is very much a function of the multimodal mode chain (i.e. access–main–egress) and the overall trip time.

The multimodal chains described by Krygsman et al. (2004) are differentiated by transport modes and total travel time. According to them, the interconnectivity ratio for the multimodal chain 'mixed-train-mixed' varies on the basis of travel's overall duration[43].

In the following table is esteemed, based on the interconnectivity ratio, and on the numbers about the average duration of a train travel in the Netherlands, plausible values of access/egress time to railway stations. Although the cited scholars argue that the access time to transport could be slightly different from the egress time, in this case is supposed that these two values are equal. Access/egress only time is, thus, obtained halving the 'Access + egress time'.

The Netherlands, outbound travel time by train (minutes)		Interconnectivity ratio	Access time + egress time (minutes)	Time for access/egress only (minutes)
Home-to-work trips	64.9	0.35	22.7	11.35
All trips	75.9	0.30	22.8	11.4
All trips, 'moderate urban' areas	80.44	0.30	24.1	12.05

Table 24. Dutch travel times and related access/egress times. Source: author's elaboration.

Access/egress time to railway station varies slightly, from 11.35 to a maximum of 12.05 minutes, in spite of the variation of travel time. In conclusion, considering the exposed arguments about interconnectivity ratio and average commuting time, it can be supposed that access and egress times is to some extent longer than the standard value of 10 minutes used in TOD studies. It can be here hypothesised a value of 12 minutes as basis to calculate the breadth of extended station area.

The value of 12 minutes has to be put in relation with the expected speed of different feeder transport modes, in order to calculate the distance reachable by each of them. Again, CBS provides useful data for the Netherlands: in fact, its database contains information about travels' length in terms of space and time, also differentiated by 'urban degree'[44]. Combining these two dimensions, the average speed can be obtained easily.

Travel speed (km/h) by transport mode and degree of urbanisation, all travel purposes, the Netherlands, year 2016						
Transport mode	The Netherlands - total	Very strong urban	Strong urban	Moderate urban	Little urban	Not urban
Car (driver)	*46,0*	41,2	46,1	45,8	48,4	48,3
Bus/tram/metro	*17,8*	13,8	20,5	20,0	25,9	-
Bike	*12,5*	11,7	12,2	12,9	12,8	13,6
Walking	*5,3*	5,7	5,1	5,3	5,1	5,2

Table 25. Travel speed in the Netherlands. Source: author's elaboration based on CBS data.

[43] Values can be deduced by figure 2, referring to the graph about mixed-train-mixed transport chain (Krygsman et al., 2004).

[44] http://statline.cbs.nl/Statweb/publication/?DM=SLNL&PA=83500NED&D1=3-4&D2=0&D3=1,4,6-8&D4=0&D5=0,17-21&D6=l&HDR=T&STB=G1,G4,G3,G2,G5&VW=T Retrieved on 24/03/2017.

Following these values, it is worth remarking the greater speed of car and bus transport in less densely urbanised areas. In the light of this research's objectives, seems correct to use speed values referred to 'moderate urban' degree of urbanisation, rounding off them. The following values have been obtained: 45 km/h for car, 20 km/h for bus, 12 km/h for bike, 5 km/h for walking. It can be also assumed that, in 'moderate urban' areas, the value of 20 km/h is mainly referred to bus transport, due to the smaller influence that, in these contexts, tram and metro transport have. Medium towns and small cities, in fact, often lack a tram network, while metro networks can be found only in major cities.

Finally, in order to extract from CBS database the desired values of travel time, have been considered only travels with the following characteristics.

- Mode: travels by train, because this transport mode represents 'main transport' in this study case.
- Purpose. All travels have been considered, because a better integration of modes can boost accessibility not only for residents, workers and students but also for tourists, people who travel to fulfil sport or leisure activities, shopping, etc. So, are here considered all travels, independently from their purpose.
- Travel's location. CBS provides travel data differentiated on the basis of 'urban degree', so have been selected data referred to the areas classified as 'moderate urban'.

In conclusion, the value of 80.44 minutes[45] has been considered, since this value, according to CBS database, corresponds to the average time of travels made by train that take place in 'moderate urban' areas. Multiplying 80.44 minutes by 0.30[46], the value of 24.1 minutes has been obtained as access + egress time. Access or egress time corresponds, thus to 12.05 minutes, rounded off to 12. In order to determine the breadth of extended station area, the value of 12 minutes is has been used to calculate the corresponding distances reachable by motorised modes. The following table reports the corresponding distances for each transport mode.

Feeder transport	Average speed (km/h)	Motorised modes: Distance covered in 12 minutes (km)
Walking	5	1
Bike	12	2.4
Bus	20	4
Car	45	9

Table 26. Speed of feeder transport and corresponding distances. Source: author's elaboration based on CBS data.

[45] Data available at http://statline.cbs.nl/Statweb/publication/?DM=SLNL&PA=83500NED&D1=4&D2=0&D3=3&D4=0&D5=0,17-21&D6=l&HDR=T&STB=G1,G4,G3,G2,G5&VW=T Retrieved on 23/03/2017.

[46] Interconnectivity ratio according to Krygsman et al. (2004).

Population

In order to calculate the amount of population dwelling in each catchment area, data provided by CBS were used. For this research's purposes, the *Kaart met statistieken per vierkant*[47] is the most accurate geographic database for the Dutch context.

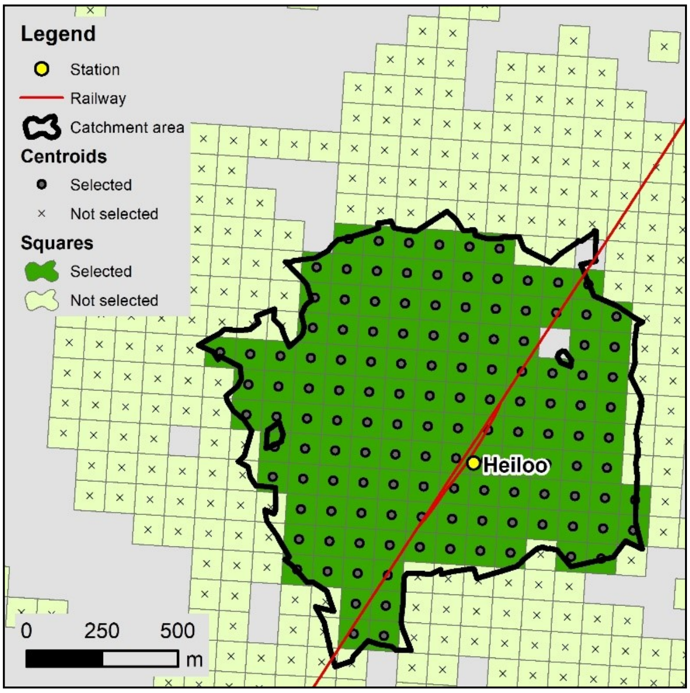

Figure 29. Exemplification of the selection operation. Source: author's elaboration based on CBS data.

The cited map splits the Dutch territory into squares, with 100-metres sides, and contains demographic information for each square. The methodology chosen to select the squares is based on geometrical rules. In fact, are considered only the squares whose centroids fall within a catchment area, as shown by image 29.

The use of centroids allows to link univocally a square to a certain catchment area; this technique is useful in those situations in which catchment areas border one another, since it prevents the risk of counting twice the same squares.

Esteemed jobs

Data about workplaces are freely available only at the municipal scale, and are not reported by the *Kaart met statistieken per vierkant*. LISA[48] database was used in order to obtain data about jobs referred to the year 2014, per each municipality within Dutch territory. Then, the quantity of jobs

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[47] Extended name: *Kaart met statistieken per vierkant van 100 bij 100 meter* (Statstical map by 100x100 metres squares). Available at https://www.cbs.nl/nl-nl/dossier/nederland-regionaal/geografische%20data/kaart-met-statistieken-per-vierkant-van-100-bij-100-meter . Retrieved on 12/04/2017.

[48] https://www.lisa.nl/data/gratis-data/overzicht-lisa-data-per-gemeente. Retrieved on 28/04/2017.

per municipality was put in relation with population figures, to find a ratio between residents and jobs. This ratio allowed to esteem the amount of workplaces located within each catchment area.

The found ratio allowed to esteem the amount of jobs for each square as defined by CBS, differentiated by municipality. E.g., if Heiloo municipality has a ratio jobs/population of 0.30, a hypothetical square belonging to Heiloo municipality with 100 inhabitants, will have an esteemed amount of 30 jobs. In conclusion, each cell – and each centroid – has attributes describing the number of residents and esteemed jobs. This allows counting the amount of people and jobs for each catchment area.

Municipality	Jobs[49] 2014	Population 2014	Ratio jobs/population
Den Helder	26,840	56,425	0.48
Hollands Kroon	16,080	47,120	0.34
Schagen	20,810	45,675	0.46
Langedijk	8,330	26,640	0.31
Heerhugowaard	22,070	53,220	0.41
Alkmaar[50]	56,200	106,590	0.53
Bergen	10,120	29,965	0.34
Heiloo	6,740	22,595	0.30
Castricum	10,010	34,130	0.29
Uitgeest	3,560	13,395	0.27
Heemskerk	8,880	41,815	0.21
Beverwijk	17,640	37,085	0.48
Velsen	33,250	67,580	0.49
Zaanstad	60,070	148,860	0.40

Table 27. Municipalities involved by catchment areas: figures about jobs and population. Source: author's elaboration based on LISA database and demographic data.

However, it is important to remark the limitations of this method. In fact, it assumes that workplaces are distributed evenly throughout municipal territories while, as experience suggests, in the reality jobs are condensed in limited areas. Moreover, it would be crucial to consider, for the place index, also activities that attract visitors, like education facilities, public and private services, touristic attractions, etc. However, the unavailability of more detailed data represents a limitation.

[49] The number of jobs corresponds to the total number of full-timers, part-timers and temporary workers.

[50] The figures about Alkmaar are have been obtained by summing up data about the former municipalities of Alkmaar itself, Graft-De Rijp and Schermer. In fact, in 2015 these three municipalities have been merged into the actual Alkmaar.

Methodology implementation and results

This paragraph illustrates the implementation of the methodology to North Holland study case, detailing the used indicators and the application of the 'three-step' node place analysis.

Node indicators

Main transport	Indicators	Description	Measure unit	Score	Code
Train[51]	Directions	Number of directions served	n	n/MAX value	-
	Frequency (workdays)	Arrivals or departures per day on workdays	n per day	n/MAX value	-
	Frequency (holydays)	Arrivals or departures per day on holydays	n per day	n/MAX value	-
	Span (workdays)	Service time on workdays	hours	hours/MAX value	-
	Span (holydays)	Service time on holidays	hours	hours/MAX value	-
	NS standards[52]	Ticket machine	Y/N	0/1	-
	Node index		-	Average of scores	N

Table 28. Node indicators. Source: author's elaboration.

Place indicators

12-minutes Isochrone area	Name	Measure unit	Score	Code
Walking area	Residential density	Population / km²	Density/MAX density	-
	Esteemed job density	Jobs / km²	Density/MAX density	-
	Walking area average value	-	Average of scores	Pw
Bike area	Residential density	Population / km²	Density/MAX density	-
	Job density	Jobs / km²	Density/MAX density	-
	Bike area average value	-	Average of scores	Pb
Public transport area	Residential density	Population / km²	Density/MAX density	-
	Job density	Jobs / km²	Density/MAX density	-
	Public t. area average value	-	Average of scores	Pp
Car-based transport area	Residential density	Population / km²	Density/MAX density	-
	Job density	Jobs / km²	Density/MAX density	-
	Car-based t. area average value	-	Average of scores	Pc

Table 29. Place indicators. Source: author's elaboration.

Feeder transport indicators

Some indicators are based on the NS standards, in these cases the presence of the considered facility corresponds to 1, while the absence corresponds to 0. The goal of Feeder

[51] Source: http://www.ns.nl/reisinformatie/download-dienstregeling . Retrieved on 08/05/2017.
[52] Source: http://www.ns.nl/stationsinformatie .

transport indicators is to evaluate the accessibility level of every isochrone area from the point of view of the considered transport mode.

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	-
	Pedestrian streets	Quality of pedestrian streets	0	No presence of pedestrian streets	-
			0.33	Few pedestrian streets	-
			0.66	Many pedestrian streets	-
			1	Extensive network of pedestrian streets	-
	Walk transport average value		Average of scores		Tw

Table 30. Indicators relative to walk transport and walking area. Source: author's elaboration.

Feeder transport	Indicator	Description	Measure unit	Score		Code
Bike	NS st.[53]	Unguarded cycle storage	Y/N	0/1		-
		Self Service bike storage	Y/N	0/1		-
		Bike rental	Y/N	0/1		-
		P. t. bike (ov-fiets)	Y/N	0/1		-
		Bike repair shop	Y/N	0/1		-
		Bike locker	Y/N	0/1		-
	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	-
	Bike transport average value		-	Average of scores		Tb

Table 31. Indicators relative to bike transport and bike area. Source: author's elaboration.

[53] Information available at http://www.ns.nl/stationsinformatie . Retrieved on 08/05/2017. Although other NS standards can be found, they have not been included since they are not present in the studied stations.

Feeder transport	Indicator	Description	Measure unit	Score	Code
Public tr.[54]	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	-
	Frequency (workdays)	Departures per day on workdays	n	n/MAX value	-
	Frequency (holydays)	Departures per day on holidays	n	n/MAX value	-
	Span (workdays)	Service time on workdays	hours	hours/MAX value	-
	Span (holydays)	Service time on holidays	hours	hours/MAX value	-
	Fare integration	Degree of fare integration	n/n[55]	n integrated companies / n transport companies	-
	Passenger facilities/NS standards[56]	Waiting room	Y/N	0/1	-
		Restaurants/kiosks	Y/N	0/1	-
	Public transport average value		-	Average of scores	Tp

Table 32. Indicators relative to public transport. Source: author's elaboration.

Feeder transport	Indicator	Description	Measure unit	Score	Code
Car-based transport	NS standards[57]	Park and ride	Y/N	0/1	-
		NS zone taxi	Y/N	0/1	-
		Taxi rank	Y/N	0/1	-
	Car parking	Car parking area	m^2	m^2 / MAX value	-
	Car based transport average value		-	Average of scores	Tc

Table 33. Indicators relative to car-based transport. Source: author's elaboration.

Place indexes are acquired by multiplying in pairwise place average values (Pw, Pb, Pp, Pc) by feeder transport average values (Tw, Tb, Tp, Tc), as explained by table 34.

Name	Formula
Walk place index	Pw*Tw
Bike place index	Pb*Tb
Public transport place index	Pp*Tp
Car-based transport place index	Pc*Tc

Table 34. Place indexes differentiated by feeder transport modes. Source: author's elaboration.

[54] Information available at: https://www.connexxion.nl/ . Retrieved on 08/05/2017.

[55] Transport companies for North Holland case study: NS, Connexxion.

[56] Information available at http://www.ns.nl/stationsinformatie . Retrieved on 08/05/2017. Although other NS standards can be found, they have not been included since they are not present in the studied stations.

[57] Information available at http://www.ns.nl/stationsinformatie . Retrieved on 08/05/2017. Although other NS standards can be found, they have not been included since they are not present in the studied stations.

General node place analysis

In this paragraph are illustrated the results of the analysis referred to North Holland and some possible policy implications. The results will be displayed following the order: general node place analysis, detailed node place analysis, 'radar diagram' analysis. The first step corresponds to the general node place analysis, reported by the following diagram and table.

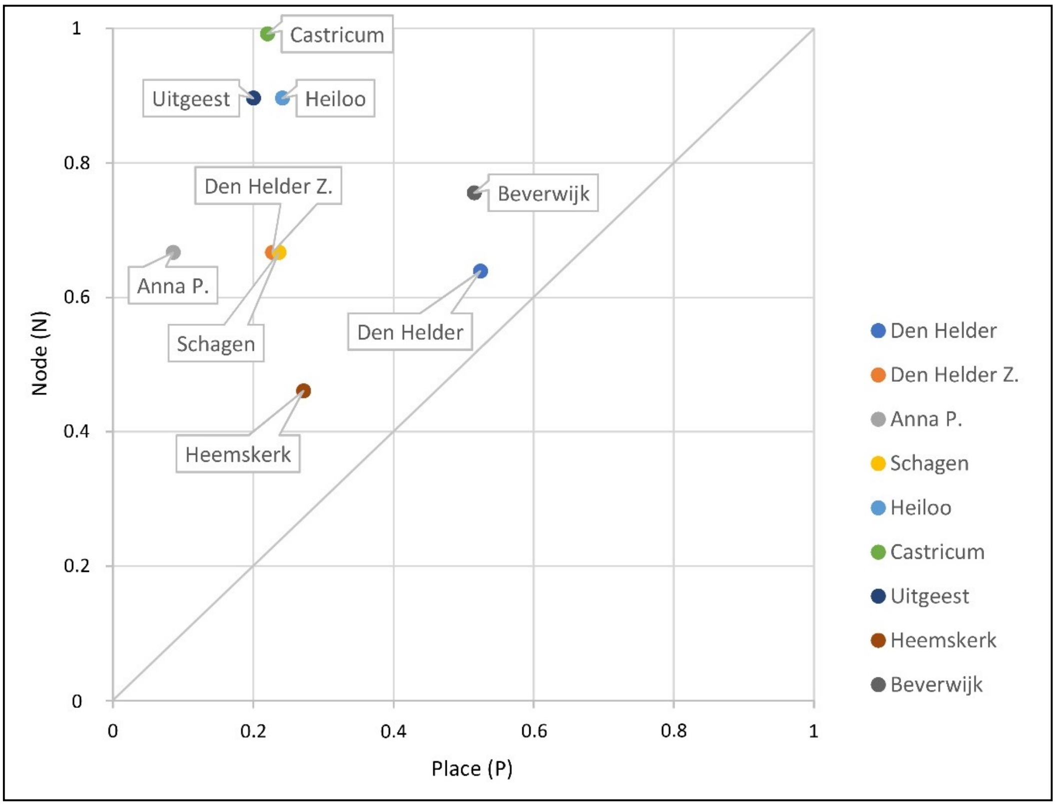


Figure 30. General node place analysis referred to North Holland study case. Source: author's elaboration.

	Den Helder	Den Helder Zuid	Anna Paulowna	Schagen	Heiloo	Castricum	Uitgeest	Heemskerk	Beverwijk
Node index (N)	0.64	0.67	0.67	0.67	0.9	0.99	0.9	0.46	0.76
General Place index (P)	0.52	0.23	0.09	0.24	0.24	0.22	0.2	0.27	0.52

Table 35. Indexes values referred to North Holland study case. Source: author's elaboration.

According to the general node place analysis, the studied railway corridor is characterised, generally speaking, by a good accessibility by main public transport – i.e. train – as confirmed by the values of Node index, between 0.46 and 0.99. This is probably due to the high transport offer provided by NS, the Dutch national railway company; in fact, the line Den Helder – Alkmaar –

Uitgeest is part of the route Den Helder – Amsterdam – Nijmegen, one of the busiest railway corridors in the Netherlands[58].

Regarding the values of General Place index, this shows much lower values in comparison to Node index, meaning that land use intensity and quality of connections between extended catchment areas could or should be higher.

Figure 31 identifies three 'families' of transport nodes with similar characteristics. The first one, comprising the stations of Castricum, Heiloo and Uitgeest, is characterised by high accessibility and low land use intensity and quality of access and egress to transport nodes. The second one, corresponding to the stations of Anna Paulowna, Den Helder Zuid and Schagen where General Place index is similar to the values of stations belonging to the first group, but accessibility by main transport is slightly lower. The third group, composed by the nodes of Beverwijk, Den Helder and Heemskerk, which represent the most 'balanced' situations, being located close to the bisector line, signalling a relative balance between accessibility, land use intensity and quality of feeder transport.

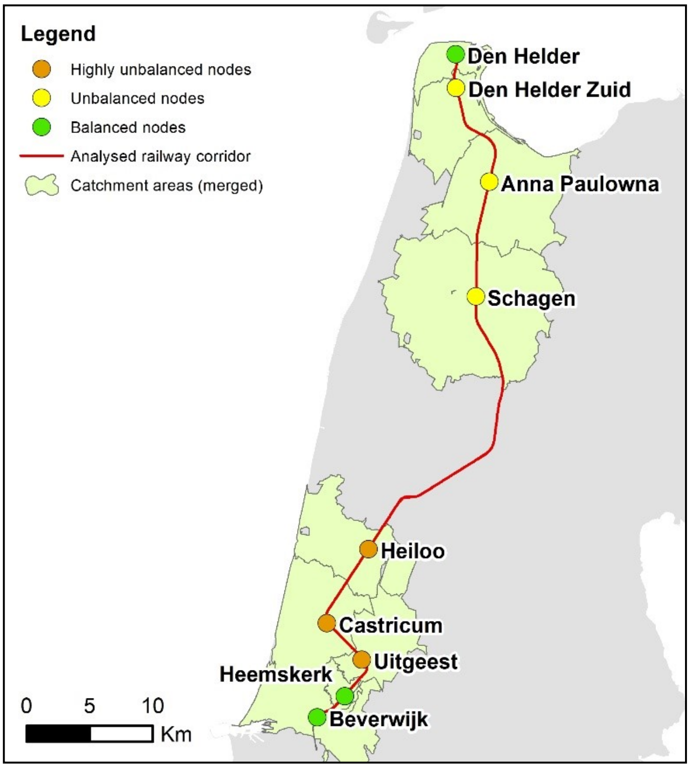


Figure 31. Map representing the found 'families' of stations. Source: author's elaboration.

Roughly, it can be said that the general node place analysis allows to define three 'families' of transport nodes in the studied area[59]: highly unbalanced nodes (Castricum, Heiloo and Uitgeest), unbalanced nodes (Anna Paulowna, Den Helder Zuid and Schagen), balanced nodes (Beverwijk,

[58] As example, the railway route Den Helder – Amsterdam – Nijmegen is served, during workdays, by an intercity train every 30 minutes, with the first and last departures, from Den Helder station, respectively at 5:04 and 22.04.

[59] In this case, it seems more correct to talk of 'families' of nodes rather than real typologies, since the grouping is not based upon statistical methods.

Den Helder and Heemskerk). However, these 'families' are not able to address specific policies, in fact, the general node place analysis is not able to specify if the found unbalances are due to low values of land use intensity, bad quality of feeder transport, or both. Moreover, also balanced nodes can 'hide' situations made by extremely diverse scenarios referred to the different catchment areas and feeder transport modes. So, a deeper analysis is needed, as shown in the next pages.

Figure 31 represents the found 'families' of stations, reporting them on a map. As can be observed, highly unbalanced nodes can be found in the lower part of the studied railway corridor, between the stations of Heiloo and Uitgeest. These stations, in fact, take advantage of a very frequent train service and serve an area with low or medium urban density and accessibility by feeder transport. Unbalanced nodes still have a good degree of accessibility by train, while urban density and quality of access to stations is slightly higher than in the first 'family'. Balanced nodes show, at least at this level of detail, a more balanced pattern, partially influenced by a lower accessibility by train in the case of Heemskerk and Beverwijk.

Detailed node place analysis

The detailed node place analysis allows differentiating the previous study by catchment areas and feeder transport mode, thus obtaining four xy diagrams.

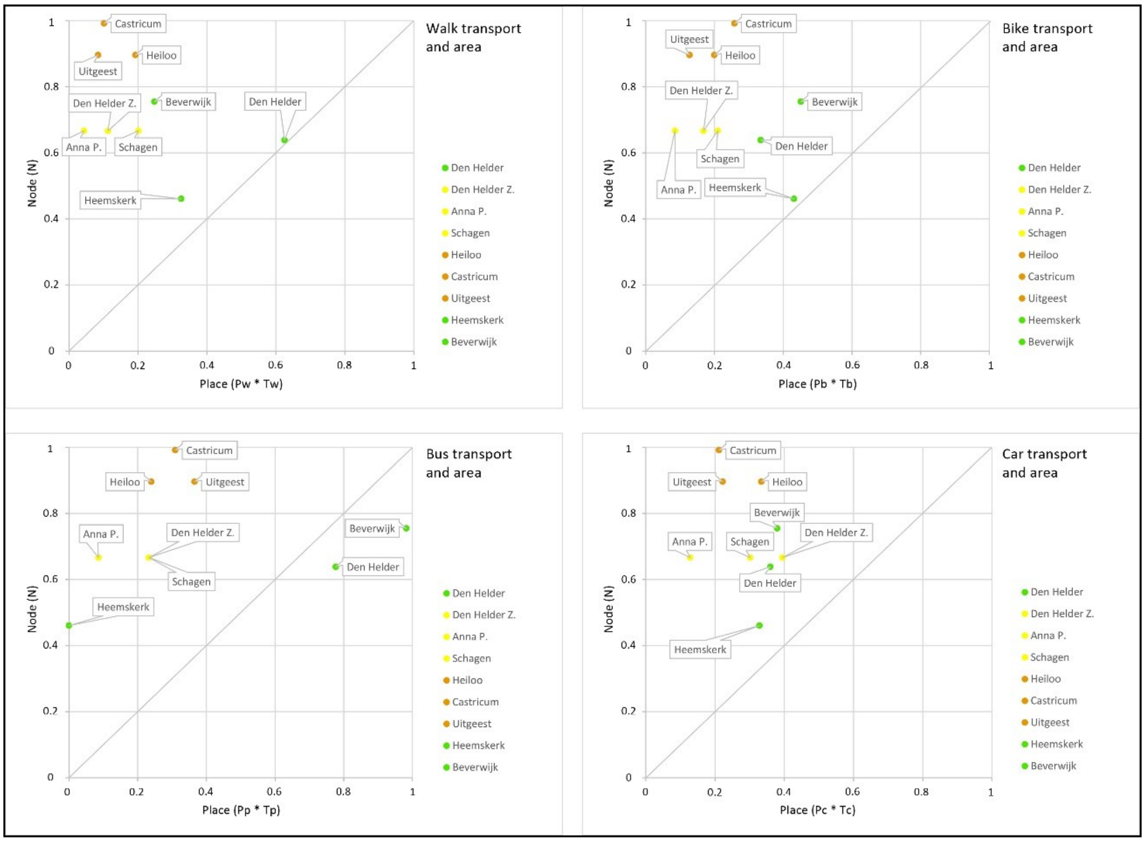


Figure 32. Detailed node place analysis referred to North Holland study case. Source: author's elaboration.

At a first glance, it can be said that 'highly unbalanced nodes' – Castricum, Heiloo and Uitgeest – show little variations, meaning that the cited catchment areas have similar characteristics in terms of density and quality of feeder transport. The transport nodes belonging to 'unbalanced nodes' family – Anna Paulowna, Den Helder Zuid and Schagen – follow a similar logic, with little variations between the different diagrams. Conversely, the 'balanced' nodes – Beverwijk, Den Helder and Heemskerk – are characterised by a higher variations degree. Beverwijk place index varies from 0.25 to 0.98, highlighting great differences between different catchment areas. Similarly, Den Helder and Heemskerk display a remarkable diversity according to the various catchment areas. The last example allows to understand the usefulness of the detailed node place analysis, in fact it underlines the possible differences that can be found within each transport node, differences that can be 'hidden' by the general node place analysis. Based upon these findings, we can sketch two different policy implications: in the case of highly unbalanced and unbalanced nodes, policies aimed to increase land use intensity and quality of feeder transport could or should be undertaken. On the other hand, in the case of balanced nodes, that are in reality characterised by highly diverse degrees of 'node' and 'place' interaction, an overall strategy valid for all catchment areas cannot be defined, but is needed a context-based approach, able to take into account peculiar situations.

Place indexes	Den Helder	Den Helder Zuid	Anna Paulowna	Schagen	Heiloo	Castricum	Uitgeest	Heemskerk	Beverwijk
Pw*Tw	0.63	0.11	0.04	0.20	0.19	0.10	0.08	0.33	0.25
Pb*Tb	0.33	0.17	0.08	0.21	0.20	0.26	0.13	0.43	0.45
Pp*Tp	0.78	0.23	0.09	0.23	0.24	0.31	0.37	0.00	0.98
Pc*Tc	0.36	0.39	0.13	0.30	0.33	0.21	0.22	0.33	0.38
Node index (N)	**0.52**	**0.23**	**0.09**	**0.24**	**0.24**	**0.22**	**0.2**	**0.27**	**0.52**

Table 36. Indexes values, detailed node place analysis referred to North Holland study case. Source: author's elaboration.

However, only with the next step of the analysis is possible to give more insights about the reasons of unbalance, addressing more precisely strategies and policies.

Radar diagrams

This paragraph reports the results of the analysis with the help of four radar diagrams representing each transport node. The following table summarises the results of the node place analysis for each station of North Holland study case. On these scores are based radar diagrams.

Transport mode/Code		Den Helder	Den Helder Zuid	Anna Paulowna	Schagen	Heiloo	Castricum	Uitgeest	Heemskerk	Beverwijk
Node index	N	0.64	0.67	0.67	0.67	0.9	0.99	0.9	0.46	0.76
Walk transport and area	Pw	0.94	0.23	0.13	0.40	0.39	0.20	0.26	0.65	0.37
	Tw	0.67	0.50	0.33	0.50	0.50	0.50	0.33	0.50	0.67
Bike transport and area	Pb	0.78	0.39	0.20	0.49	0.47	0.36	0.30	0.76	0.79
	Tb	0.33	0.33	0.33	0.33	0.33	0.67	0.33	0.50	0.50
Public transport and area	Pp	0.87	0.36	0.17	0.36	0.52	0.50	0.50	-	1.00
	Tp	0.88	0.69	0.52	0.68	0.38	0.66	0.70	-	0.98
Car-based transport and area	Pc	0.72	0.53	0.21	0.50	0.49	0.28	0.33	0.82	0.62
	Tc	0.33	0.83	0.56	0.53	0.71	0.83	0.68	0.47	0.57

Table 37. North Holland node place analysis: scores. Source: author's elaboration.

In the following pages are reported radar diagrams referred to North Holland study case, sorted by 'family' as previously described: figure 33 contains diagrams referred to 'Highly unbalanced nodes', figure 35 contains diagrams referred to 'Unbalanced nodes', figure 37 is referred to 'Balanced nodes'. Triangles with irregular shape advise that some interventions – regarding land use or transport – could be needed; however, an assessment of single cases is necessary in order to unveil local conditions that represent obstacles to transport improvement and/or urban development.

The analysis led with the help of radar diagrams helps to display the relationships between the three factors considered by this methodology, i.e. accessibility by main transport, intensity of land use and quality of feeder transport.

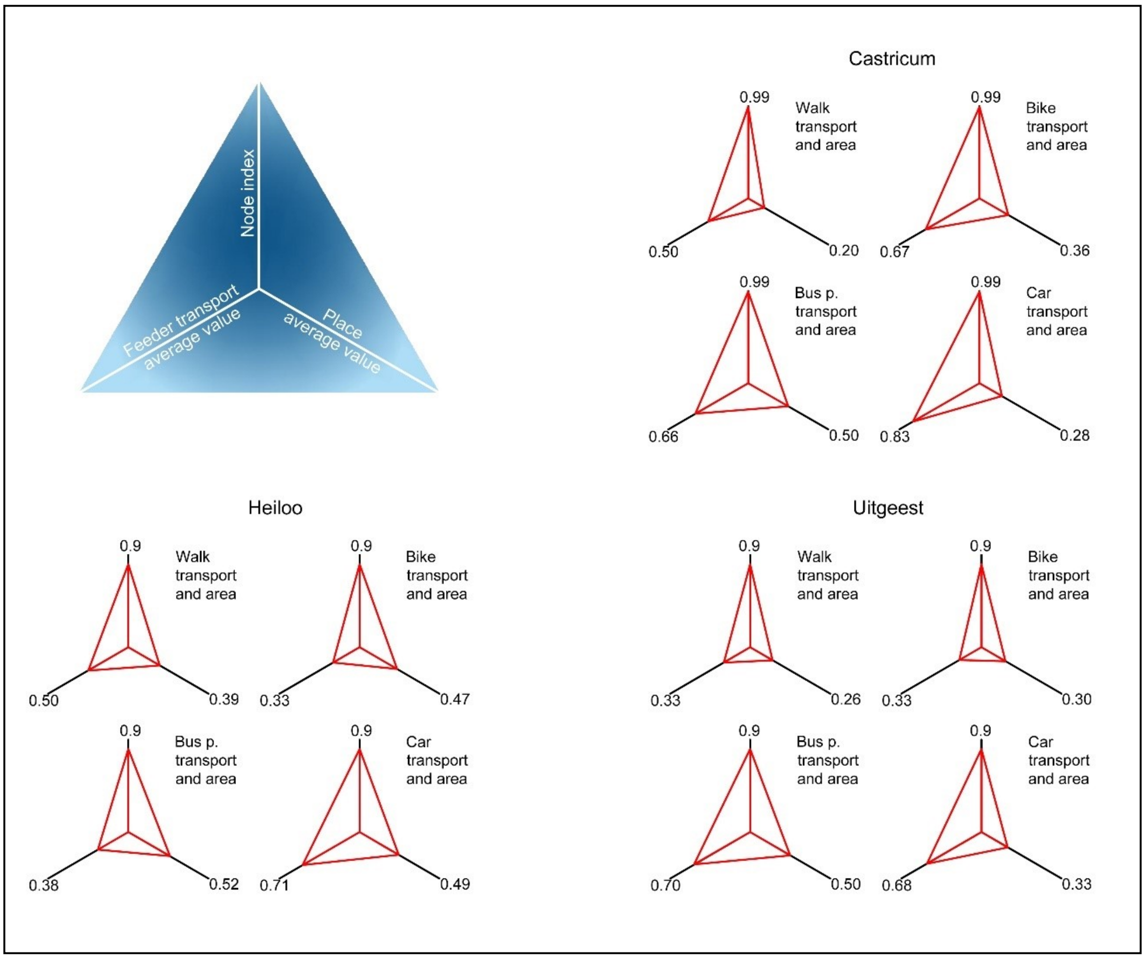


Figure 33. Example radar diagram and diagrams referred to 'Highly unbalanced nodes': Castricum, Heiloo and Uitgeest. Source: author's elaboration.

The stations belonging to the family of highly unbalanced nodes – Castricum, Heiloo and Uitgeest – show a similar 'tendency' towards the vertical axis of the diagram. In the case of Castricum, place index shows the lowest values, especially in the cases of walk, bike and car catchment areas. However, it is important to note that is probably due to the existence, close to Castricum station, of the *Noordhollands Duinreservaat*[60], a natural protected area[61].

Results referred to Heiloo and Uitgeest display that increases of urban density are possible, especially in car catchment areas, while in other zones they would require an improvement of accessibility by feeder transport. Especially, Uitgeest shows poor accessibility by bike and walking, influenced by the poor physical quality of bike and walk accesses to the station.

[60] https://www.pwn.nl/noordhollands-duinreservaat . Retrieved on 12/07/2017.

[61] This represents a possible 'room for improvement' of the model. In fact, natural protected areas, even if cannot be used for urban development, they take advantage of good public transport accessibility, thus suggests considering leisure activities or touristic destinations.

Figure 34. View from Castricum station's platform. Looking south, the Provincial Archaeologic Centre and some natural areas can be seen. Source: author's picture.

The stations classified as unbalanced nodes – Anna Paulowna, Den Helder Zuid and Schagen – have quite differentiated characteristics. Anna Paulowna is characterised by low feeder transport indexes and very low place indexes, influenced by the position of the station in a rural area[62]. It can be said that this transport node has high potential for urban development, though a significant increase of feeder public transport is needed. Similarly, in the case of Den Helder Zuid Feeder transport value often exceeds Place value. Schagen station cannot be described by a dominant pattern: Node index is always prevalent, while Place and Feeder transport indexes are always low, with some little variations, e.g. Feeder transport index referred to bus transport overwhelms Place index; conversely, in the case of bike transport Place index is slightly higher than Feeder transport index.

The stations classified as balanced nodes – Beverwijk, Den Helder and Heemskerk – have much differentiated characteristics. Beverwijk shows a slight prevalence of Feeder transport on Place in the case of walk catchment area, but this scenario inverts if we consider bike catchment area. Car catchment area shows a substantial balance, while bus catchment area displays very high values of density and accessibility[63].

[62] Anna Paulowna station is located within Hollands Kroon municipality, characterised by small hamlets scattered in the countryside, without a main urban centre.

[63] The high value of bus accessibility is probably due to the presence, at Beverwijk railway station, of a bus station with many feeder lines.

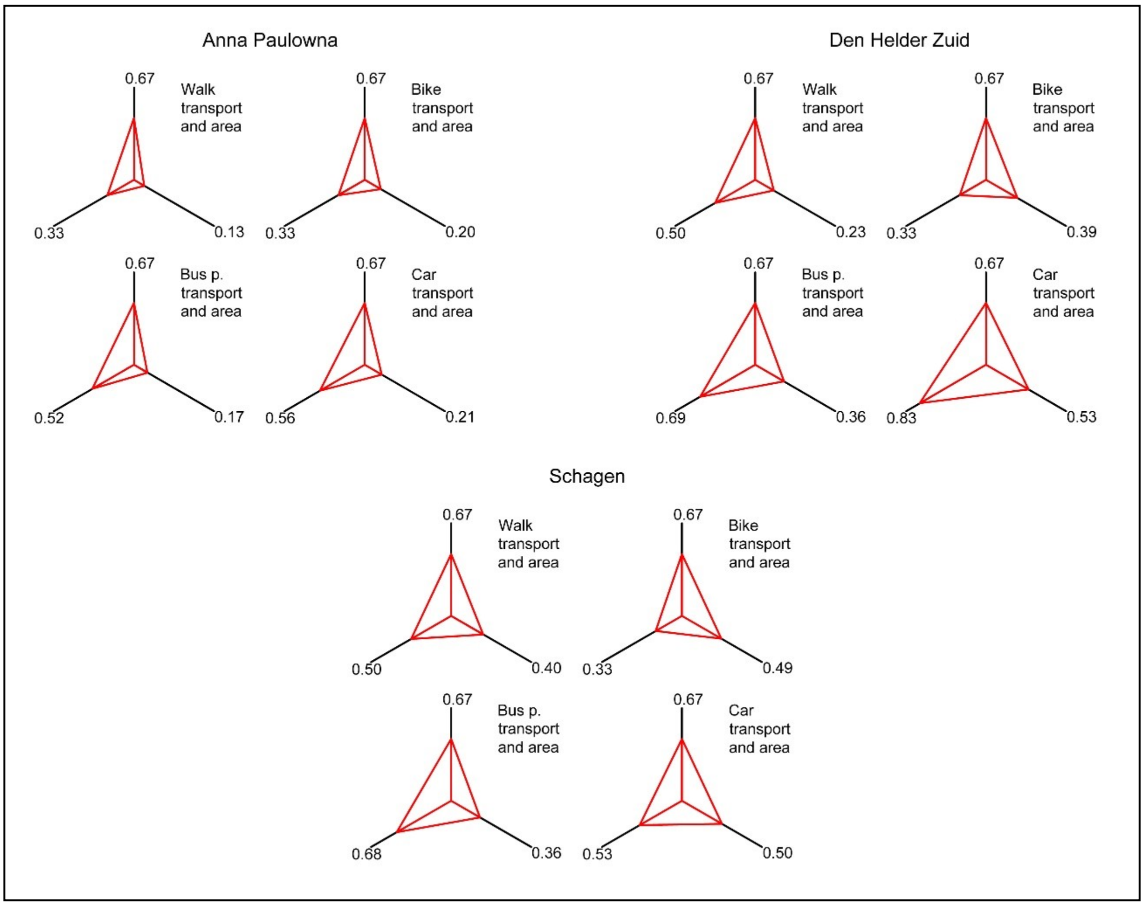


Figure 35. Radar diagrams referred to 'Unbalanced nodes': Anna Paulowna, Den Helder Zuid and Schagen. Source: author's elaboration.

Figure 36. Bike and pedestrian underpass at Uitgeest station. Source: author's picture.

Den Helder, and Heemskerk instead, show Place indexes generally higher than Feeder transport indexes, and, unique cases, also higher than Node index, signalling the need for an improvement of feeder transport and main transport. It is important to underline the peculiar situation of Heemskerk station, that has no bus feeder transport lines, in so impeding the definition of a 'bus catchment area'[64].

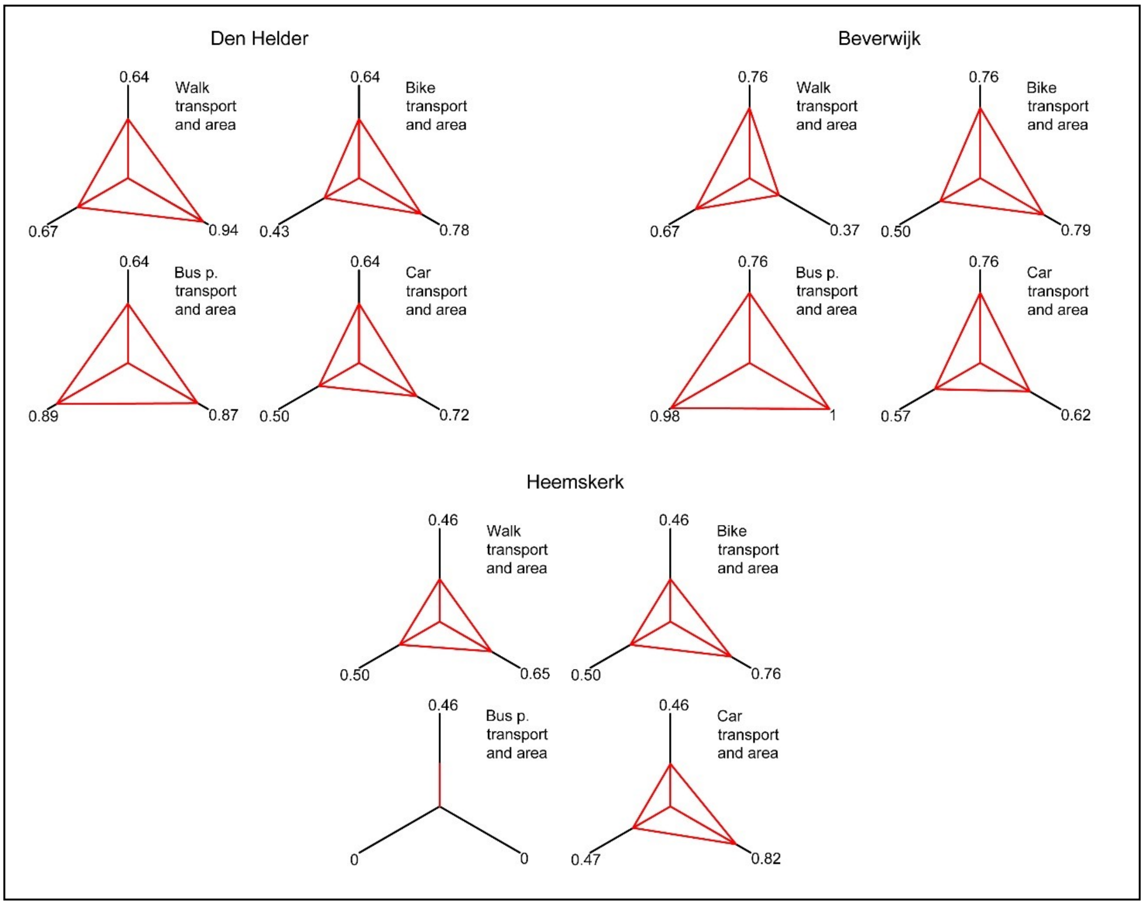


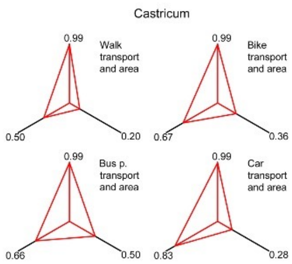
Figure 37. Radar diagrams referred to 'Balanced nodes' Den Helder, Beverwijk and Heemskerk. Source: author's elaboration.

[64] As already underlined in the chapter about methodology, in the case in which there are no bus lines stopping at the station, it is not possible to define the relative catchment area.

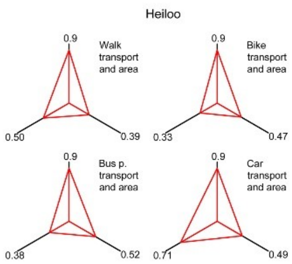
Figure 38. Bus station at Beverwijk railway station. Source: author's picture.

Actual situation and suggested planning strategies

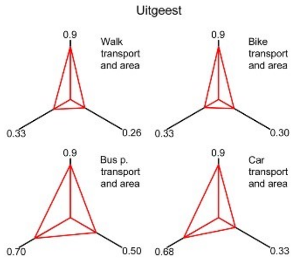
In the following diagrams are reported, sorted by station 'family', the radar diagrams referred to each transport node and, in the right column, some notes about the results of the analysis describing the actual situation, policy implications and suggested planning actions.



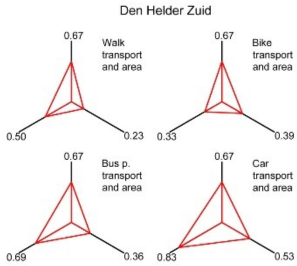
Actual situation:
Castricum station has very good accessibility by train, medium accessibility by feeder modes and low urban density. This unbalance is more evident in the cases of walk and car area.
Suggested planning strategies:
Residential and job density could be increased in catchment areas, especially in walk and car areas. However, it is important to remember that close to Castricum station there is a natural protected area, where urban development cannot be pursued. However, this facility can benefit from the presence of the transport node.



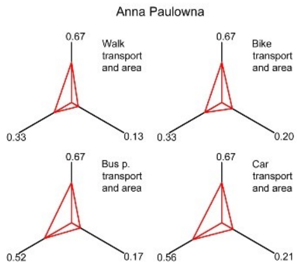
Actual situation:
Heiloo station has very good accessibility by train. The values of place and feeder transport indexes are quite balanced, so a dominating pattern cannot be recognised.
Suggested planning strategies:
Slight increases of density are possible in walk and car catchment areas; in other cases, they would need an improvement of feeder transport.



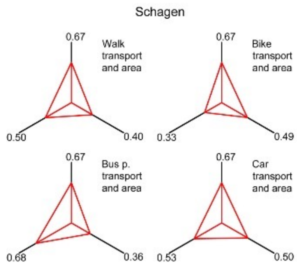
Actual situation:
As occurs in the previous two cases, train service guarantees high accessibility to Uitgeest, while walk and bike areas suffer of scarce accessibility and low density.
Suggested planning strategies:
Walk and bike catchment areas could host new urban development projects, together with a substantial improvement of feeder transport. In the light of actual accessibility, urban density can be increased within public transport and car-based transport catchment areas.



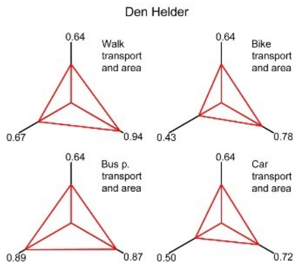
Actual situation:
Den Helder Zuid has medium accessibility by train, and good feeder transport quality, except for the case of bike, in which there is substantial balance between urban density and quality of feeder transport.
Suggested planning strategies:
Considering the actual accessibility by train and feeder transports, urban density can be increased in all catchment areas except bike area, where an improvement of bike feeder transport is necessary.



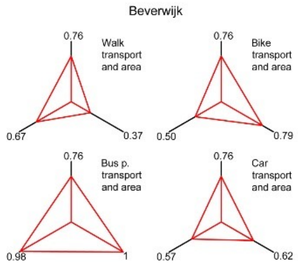
Actual situation:
Anna Paulowna station, placed within Hollands Kroon municipality, shows very low urban density and low accessibility by feeder transport, especially in the case of walk and bike transport. On the other hand, train service has a proper level of quality.
Suggested planning strategies:
This transport node has great potentialities in terms of urban development, within each catchment area, but at the same time it requires an improvement of feeder transport, especially in the case of walk and bike mobility.



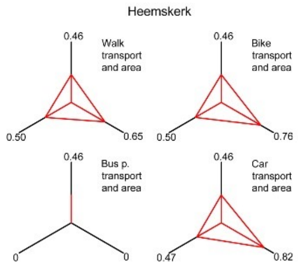
Actual situation:
Schagen station shows good accessibility by train, and a quite balanced pattern of place and feeder transport indexes.
Suggested planning strategies:
Small density increases are possible, as in the case of public transport catchment area; in other cases, they should be accompanied by the enhancement of feeder transport. In general, in this transport node substantial urban developments should be combined with transport improvements, regarding both main transport and feeder transport.



Actual situation:
Den Helder station has good accessibility by train, while place indexes outnumber feeder transport indexes, showing an 'unbalance' towards place index.
Suggested planning strategies:
In the light of accessibility by train and feeder transport, urban density should not be intensified. Main transport is insufficient in comparison to urban density, while feeder transport ameliorations seem necessary for walk, bike and car-based mobility.



Actual situation:
Looking at different feeder transports and catchment areas, Beverwijk station shows a quite differentiated situation. Walk catchment area can host small increases of urban density, while bike transport seems insufficient; the station has very high accessibility by public transport, matching urban density; car transport and area show a relative balance.
Suggested planning strategies:
Urban density should not be increased, especially within bike and public transport catchment areas; bike environment needs to be slightly improved. An upgrading of main transport would match the high urban density.



Actual situation:
Heemskerk station has the lowest train service level among the studied nodes. A general predominance of place index can be observed, while, regarding public transport, this node is not linked to bus network, therefore it is impossible to determine the extent of public transport catchment area.
Suggested planning strategies:
Place value is always higher than other values, meaning that an improvement of main and feeder transport is needed. Heemskerk station should be connected to bus network.

Appendix

Node indexes (N)

Node indicators	Value					Score				
	Den Helder	Den Helder Zuid	Anna Paulowna	Schagen	Heiloo	Den Helder	Den Helder Zuid	Anna Paulowna	Schagen	Heiloo
Directions	1	2	2	2	4	0.16	0.33	0.33	0.33	0.67
Frequency (workdays)	72	72	72	72	152	0.36	0.36	0.36	0.36	0.76
Frequency (holydays)	60	60	60	60	128	0.47	0.47	0.47	0.47	1
Span (workdays)	18	18	18	18	19	0.9	0.9	0.9	0.9	0.95
Span (holidays)	15	15	15	15	16	0.93	0.93	0.93	0.93	1
Ticketing	Y	Y	Y	Y	Y	1	1	1	1	1
N	-					0.64	0.67	0.67	0.67	0.89

Node indicators	Value				Score			
	Castricum	Uitgeest	Heemskerk	Beverwijk	Castricum	Uitgeest	Heemskerk	Beverwijk
Directions	6	4	2	4	1	0.67	0.33	0.67
Frequency (workdays)	200	152	60	76	1	0.76	0.3	0.38
Frequency (holydays)	128	128	52	62	1	1	0.41	0.48
Span (workdays)	19	19	17	20	0.95	0.95	0.85	1
Span (holidays)	16	16	14	16	1	1	0.87	1
Ticketing	Y	Y		Y	1	1	0	1
N	-				0.99	0.89	0.46	0.75

Place average values (Pw, Pb, Pp, Pc)

Place indicators		Value: Den Helder	Value: Den Helder Zuid	Value: Anna Paulowna	Value: Schagen	Value: Heiloo	Score: Den Helder	Score: Den Helder Zuid	Score: Anna Paulowna	Score: Schagen	Score: Heiloo
Walking area	Est. residential dens.	7,344	2,122	1,535	3,518	4,251	0.88	0.25	0.18	0.42	0.51
	Est. job dens.	3,525	702	284	1,352	919	1.00	0.20	0.08	0.38	0.26
	Pw	-					0.94	0.23	0.13	0.40	0.39
Bike area	Est. residential dens.	3,368	1,483	1,013	1,914	2,237	0.65	0.29	0.19	0.37	0.43
	Est. job dens.	1,616	882	355	1,077	884	0.91	0.5	0.20	0.61	0.5
	Pb	-					0.78	0.39	0.20	0.49	0.47
Bus public transport area	Est. residential dens.	3,379	1,526	812	1,215	3,301	0.87	0.39	0.21	0.31	0.85
	Est. job dens.	1,622	608	251	773	365	0.87	0.33	0.13	0.41	0.19
	Pp	-					0.87	0.36	0.17	0.36	0.52
Car-based transport area	Est. residential dens.	2,308	710	218	275	815	0.66	0.20	0.06	0.07	0.23
	Est. job dens.	1,107	1,209	506	1,317	1,049	0.78	0.85	0.36	0.93	0.74
	Pc	-					0.72	0.53	0.21	0.50	0.49

Place indicators		Value: Castricum	Value: Uitgeest	Value: Heemskerk	Value: Beverwijk	Score: Castricum	Score: Uitgeest	Score: Heemskerk	Score: Beverwijk
Walking area	Est. residential dens.	2,203	3,165	8,337	3,457	0.26	0.38	1.00	0.41
	Est. job dens.	499	470	1,068	1,167	0.14	0.13	0.30	0.33
	Pw	-				0.20	0.27	0.65	0.37
Bike area	Est. residential dens.	1,747	1,668	5,203	3,018	0.36	0.32	1.00	0.58
	Est. job dens.	683	482	901	1,767	0.39	0.27	0.51	0.99
	Pb	-				0.36	0.30	0.76	0.79
Bus public transport area	Est. residential dens.	3,002	2,938	-	3,881	0.77	0.76	-	1.00
	Est. job dens.	426	439	-	1,862	0.23	0.23	-	1.00
	Pp	-				0.50	0.50	-	1.00
Car-based transport area	Est. residential dens.	522	883	3,493	805	0.15	0.25	1.00	0.23
	Est. job dens.	589	583	913	1,423	0.41	0.41	0.64	1.00
	Pc	-				0.28	0.33	0.82	0.62

Feeder transport average values – walking (Tw)

Indicators	Value					Score				
	Den Helder	Den Helder Zuid	Anna Paulowna	Schagen	Heiloo	Den Helder	Den Helder Zuid	Anna Paulowna	Schagen	Heiloo
Sidewalks	-	-	-	-	-	1.00	1.00	0.66	1.00	1.00
Pedestrian streets	-	-	-	-	-	0.33	0.00	0.00	0.00	0.00
Tw	-					0.66	0.50	0.33	0.50	0.50

Indicators	Value				Score			
	Castricum	Uitgeest	Heemskerk	Beverwijk	Castricum	Uitgeest	Heemskerk	Beverwijk
Sidewalks	-	-	-	-	1.00	0.66	1.00	1.00
Pedestrian streets	-	-	-	-	0.00	0.00	0.00	0.33
Tw	-				0.50	0.33	0.50	0.66

Feeder transport average values – bike (Tb)

Indicators	Value					Score				
	Den Helder	Den Helder Zuid	Anna Paulowna	Schagen	Heiloo	Den Helder	Den Helder Zuid	Anna Paulowna	Schagen	Heiloo
Unguarded cycle storage						0	0	0	0	0
Self Service bike storage	Y					1	0	0	0	0
Bike rental						0	0	0	0	0
P. t. bike (ov-fiets)	Y	Y	Y	Y	Y	1	1	1	1	1
Bike repair shop						0	0	0	0	0
Bike locker		Y	Y	Y	Y	0	1	1	1	1
Quality of bike envir.						1	1	1	1	1
Tb	-					0.43	0.43	0.43	0.43	0.43

Indicators	Value				Score			
	Castricum	Uitgeest	Heemskerk	Beverwijk	Castricum	Uitgeest	Heemskerk	Beverwijk
Unguarded cycle storage			Y	Y	0	0	1	1
Self Service bike storage	Y				1	0	0	0
Bike rental	Y			Y	1	0	0	1
P. t. bike (ov-fiets)	Y	Y	Y	Y	1	1	1	1
Bike repair shop	Y				1	0	0	0
Bike locker		Y	Y		0	1	1	0
Quality of bike envir.					1	1	1	1
Tb	-				0.71	0.43	0.57	0.57

Feeder transport average values – public transport (Tp)

Indicators	Value					Score				
	Den Helder	Den Helder Zuid	Anna Paulowna	Schagen	Heiloo	Den Helder	Den Helder Zuid	Anna Paulowna	Schagen	Heiloo
Feeder transport	Y	Y	Y	Y	Y	-	-	-	-	-
Feeder lines	6	3	3	7	1	0.86	0.43	0.43	1.00	0.14
Frequency (workdays)	153	90	18	91	9	0.84	0.49	0.10	0.50	0.05
Frequency (holydays)	96	67	15	12	-	0.61	0.42	0.09	0.08	0.00
Span (workdays)	18	18	10	16	9	0.95	0.95	0.53	0.84	0.47
Span (holidays)	15	15	15	12	-	0.88	0.88	0.88	0.71	0.00
Fare integration	2	2	2	2	2	1	1	1	1	1
Waiting room	Y	Y	Y		Y	1	1	1	0	1
Restaurants/ kiosks	Y			Y	Y	1	0	0	1	1
Tp	-					0.89	0.65	0.50	0.64	0.46

Indicators	Value				Score			
	Castricum	Uitgeest	Heemskerk	Beverwijk	Castricum	Uitgeest	Heemskerk	Beverwijk
Feeder transport	Y	Y	N	Y	-	-	-	-
Feeder lines	3	2	-	6	0.43	0.29	-	0.86
Frequency (workdays)	73	58	-	182	0.40	0.32	-	1.00
Frequency (holydays)	44	46	-	158	0.28	0.29	-	1.00
Span (workdays)	18	19	-	19	0.95	1.00	-	1.00
Span (holidays)	15	17	-	18	0.88	1.00	-	1.00
Fare integration	2	2	-	2	1	1	-	1
Waiting room	Y	Y	-	Y	1	1	-	1
Restaurants/ kiosks		Y	-	Y	0	1	-	1
Tp	-				**0.62**	**0.74**	**-**	**0.98**

Feeder transport average values – car-based transport (Tc)

Indicators	Value					Score				
	Den Helder	Den Helder Zuid	Anna Paulowna	Schagen	Heiloo	Den Helder	Den Helder Zuid	Anna Paulowna	Schagen	Heiloo
Park and ride		Y	Y	Y	Y	0	1	1	1	1
NS zone taxi	Y	Y				1	1	0	0	0
Taxi rank	Y		Y	Y	Y	1	0	1	1	1
Car parking	0	6,000	2,700	2,400	4,500	0.00	1.00	0.45	0.40	0.75
Tc	-					**0.50**	**0.75**	**0.61**	**0.60**	**0.69**

Indicators	Value				Score			
	Castricum	Uitgeest	Heemskerk	Beverwijk	Castricum	Uitgeest	Heemskerk	Beverwijk
Park and ride	Y	Y	Y	Y	1	1	1	1
NS zone taxi					0	0	0	0
Taxi rank	Y	Y		Y	1	1	0	1
Car parking	6,000	4,100	3,600	2,800	1.00	0.68	0.60	0.47
Tc	-				**0.75**	**0.67**	**0.40**	**0.62**

Chapter 5

Campania study case

The Italian study case refers to a short railway corridor linking the towns of Salerno and Mercato San Severino, located in Campania Region, in the south of Italy[65].

Figure 39. Urban pattern and railway infrastructures of Campania Region. Source: author's elaboration.

From the point of view of urban and infrastructural pattern, Campania Region is characterised by a strong polarisation around Naples, the main administrative centre and, by far, the most populous municipality of the Region[66]. A remarkable share of population and activities concentrates along the coast, roughly shaping an imaginary triangle with its vertices on Naples, Caserta and Salerno, while the northern part of the province of Caserta, the southern sector of the Province of Salerno and the Provinces of Avellino and Benevento show a much lower population and infrastructural density.

[65] All the maps in this chapter are based upon 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.

[66] Campania Region has five provincial administrative centres: Naples (regional administrative centre), Avellino, Benevento, Caserta and Salerno. The former Province of Naples has been recently transformed into 'Metropolitan City'.

This pattern is confirmed by the map referred to the Eurostat degree of urbanisation (Dijkstra & Poelman, 2014), that highlights how municipalities classified as 'Cities' are concentrated around Naples, while the only isolated 'red spots' correspond to the Provincial administrative centres. In the immediate surroundings, a 'ring' of municipalities classified as 'Towns and suburbs' can be observed, while the remainder of the regional territory is made up by 'Rural areas', with only some municipalities classified as 'Towns and suburbs'.

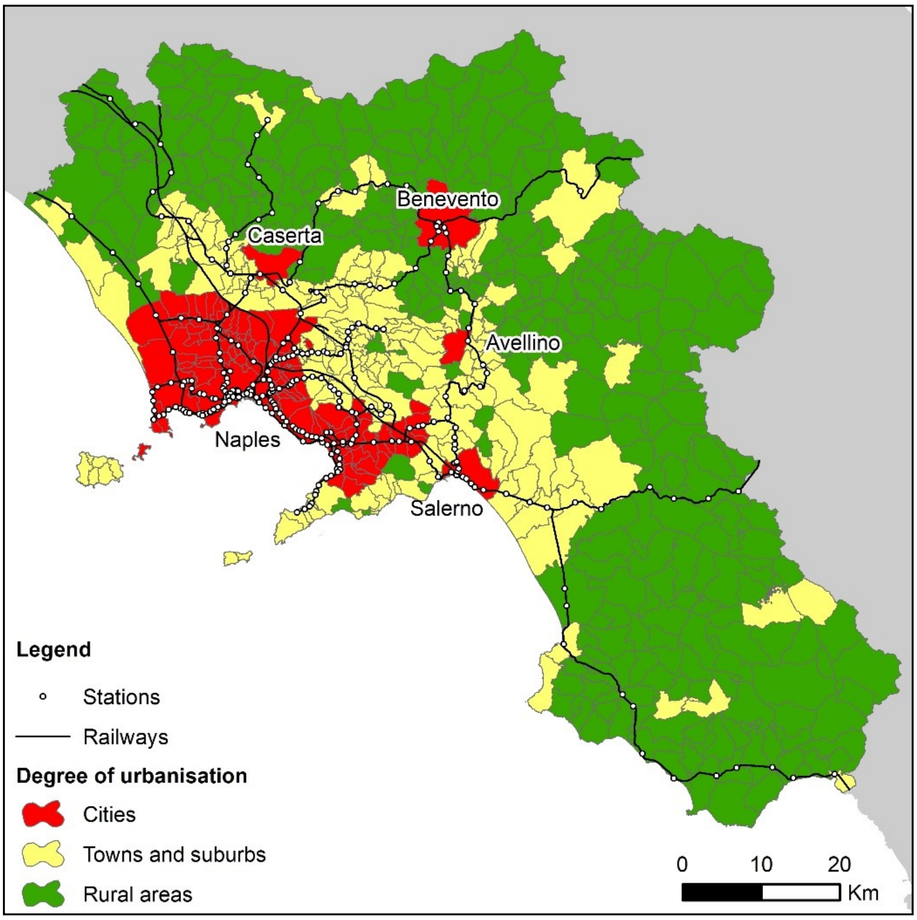


Figure 40. Campania Region. Urban degree of municipalities, and railway infrastructures. Source: author's elaboration.

In one of these 'intermediate' areas is located the study case described in this chapter. The study area roughly corresponds to the Irno River Valley, a small valley north of the coastal town of Salerno.

The studied railway line stretches for 17.6 kilometres, linking Salerno to the town of Mercato San Severino, crossing a hilly territory spotted by several urban centres, industrial and commercial areas, education facilities. Though it is a single-track, non-electrified railway, it has a relevant role for the public mobility of the area, since it links many small towns ad hamlets to the city centre of Salerno, that represents the most populous and attractive urban centre of this territory. In the station of Salerno, passengers can find connections to the major Italian cities, as

Rome, Naples and Milan, and to many local destinations; while Mercato San Severino station provides links with other local railways.

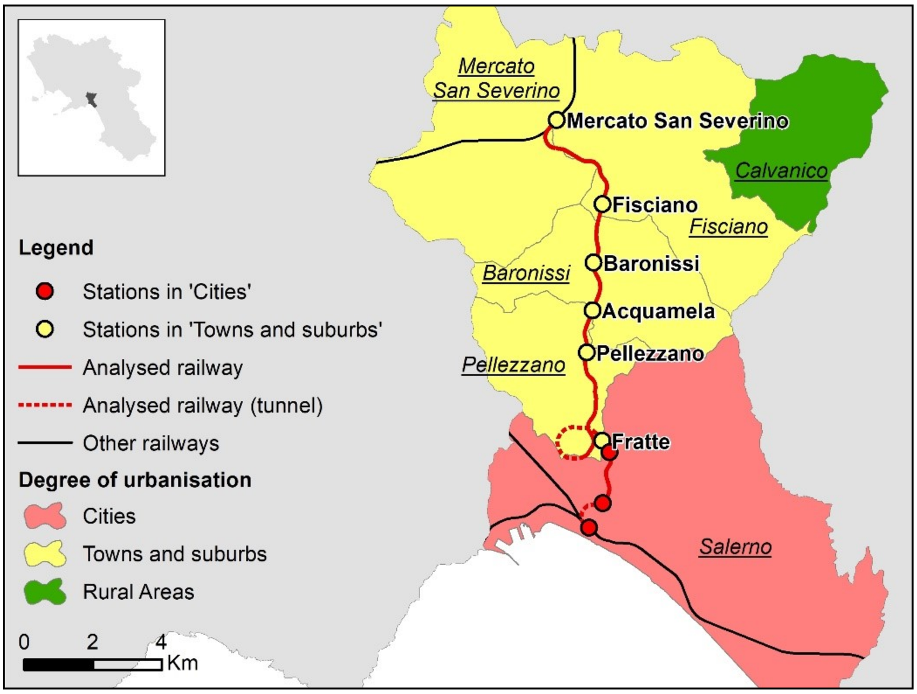


Figure 41. Analysed railway corridor. Source: author's elaboration.

The study area encompasses six municipalities: Salerno, Pellezzano, Baronissi, Fisciano, Mercato San Severino and Calvanico[67]. The stations falling within municipalities classified as 'Towns and suburbs' by Eurostat (Dijkstra & Poelman, 2014) are: Mercato San Severino, Fisciano, Baronissi, Acquamela, Pellezzano and Fratte[68]. The stations located within Salerno municipal borders have been excluded because this municipality is classified as 'City'. On the other hand, the small town of Calvanico, although classified as 'Rural area', has been considered anyway because, as will be shown in the chapter, its territory partially belongs to some catchment areas; moreover, this municipality, from the point of view of accessibility, is part of the study area's transport 'basin', since its access roads pass through the adjacent municipality of Fisciano.

One of the main reasons of interest of this study case is represented by the presence, in the studied territory, of several places for high education, especially high schools and university campuses. The University of Salerno, in fact, is located in this area, consisting of two campuses: the main one, placed in Fisciano Municipality, and the secondary one – the Department of Medicine – located within the Municipality of Baronissi.

The complex of Fisciano University Campus was built at the beginning of the 1980s as new location for the University of Salerno. The choice fell on an area highly accessible by car, placed

[67] The railway links the town of Salerno (about 135,000 inhabitants) to Mercato San Severino (22,000), passing through Pellezzano (10,000), Baronissi (16,000), Fisciano (13,000).

[68] Though Fratte station is located on the border between Salerno and Pellezzano, it has been considered in this study.

close to the intersection of three motorways, without considering public transport accessibility. During time, the presence of this attractor in an area served by scarce public transport connections, has highlighted the necessity for its improvement. A bus terminal has been realised and recently improved, while the railway line between Salerno and Mercato San Severino, closed in 1967, reopened in 1990[69].

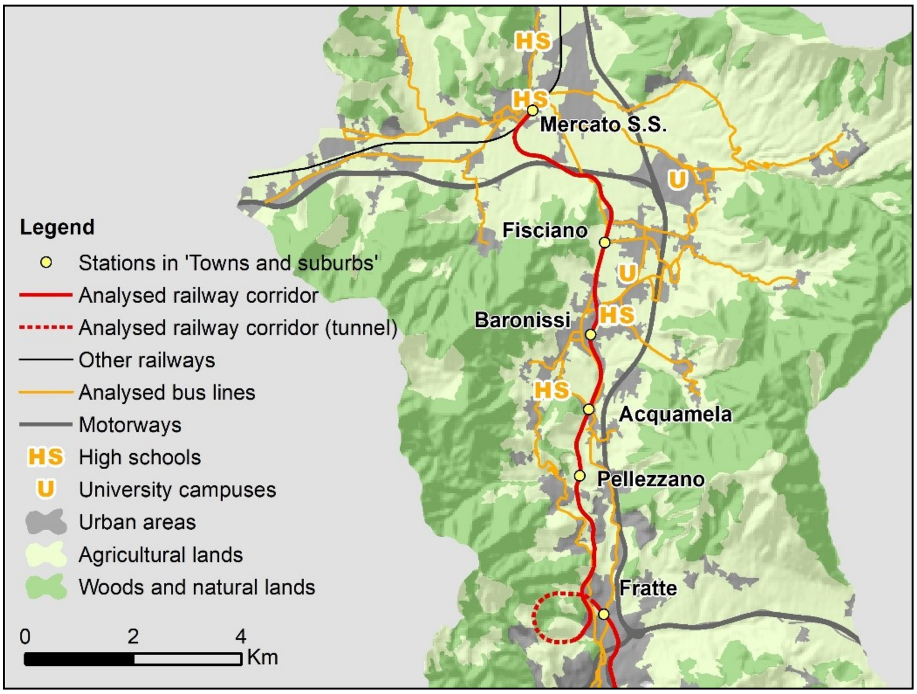


Figure 42. Mobility infrastructures, urban areas and facilities in the study area. Source: author's elaboration.

The main access of Fisciano campus is only 3.2 kilometres far – less than 2 kilometres as the crow flies – from Fisciano station, and this has given the spur to a debate on which would be the best way to connect it with the railway infrastructure.

Two different ideas emerged in the last years. The first intends to divert the actual railway line through the campus, reaching the station of Mercato San Severino from the north side. This solution would allow the realisation of 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*, *Baronissi Città dei giovani* – serving the Department of Medicine (Gerundo, Fasolino, & Eboli, 2005).

The second hypothesis, believed to be less expensive, corresponds to the construction of a 'people mover', a rope-guided transport system able to connect the station of Fisciano with the two locations of University of Salerno: Fisciano campus and the Department of Medicine (Simeone & Papa, 2010). However, none of these hypotheses has been adopted, with the issue of connections between university campuses and rail transport still unsolved.

[69] Source: https://it.wikipedia.org/wiki/Ferrovia_Salerno-Mercato_San_Severino . Retrieved on 22/05/2017.

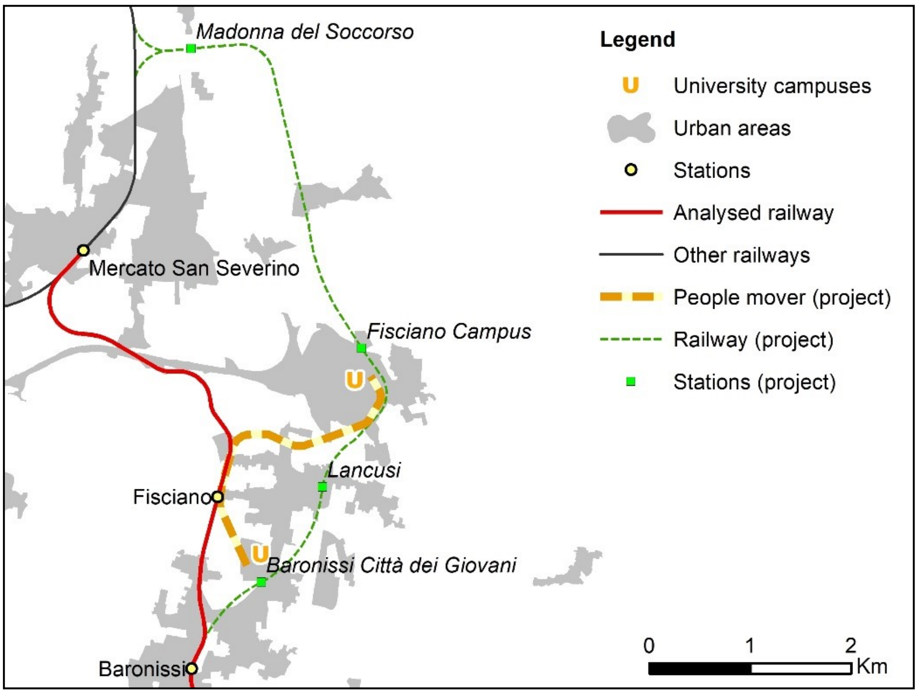


Figure 43. Actual configuration of railways in the study area, and proposed interventions. Source: author's elaboration based upon Gerundo et al., (2005) and Simeone & Papa (2010).

Both options would benefit from a substantial improvement of the existing railway line. In fact, it is actually a single-track, not-electrified railway, although electrification and removal of some level crossings are currently planned.

However, even if these hypotheses remain at the project stage, they witness the relevance of transport issue in the area. In fact, the analysed study case represents the inconveniences and costs of the missed integration between land use and transport planning.

One of the goals linked to this study case is to address the policy debate, highlighting benefits and threats of different land use and public transport integration patterns. In fact, the selected case seems an adequate test for 'extended station area' approach, because in the past decades, planning choices have been made following a car-oriented approach, with services, facilities, industrial areas, planned according to road accessibility, without considering public transport accessibility.

Data sources

In order to esteem the average travel time for access and egress to transport, data coming from the Italian *Istituto Nazionale di Statistica* – ISTAT – are used. ISTAT carries out, together with the ten-year national census, data about commuting travel. The latest available information date back to 2011, representing most complete and appropriate data source. The statistics provided by ISTAT are differentiated on the basis of transport modes[70]:

- Train.

[70] https://www.istat.it/it/archivio/139381 Retrieved on 13/3/2013.

- Tram.
- Metro.
- Intercity bus.
- Urban bus/trolleybus.
- School bus/company bus.
- Motorbike.
- Bike.
- Car (driver).
- Car (passenger).
- Walking.
- Other.

The listed voices correspond to the prevalent transport mode. Trips made, e.g. by train, correspond to the travels in which there could be access and egress trips made by other transport modes, but with train still covering much of the distance. ISTAT Census makes the following distinction[71], based on trip's purposes, since it considers only commuting trips:

- Work.
- School and education.

In this study case, railway transport corresponds to the main transport mode, since it links the served towns to the city centre of Salerno, not influenced by road congestion. Thus, average commuting time referred to trips with railway transport as main mode, seems to approximate the average commuting time for this research's objective.

Travel time

National Census, led every ten years by ISTAT, asks people who travel daily for work's and education's purposes, which is the amount of time that they spend for their trips in minutes (0 to 15, 16 to 30, 31 to 60 more than 60). This analysis results into a grouped class distribution, as shown by table 38 in which are reported data referred to travel time as collected by ISTAT with the last census of 2011. The table also differentiates travel time for all modes and travel time with train as main mode; in this case, train occupies the longest part of the travel, while access and egress to station rely on other transport modes.

These data are referred solely to commuting mobility, i.e. home-to-work and home-to-school travels, preventing a complete comparison with data carried out by CBS for the Dutch context. However, the comparison between all modes and train trips shows some common elements with Dutch data, e.g. the train is used to longer journeys, with 45% of travels lasting more than 60 minutes, while the overall average is only 5%.

[71] https://www.istat.it/it/archivio/139381 Retrieved on 13/3/2013.

Travels by transport mode and travel time, Italy, year 2011 Home-to-work and home-to-school commuting travels			
Transport mode	Travel time	N. of travels	%
All modes	total	28,852,721	100%
	0 to 15 minutes	15,888,408	55%
	16 to 30 minutes	7,604,896	26%
	31 to 60 minutes	3,903,633	14%
	more than 60 minutes	1,455,784	5%
Train as main mode	total	865,684	100%
	0 to 15 minutes	28,405	3%
	16 to 30 minutes	111,352	13%
	31 to 60 minutes	340,148	39%
	more than 60 minutes	385,779	45%

Table 38. Travel time referred to Italian context. Source: author's elaboration based on ISTAT data.

The numbers referred to the Italian context can be the basis to approximate the average travel time, applying the weighted mean method, using the central value of classes as representative of each class, i.e. 7.5, 22.5, 45 minutes, and linking the last class – more than 60 minutes – to the value of 75 minutes (Mecatti, 2010).

Travel time of trips by train, Italy, year 2011 Home-to-work and home-to-school commuting travels			
Travel time	N.	Extreme values	Middle values
total	865.684	-	-
0 to 15 minutes	28.405	0 to 15	7.5
16 to 30 minutes	111.352	16 to 30	22.5
31 to 60 minutes	340.148	31 to 60	45
more than 60 minutes	385.779	61 to ∞ *	75
* For the last class is hypothesised an upper value of 90 minutes, thus equalizing the width (30 minutes) of the previous class.			

Table 39. Class distribution, extreme and middle values. Source: author's elaboration based on ISTAT data.

The values obtained are 56.2 minutes for home-to-work trips and 54.2 minutes for all travels (home-to-work plus home-to-school). Although the figures referred to the Italian context are obtained indirectly – while the ones referred to the Netherlands come from a direct survey – table 40 proposes a comparison.

As displayed by statistics, commuting time by train is noticeably higher than the overall average time. Moreover, it shows remarkable differences between Dutch and Italian values, with the average travel time referred to Dutch context noticeably higher than the average travel time relative to Italy. These differences suggest considering different values of travel duration, according to the studied context.

Country and transport modes	Average commuting time – outbound trip (minutes)	Source
The Netherlands (all modes)	23.02	CBS (2015)
The Netherlands (train as main mode, home-to-work trips)	64.86	
The Netherlands (train as main mode, all trips)	75.95	
The Netherlands, 'moderate urban' (train as main mode, all trips)	80.44	
Italy (all modes)	19.9[72]	ISTAT (2011)[73]
Italy (train as main mode, home-to-work trips)	56.2[74]	
Italy (train as main mode, home-to-work and home-to-school trips)	54.2[75]	

Table 40. Comparison between values referred to the Netherlands and Italy. Source: author's elaboration.

Finally, in order to extract the needed values of travel time from ISTAT database, have been considered only travels with the following characteristics.

- Mode: travels made by train, because this transport mode well represent the 'main transport'.
- Purpose: travels for work and education purposes. ISTAT does not investigate travels for other purposes. In conclusion, the value of 54.2 minutes has been used.

Access and egress time

As already explained in the chapter referred to the North Holland study case, the study lead by Krygsman et al. (2004) is used to assess the duration of access and egress to transport nodes applying the concept of 'interconnectivity ratio'.

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

Table 41. Travel times and related access/egress times. Source: author's elaboration.

According to Krygsman et al. (2004), the value of interconnectivity ratio is 0.45, resulting into an 'access+egress' time of 24.4 minutes. Halving this value, the figure of 12.2 minutes has been obtained as access or egress time, rounded off to 12 minutes.

As can be observed, access / egress time is around 12 minutes, similar to the value referred to the Dutch study case, despite the average duration of travel time – around 55 minutes – is shorter than the corresponding data referred to the Netherlands – around 80 minutes[76].

[72] Figure obtained by the author based on the data provided by ISTAT.
[73] Data available at https://www.istat.it/it/archivio/139381. Retrieved on 13/3/2017.
[74] Figure obtained by the author based on the data provided by ISTAT.
[75] Figure obtained by the author based on the data provided by ISTAT.

Travel speed

Once known the duration of access/egress time, values of travel speed referred to the Italian study case are needed in order to estimate the extent of stations' catchment areas. According to the Italian Observatory on Mobility (ISFORT, 2017), the 'perceived' speed of transport modes is 15 km/h for bike, 24 km/h for public transport and 32 km/h for car transport, while values about walking are not provided in the cited document. However, these data seem inadequate since they embrace urban and extra urban travels, and they do not differentiate trips by transport modes – e.g. urban buses have a very different speed in comparison to intercity buses or high-speed trains.

Therefore, in order to obtain a reliable value of speed for walking, bus and car, an analysis specifically referred to the study area has been conducted, with the help of the 'directions' function of Google Maps[77]. Google Maps does not provide data about cycling times for the studied area, consequently the value of 12 km/h, previously used for the North Holland study case, has been used.

In order to find a reliable figure for feeder transports speed, significant routes have been analysed, using the values of distance and time provided by Google Maps to calculate the correspondent values of speed. For walking mode, five routes have been considered, linking the stations to relevant destinations, like Town Halls, high schools, etc. The average speed is 4.94 km/h, rounded off to 5 km/h.

Route	Distance (km)	Time (min)	Speed (km/h)
Mercato S.S.: station - Town Hall	0.8	10	4.8
Fisciano: station - public gardens (Lancusi town centre)	0.7	8	5.3
Baronissi: station - Department of Medicine	1.4	16	5.3
Acquamela: station - High School	0.9	13	4.2
Fratte: station - shopping centre	0.6	7	5.1
Average speed	4.94		

Table 42. Walking routes and corresponding speed. Source: author's elaboration.

In the case of feeder public transport, have been considered bus lines running from stations to significant destinations. The value of travel time provided by Google Maps includes the time needed to cover the distance between the station and the bus stop, and from the bus stop to the destination. Although none of the considered stations can be defined a train-bus interchange node, bus stops and terminals are usually placed within short distances from stations. In the case of Pellezzano, has been considered the route between the small town of Coperchia, where the station

[76] It is crucial to remember that a so remarkable difference of average travel time between Italy and the Netherlands is probably caused by many factors, as the different inquiry methods adopted – a yearly survey on travel habits for CBS, data about commuting obtained by the ten-years national census for ISTAT – the different amount of population involved – sample case survey for CBS, all-inclusive census for ISTAT – the different travel's purposes considered – all purposes in the Dutch case, home-to-work and home-to-school travels in the Italian case. Moreover, as explained in the previous chapter, the figures referred to travel time in Italy are an approximation and are not based on a direct detection of travel behaviour.

[77] https://www.google.it/maps .

is located, and Pellezzano Town Hall, considering that Pellezzano train station is not linked to bus network. A further route has been considered, linking Fratte station to Mercato S.S. station, covered by bus line 10, which represents the 'backbone' of bus transport in the area, since it connects the centre of Salerno to the small towns along the way northward to Mercato San Severino. The average speed is 21.6 km/h, rounded off to 22 km/h.

Route[78]	Line n.	Distance (km)	Time (min)	Speed (km/h)
Mercato S.S. station - Mercato S.S. Hospital	54	2.8	7	24.0
Mercato S.S. station - University campus bus terminal	57	3.4	12	17.0
Fisciano station - Fisciano Town Hall	23	3.1	9	20.7
Fisciano station - University campus bus terminal	55	3.6	9	24.0
Coperchia (Pellezzano) - Pellezzano Town Hall	22	1.7	5	20.4
Fratte station - Mercato S.S. station	10	11.5	29	23.8
Average speed	21.6			

Table 43. Feeder public transport routes and corresponding speed. Source: author's elaboration.

In the case of car-based transport, eight routes have been considered, as summarised by the following table.

Route	Dist. A-B (km)	Dist. B-A (km)	A-B, workdays, 8.30 a.m.		B-A, workdays, 8.30 a.m.		A-B, workdays, 4.30 p.m.		B-A, workdays, 4.30 p.m.	
			Time (min)	Speed (km/h)	Time (min)	Speed (km/h)	Time (min)	Speed (km/h)	Time (min)	Speed (km/h)
Mercato S.S. st. (A) - Mercato S.S. Hospital (B)	1.6	1.6	4	24.0	4	24.0	4	24.0	4	24.0
Mercato S.S. st. (A) - University campus[79] (B)	3.5	3.7	9	23.3	8	27.8	8	26.3	8	27.8
Fisciano station (A) - Fisciano Town Hall (B)	4.1	4.9	9	27.3	12	24.5	9	27.3	12	24.5
Fisciano Station (A) - University Campus[80] (B)	4.6	3.9	9	30.7	9	26.0	9	30.7	9	26.0
Fisciano Station (A) - Calvanico Town Hall (B)	7.4	7.4	16	27.8	16	27.8	16	27.8	16	27.8
Fratte station (A) - Mercato S.S. station (B)	13	13	20	39.0	20	39.0	18	43.3	18	43.3
Avg. speed	28.9									

Table 44. Car-based transport routes and corresponding speed. Source: author's elaboration.

[78] Timetable also available at http://www.fsbusitaliacampania.it/#orari . Retrieved on 30/05/2017.
[79] Considered main car park as destination.
[80] Considered main car park as destination.

It was necessary to take into account separately routes from A to B and vice versa. In fact, in many cases, the values of distance are slightly different, due to the configuration of street network, which forces drivers to some de-tours along one-way streets. Google Maps allows predicting travel time by car also considering traffic conditions at certain moments of the week. For this reason, two different times of a workday were considered: 8.30 a.m., representing the peak hour and 4.30 p.m., an hour with medium road congestion. The value of overall speed has been obtained by averaging all values of speed. The average speed is 28.9 km/h, rounded off to 30 km/h.

In the following image are represented walking and car routes and bus lines used to esteem the average speed for each transport mode. The intricate network of bus lines has suggested to carry out two different images with, walking and car-based transport routes (left section), and bus network of the study area (right section).

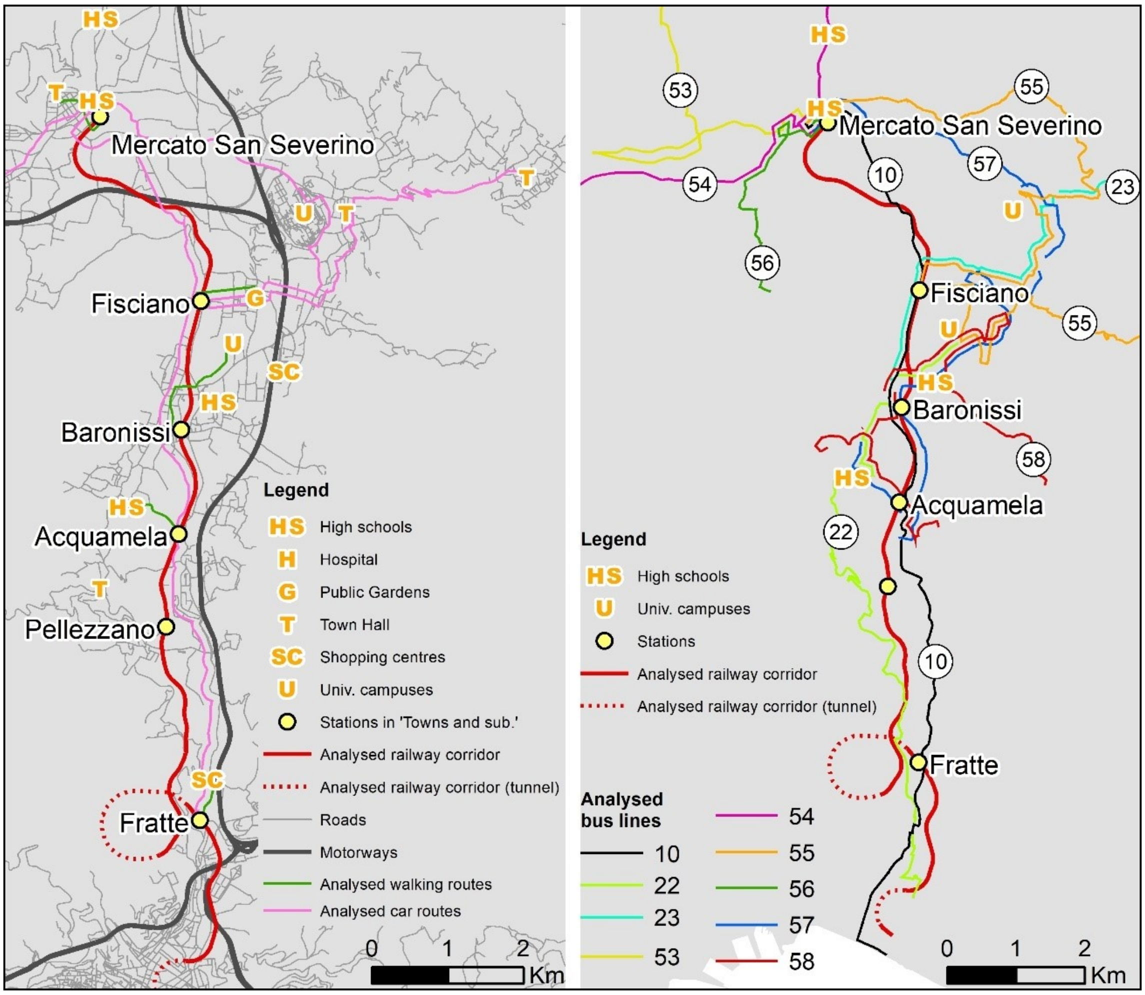


Figure 44. Map on the left: walking and car-based transport routes. Map on the right: bus lines. Source: author's elaboration.

All railway stations, except Pellezzano, allow transfers train-bus and vice versa, even if no one of them can be defined as integrated transport node with, for example protected paths from train platform to bus stops, park and ride, bike facilities, etc.

The following table lists bus lines connected to stations, with the indication of distances between station's main entrance and the closest bus terminal or stop. All bus lines belong to Busitalia Campania[81], a satellite society of *Ferrovie dello Stato Italiane* Group, which in January 2017 acquired CSTP, the former bus provincial transport company[82].

Station	Distance station – bus terminal or stop (m)	Bus line n.	Span on workdays (hh:mm)	Rides per direction/workday	Holyday service (Y/N)
Mercato San Severino	250 (Via Pioppi bus terminal)	10	18:00	37	Y[83]
		53	12:30	10	N
		54	12:00	22	N
		55	12:00	6	N
		56	11:30	9	N
		57	11:00	15	N
Fisciano[84]	50 (Via Nastri bus stop)	55	12:00	6	N
	100 (Via Ferriera bus stop)	10	18:00	37	Y
		23	16:00	16	N
Baronissi	250 (Town Hall bus stop)	10	18:00	37	Y
		22	15:00	28	Y[85]
		57	11:00	12	N
		58[86]	14:00	17	N
Acquamela	75 (Via Conforti bus stop)	57	11:00	12	N
		58[87]	12:30	10	N
Pellezzano	-	-	-	-	-
Fratte	50 (Via Dei Greci bus stop)	10	18:00	37	Y

Table 45. Detail of feeder public transport for each station. Source: author's elaboration.

As highlighted by table 45, the frequency during workdays goes from the maximum of 37 for line 10 to rare services of six/nine rides per day respectively referred to lines 55 and 56. Bus

[81] http://www.fsbusitaliacampania.it/ .

[82] http://www.salernotoday.it/cronaca/cessione-cstp-intesa-sindacati-busitalia-12-ottobre-2016.html Retrieved on 18/09/2107.

[83] Service on holydays. Span: 17h30min, rides: 18.

[84] In the case of Fisciano station, two bus stops have been considered. The average value of 75 m has been used to fill the list of indicators.

[85] Service on holydays. Span: 14h, rides: 10.

[86] Line 58 branch Baronissi Town Hall – Fusara.

[87] Line 58 branch Baronissi Town Hall – Aiello.

service drastically reduces during holydays, when only lines 10 and 22 run – the only ones leading to Salerno city centre – although with lower frequency.

In conclusion, the values used for the Italian study case are reported in the following table, where are put in relation with the access/egress time of 12 minutes, obtaining the corresponding distance for each transport mode.

Feeder transport	Average speed (km/h)	Source	Distance covered in 12 minutes (km)
Walking	5	Google Maps	1
Bike	12	CBS (NL)	2.4
Public transport - bus	22	Google Maps	4.4
Car	30	Google Maps	6

Table 46. Feeder transport speed and corresponding distances. Source: author's elaboration.

The following figures represent stations' catchment areas obtained through the application of the network distance analysis (Gutiérrez & García-Palomares, 2008), with the help of a GIS software.

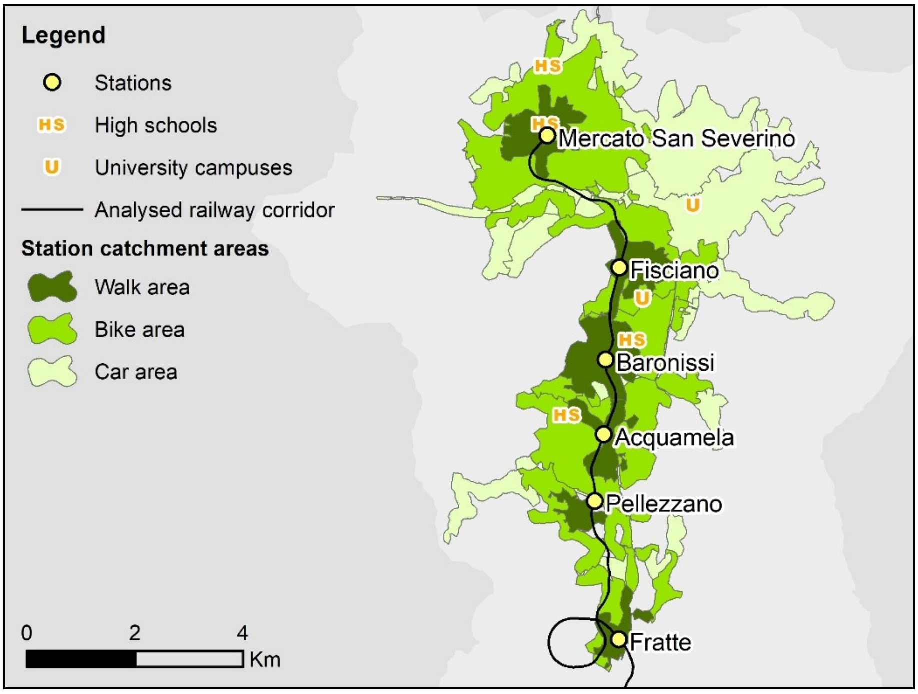


Figure 45. Station catchment areas referred to walk, bike and car transport modes. Source: author's elaboration.

The catchment areas linked to the stations of Fratte and Pellezzano show high irregularity. This is due to the complex geographical and infrastructural pattern of that part of the study area. In fact, the cited stations are placed at the mouth of Irno River Valley, which represents a narrow passage from the coastal city of Salerno to the inland plain of Mercato San Severino.

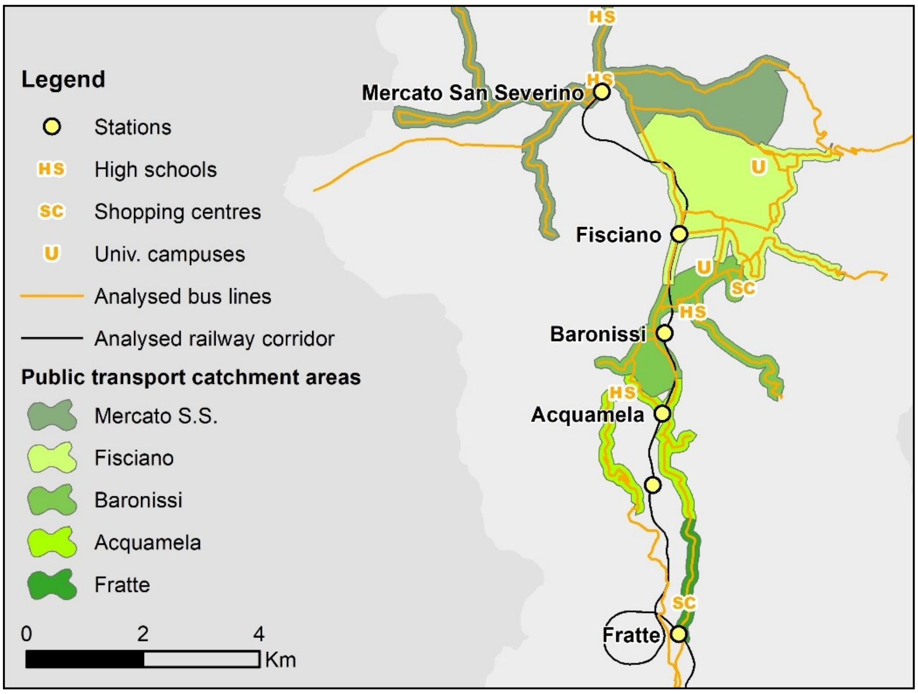


Figure 46. Feeder public transport catchment areas. Source: author's elaboration.

Population and workers esteem

The ISTAT database provides data about population, firms and employees related to the last Censuses of population of 2011 and industry and services of 2012. However, these data are referred to census tracts, whose shape does not match the shape of station's catchment areas. This means that their borders split some tracts into two or more sub-parcels for which data referred to the original tract are no longer usable.

Thus, a method able to esteem the amount of population belonging to each sub-parcel is needed. With the help of a GIS software, is possible to overlay the neighbourhood map, containing data about population, area and population density, with station catchment areas. The operation of overlay allows to define the shape and area of sub-parcels and to make an estimation of population living in the sub-parcels.

As first step, a calculation of residential and job density for each census tracts is made with a GIS software, using data relative to the total amount of population and jobs for each census tract and the value of area, obtained by census tracts 'shapefile'[88], available at ISTAT website[89].

As second step, stations' catchment areas are overlaid with the map of census tracts in order to extract those tracts, or their parts, that are involved by catchment areas. Once known which census tracts, or which sections of them, belong to catchment areas, is possible to esteem their population based on values about density calculated with the first step.

[88] A 'shapefile' is a vector file containing geographic and statistical data used by GIS software. In this case, the census tract shapefile contains data about shape and coordinates of census tracts and data about population and employees.

[89] https://www.istat.it/it/archivio/104317 . Accessed on 24/06/2017.

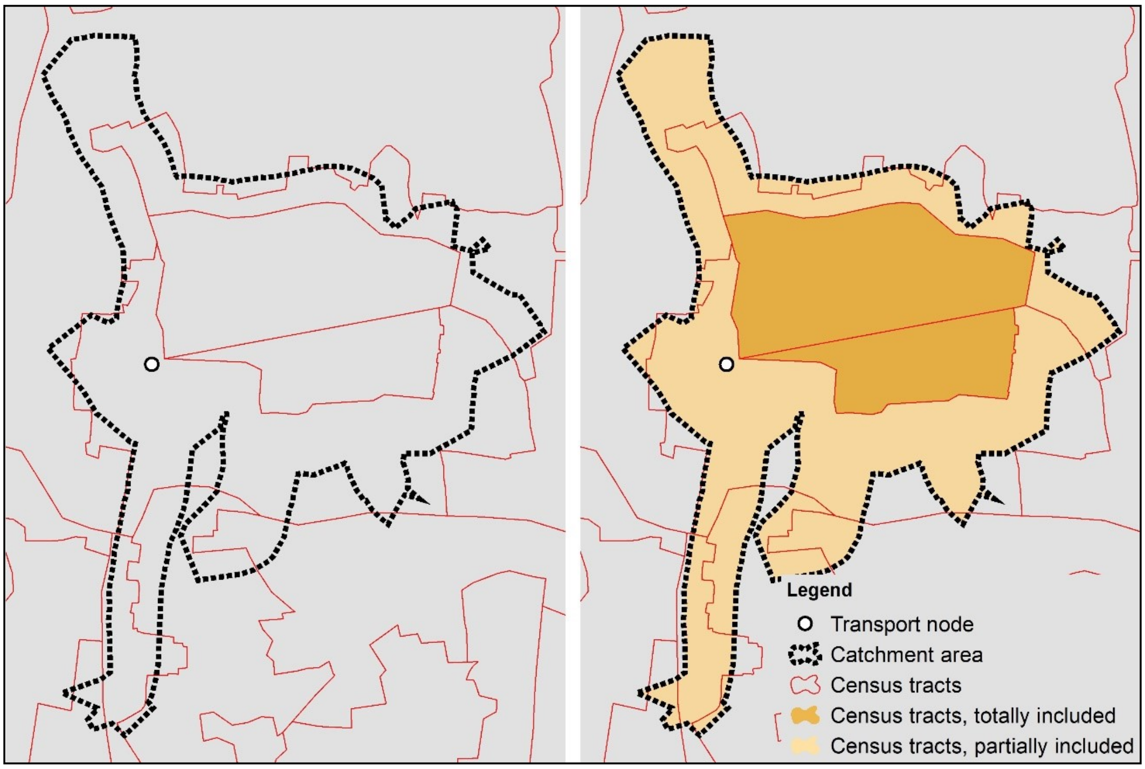


Figure 47. Example of selection procedure of census tracts. Source: author's elaboration.

Figures 47 and 48 help clarifying this method. In figure 47, in the map on the left, catchment area overlays census tracts. In the map on the right, are highlighted the tracts completely contained by the catchment area (dark orange) and the sections of census tracts partially included (light orange).

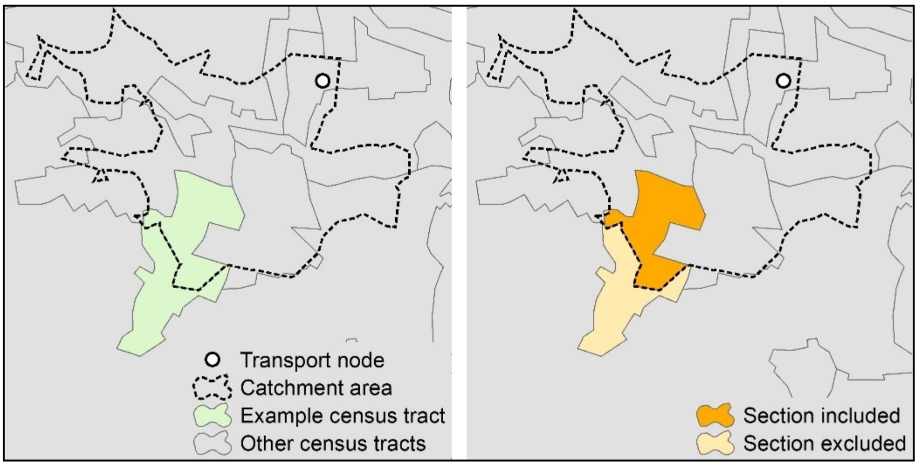


Figure 48. Example of 'cut' procedure of a census tract. Source: author's elaboration.

The following table shows the procedure used to estimate the amount of population and employees in each section of the census tracts 'cut' by catchment areas. The table displays as example a census tract with 799 inhabitants and 95 employees, these figures allow to calculate the value of density – respectively 8,802 inhabitants/km² and 1,046 employees/km². These figures are used, in turn, to estimate the value of expected inhabitants and employees for each section, since the values of area can be calculated by a GIS software.

Area	Inhabitants	Employees	Area	Inh. density	Emp. density
Entire census tract[90]	799	95	0.090768 km^2	8802 inh./km^2	1046 em./km^2
Section within catch. area	?	?	0.047683 km^2	8802 inh./km^2	1046 em./km^2

Table 47. Data referred to the example census tract. Source: author's elaboration.

The amount of population and employees is obtained by multiplying the values of density and the area[91]. In this case, figures are respectively 419 inhabitants and 50 employees.

Although this method presents some limitations, since is based on the necessary assumption that population and jobs are equally distributed in each census tract, it uses the most accurate and systematic survey available for the Italian territory. Moreover, the possible imprecisions are mitigated by the design of census tracts, detailed enough in correspondence of urban cores, while bigger tracts are often referred to lands with little or no population and employing centres, corresponding to impervious or inaccessible areas.

[90] Census tract n. 650900000007

[91] Esteemed population = density * area

Methodology implementation and results

Node indicators

The following paragraphs report the indicators used for this study case. If compared to the set of indicators used for the North Holland study case, some differences can be found. In fact, some adjustments have been necessary in order to adapt the set of indicators to this study case's characteristics. Differently from the study case referred to North Holland, indicators about span have not been considered, since the analysed transport network is characterised by great variability of frequency, while span show very little variations, altering the final results[92]. As done for North Holland study case, the value of each indicator is compared to the maximum value found among the analysed stations. To each indicator is thus assigned a score between 0 and 1, respectively representing the lowest and the highest value possible.

Main transport	Indicators	Description	Measure unit	Score	Code
Train[93]	Directions	Number of directions served	n	n/MAX value	-
	Frequency (workdays)	Arrivals or departures per day on workdays	n per day	n/MAX value	-
	Frequency (holydays)	Arrivals or departures per day on holidays	n per day	n/MAX value	-
	Ticketing[94]	Ticket machine/desk	Y/N	0/1	-
	Node index		-	Average of scores	N

Table 48. Node indicators. Source: author's elaboration.

Place indicators

Regarding Place indicators, in addition to the usual set, is considered one indicator accounting for the number of students; in fact, one of the main issues of the study area is the accessibility of education facilities.

As already sketched in the paragraph about the description of the study area, Irno River Valley can be considered a typical example of 'missed' integration between land use and public transport, where the choices of urban development have been made in the light of car accessibility, without paying enough attention to public transport accessibility. Today, this area is facing the consequences of those choices, with many facilities that are placed too far from stations, and where the connections between stations and 'attractors' are too weak and do not allow to shape an effective public and non-motorised transport network.

In the studied municipalities, there are four high schools and two university locations, with more than 1,600 high school students and around 34,000 university students. These figures help to

[92] In this specific case, it can occur that transport services with similar span but very different frequency are characterised by similar scores, not adequately representing reality. In fact, in this study case, most transport lines have a similar service time, starting in the early morning and ending in the evening, while frequency of service marks a real difference between them.

[93] All information about train timetable are available at: https://prm.rfi.it/qo_prm/ . Retrieved on 18/05/2017.

[94] Source: http://www.lestradeferrate.it/mono18.htm . Retrieved on 23/06/2017.

understand the relevance of this specific issue, that lead to consider an additional place indicator, representing the total amount of students, which is not detected by data about residents and jobs.

12-minutes Isochrone area	Name	Measure unit	Score	Code
Walking area	Esteemed residential density[95]	Population / km^2	Density/MAX density	-
	Esteemed job density[96]	Jobs / km^2	Density/MAX density	-
	Number of students[97]	n	n/MAX	-
	Walking area average value	-	Average of scores	Pw
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 place average value	-	Average of scores	Pb
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 place average value	-	Average of scores	Pp
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 place avg. value	-	Average of scores	Pc

Table 49. Place indicators. Source: author's elaboration.

Feeder transport indicators

The goal of Feeder transport indicators is to evaluate the accessibility level of each isochrone area, using specific indicators.

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

Table 50. Indicators relative to walk transport and walking area. Source: author's elaboration.

[95] Source: ISTAT (Italian Statistical Institute), Population Census 2011.
[96] Source: ISTAT (Italian Statistical Institute), Industry and Services Census 2012.
[97] 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.

In the case of walk and bike transport all indicators are based on qualitative analyses, since the use of quantitative indicators, i.e. indicators referred to the length of sidewalks and bike lanes, would have requested too much time in the phase of data collection. Moreover, it is impossible to use them in the case of bike transport, since in the study area does not exist an authentic bike network. So, four elements that have a decisive impact on bike modal choice have been selected: presence and quality of bike lanes, expected traffic intensity (Buehler, & Pucher, 2012; Xing, Handy, & Mokhtarian, 2010) average size of the roads that give access to stations, average slope of streets within bike area (Dill, & Voros, 2007).

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	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	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	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

Table 51. Indicators relative to bike transport and bike area. Source: author's elaboration.

The traffic intensity is strongly influenced by the presence of major roads in the bike area, in fact, vehicular traffic is concentrated along the roads heading towards Salerno[98]. In the case of feeder public transport – in this case corresponding to bus transport – the same set of indicators referred to main transport has been used. Moreover, indicators related to the degree of fare integration, attractiveness and the quality of waiting places were added, since these factors are believed to have a strong influence on public transport, as pointed out by some authors (Mees, 2010; Walker, 2012).

[98] For the definition and the analysis of bike areas are not considered motorways.

Feeder transport	Indicator	Description	Measure unit	Score	Code
Public transport	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[99]	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 (holydays)	Departures per day on holidays	n	n/MAX value	-
	Fare integration	Degree of fare integration	n/n[100]	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

Table 52. Indicators relative to public transport. Source: author's elaboration.

In the case of car-based transport, it is assumed that the quality of road network is equal throughout the whole study area, while the extension of car parking and their distance to the station are factors that could influence the use of car-based transport as feeder modes.

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

Table 53. Indicators relative to car-based transport. Source: author's elaboration.

The indicators referred to feeder transport have been put in relation with place indicators. As already mentioned, they have been used as multipliers of Place indicators, thus obtaining four Place indexes referred to each feeder transport mode, as reported in Table 54.

Name	Formula
Walk place index	Pw*Tw
Bike place index	Pb*Tb
Public transport place index	Pp*Tp
Car-based transport place index	Pc*Tc

Table 54. Place indexes differentiated by feeder transport modes. They are acquired by multiplying place indicators (Pw, Pb, Pp, Pc) and feedeer transport indicators (e.g. Tw, Tb, Tp, Tc). Source: author's elaboration.

[99] Source: http://www.fsbusitaliacampania.it/#orari . Retrieved on 22/05/2017.
[100] Transport companies for this study case: Trenitalia, Busitalia.

General node place analysis

This paragraph reports the results of the 'three-step' analysis, with a short comment of the possible policy implications.

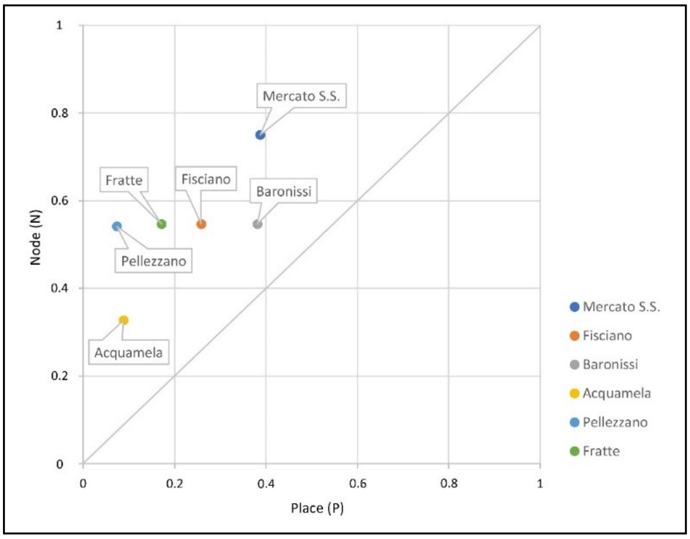


Figure 49. General node place analysis. Source: author's elaboration.

The picture given by the General node-place analysis describes a territory where transport nodes are characterised by prevailing '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 so high. Along the studied railway line, the station of Mercato San Severino has the highest node score, in fact, beyond railway service, it is arrival/departure point of some direct bus linking to Naples[101]. The stations of Fisciano, Baronissi, Pellezzano and Fratte present a very similar node index, due to the substantial homogeneity of railway service along the line, with all trains calling at all these stations. The only exception is the small station of Acquamela, where only few trains call.

Regarding place index, we can observe that the nodes of Mercato S.S., Baronissi and Fisciano have the highest scores, reflecting the real arrangement of these stations, located within urban cores – especially Mercato S.S. and Baronissi – while the stations of Fratte, Acquamela and Pellezzano are placed far from urban areas, or in zones with difficult accessibility.

Detailed node place analysis

The second step consists of a fourfold node-place analysis, differentiated by catchment area and transport mode.

[101] The bus service replaces direct trains to Naples that used to stop at Mercato S.S. station until 2009.

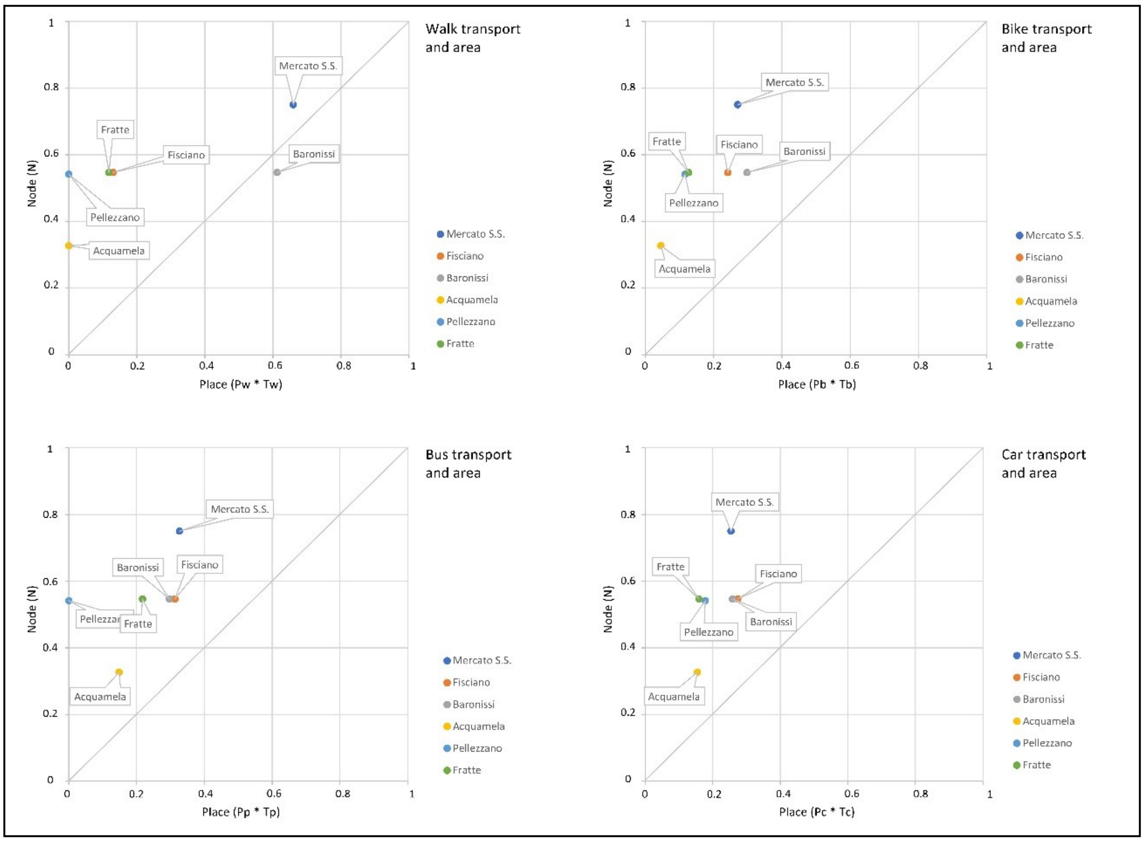


Figure 50. Detailed node place analysis. Source: author's elaboration.

The detailed node-place analysis shows a remarkable variability of the results. Regarding Mercato San Severino place value is high in the case of walk transport and area, while is lower in the other cases. This is probably due to the location of the station, within the urban core, with a good walking environment, while other station areas have much sparser settlements and worse connection.

In the case of Fisciano the highest value is reached in the cases of bus and car transport and area, even though in a situation of general low place values. The lowest place figure refers to walk transport and area, pointing out the off-centre position of the station. Baronissi is, probably, the most 'urban' of the analysed nodes. In fact, it is located within urban core of Baronissi, a town characterised by a high quality of walking environment, as witnessed by the value place index referred to walk transport and area. Acquamela, Pellezzano and Fratte show similar characteristics, generally with low place indexes, influenced by low density of areas surrounding the station and poor accessibility.

Radar diagrams

The third step of the study is represented by the radar diagrams reported in figures 51 and 52, which report the values of Node index, Place average values and Feeder transport average values.

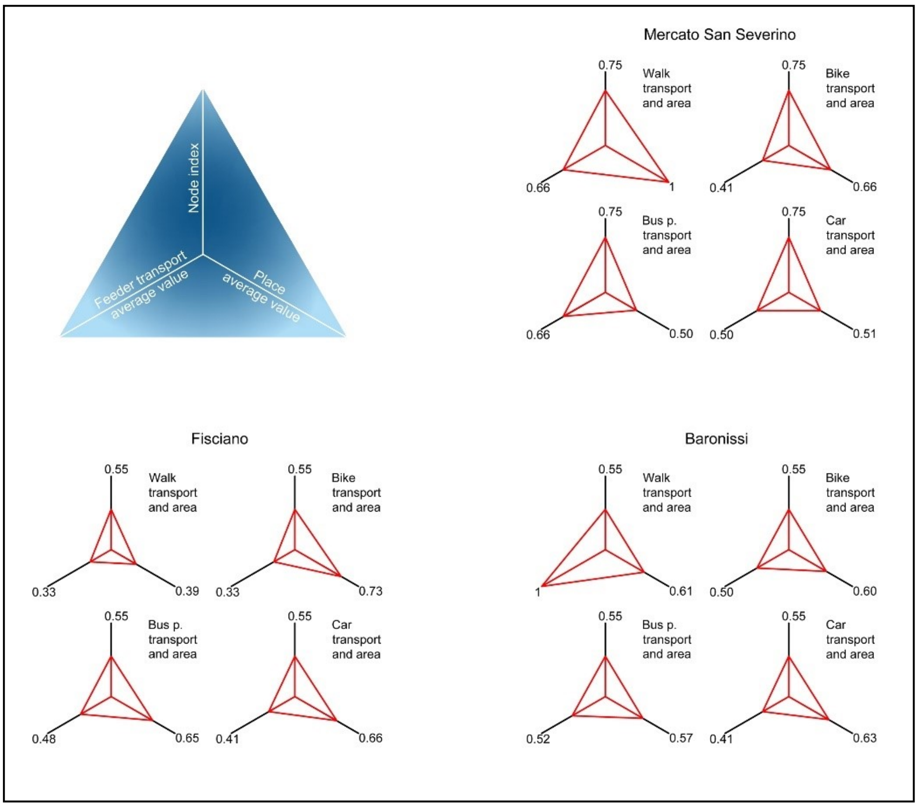


Figure 51. Radar diagrams referred to Mercato S.S., Fisciano and Baronissi. Source: author's elaboration.

Radar diagrams highlight the reasons of unbalance. E.g., in the case of Mercato S.S., we can see how in the case of walk and bike, place average value outreaches feeder transport, suggesting that actions aimed to improve transport – especially feeder transport – are needed. In the case of Fisciano, we can observe a tendency towards a greater place indicator in the cases of bike, bus and car transport, suggesting the need for an improvement of accessibility, while in the case of walk transport and area, the low value of place indicator is probably determined by the placement of the station at the edge of urban area. Fisciano University campus falls within bus transport catchment area, but the related place indicator is not high as we could expect. This is due to the low residential and job density of the remaining catchment area. As already mentioned, Baronissi station is placed in the core of a vibrant, walking-friendly urban area, in fact the radar diagrams referred to this station reflect this pattern. Acquamela station is a single-track stop in the south sector of the municipality of Baronissi, located in a mostly agricultural area and far from urban centres. In fact, this node shows low values of the three indicators considered. Pellezzano station, despite the good accessibility by train, is characterised by a null value of accessibility by walk feeder transport – the station can be reached only by a road with no sidewalks – and by bus transport – there are not bus that stop at the station. The analysis of Fratte station indicates that a slight increase of place indicator could be possible in the case of walk and bike area, together with an improvement of accessibility.

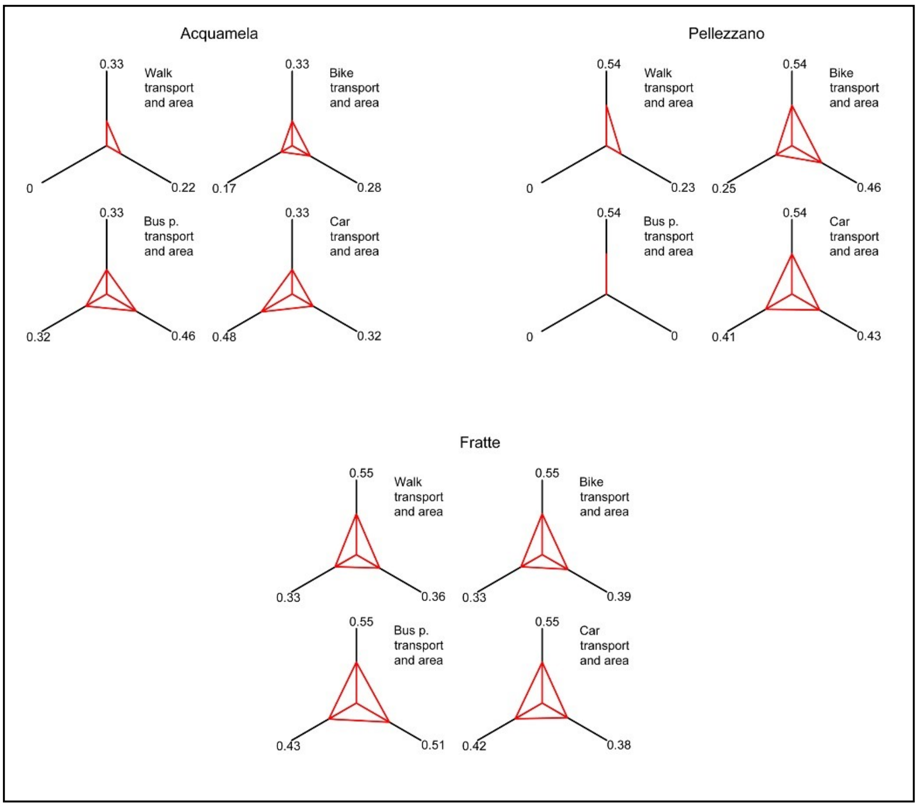
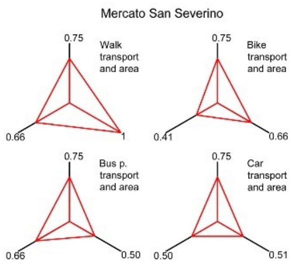


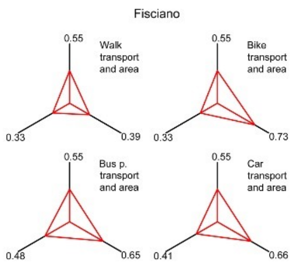
Figure 52. Radar diagrams referred to Acquamela, Pellezzano and Fratte. Source: author's elaboration.

Actual situation and suggested planning strategies

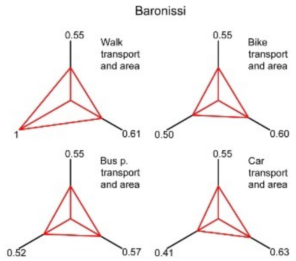
The following diagram contains the analysis of the actual situation and sketches some planning strategies suggested by radar diagrams.



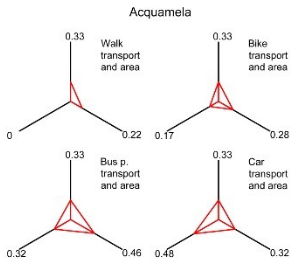
Actual situation:
The station of Mercato S.S. has a good level of accessibility by train. Urban density is high within walk catchment area, while is moderte in other catchment areas; feeder transport has medium values.
Suggested planning strategies:
Urban density should not be increased in walk catchment area, while other catchment areas could host new residents and activities, together with an amelioration of accessibility by main and feeder transport.



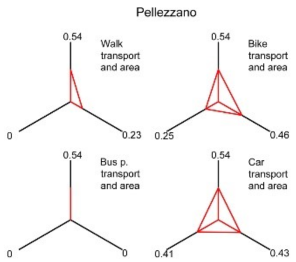
Actual situation:
Fisciano station shows a medium degree of accessibility by train and scarce quality of feeder transport, while urban density is slightly higher, especially in the cases of bike and car area.
Suggested planning strategies:
An improvement of bike feeder transport is necessary, while increases of urban density would require an upgrade of accessibility by main and feeder transports.



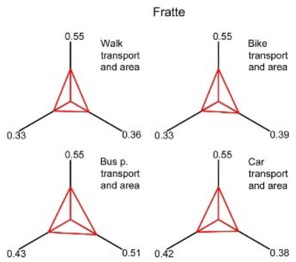
Actual situation:
Baronissi station shows a substantial balance, except for walking environment, whose high quality is not matched by main transport quality and urban density.
Suggested planning strategies:
Increases of urban density should be accompanied by enhancement of accessibility by main transport and feeder transports. Walk catchment area is a partial exception, in fact it shows very good quality of walking environment.



Actual situation:
The small single-track station of Acquamela, located within Baronissi municipality, has very low accessibility by main transport: in fact, only few trains call there. Feeder transport accessibility and urban density show low values also.
Suggested planning strategies:
Acquamela has good potentials for urban density increases, though main transport and feeder transport should be greatly upgraded. Accessibility by walking and bike have extremely low values: this is due to the absence of sidewalks, bike lanes and poor quality of walking and cycling environment in general.



Actual situation:
Despite a medium degree of accessibility by train, Pellezzano station is characterised by low urban density of catchment areas and poor quality of feeder transport.
Suggested planning strategies:
This station shows good potentialities for urban development, especially in the case of walk and public transport catchment areas. However, walk and public transport feeder transport must be provided, and an upgrade of accessibility by main transport is necessary in the case of density increases in all catchment areas.



Actual situation:
Fratte station shows a substantial balance between all indexes in each catchment area, even though each value
Suggested planning strategies:
An increase of urban density would require an improvement of accessibility by train and feeder transport, regardless of the catchment area considered.

Appendix

Node indexes (N)

Node 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 (holydays)	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
N	-						0.75	0.55	0.55	0.33	0.54	0.55

Place average values (Pw, Pb, Pp, Pc)

Place indicators		Value						Score					
		Mercato S.S.	Fisciano	Baronissi	Acquamela	Pellezzano	Fratte	Mercato S.S.	Fisciano	Baronissi	Acquamela	Pellezzano	Fratte
Walking area	Est. residential density	4,695	3,497	4,572	317	1,803	3,167	1	0.74	0.97	0.06	0.38	0.67
	Est. job density	1,664	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
	Pw	-						1	0.39	0.61	0.22	0.23	0.36
Bike area	Est. residential density	1,821	2,061	3,080	1,607	2,922	2,048	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	1,020	2,700	260	370	0	0	0.38	1	0.10	0.14	0	0
	Pb	-						0.66	0.73	0.60	0.28	0.46	0.39
Public transport area	Est. residential density	1,787	1,331	2,529	2,576	0	1,344	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	1,020	32,000	2,960	370	0	0	0.03	1	0.09	0.01	0	0
	Pp	-						0.50	0.65	0.57	0.46	0	0.50
Car-based transport area	Est. residential density	1,272	1,240	2,571	1,702	2,045	1,657	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	1,020	34,700	260	370	0	0	0.03	1	0.01	0.01	0	0
	Pc	-						0.59	0.66	0.63	0.32	0.43	0.38

Feeder transport average values – walking (Tw)

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
Tw	-						0.66	0.33	1.00	0.00	0.00	0.33

Feeder transport average values – bike (Tb)

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
Tb	-						0.41	0.33	0.50	0.17	0.25	0.33

Feeder transport average values – public transport (Tp)

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 (holydays)	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
Tp	-						0.66	0.48	0.52	0.32	0.00	0.43

Feeder transport average values – car-based transport (Tc)

Indicator	Value						Score					
	Mercato S.S.	Fisciano	Baronissi	Acquamela	Pellezzano	Fratte	Mercato S.S.	Fisciano	Baronissi	Acquamela	Pellezzano	Fratte
Car parking	3,100	400	1,000	1,450	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
Tc	-						0.50	0.41	0.41	0.48	0.41	0.42

Chapter 6

Central Italy study case

The third study case is referred to the municipalities involved in the rebuilding plan of Central Italy, hit by the earthquakes occurred between August 2016 and January 2017[102]. The area corresponds to 131 municipalities belonging to four different regions: Abruzzo, Lazio, Marche and Umbria, as defined by the Rebuilding Act of December 2016[103].

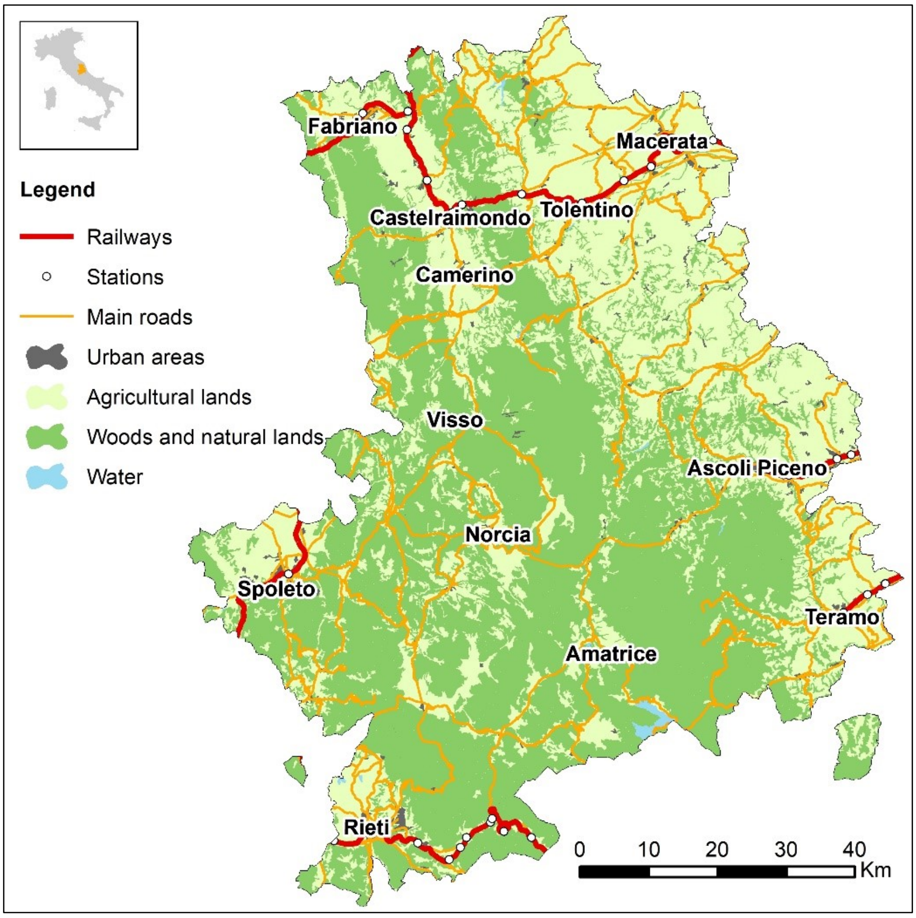


Figure 53. Central Italy study area, urban and infrastructural pattern. Source: author's elaboration.

This area corresponds to a hilly and mountainous territory located across the Apennines mountain range, characterised by low population density and scarce accessibility, especially by public transport[104].

[102] The main earthquakes, with a magnitude of 5 or greater, happened on 24th August 2016, 26th and 30th October 2016 and 18th January 2017.

[103] Rebuilding Act of 15th December 2016 (*Legge di conversione 15 dicembre 2016 n. 229 del decreto-legge 17 ottobre 2016 n. 189*). Available at http://www.gazzettaufficiale.it/atto/stampa/serie_generale/originario . Retrieved on 14/07/2017.

[104] All maps in this chapter are based upon data freely available at OpenStreetMap https://www.openstreetmap.org/#map=9/43.0067/13.4431&layers=T and ISTAT websites https://www.istat.it/it/archivio/104317 . Retrieved on 28/06/2017.

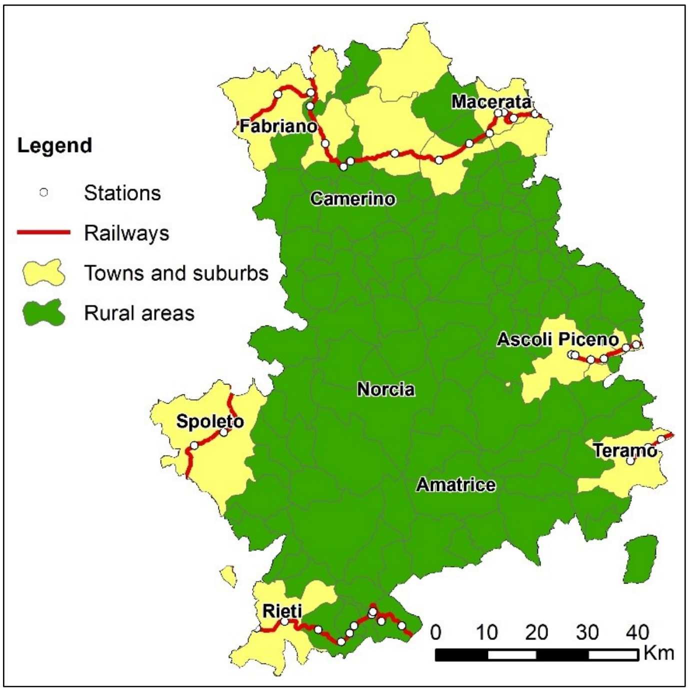


Figure 54. Urban degree of municipalities, and railway infrastructures. Source: author's elaboration based on Dijkstra & Poelman (2014).

There are two main reasons behind the choice of this study case: the use of the defined methodology in order to help increasing accessibility by public transport; secondarily, the use of extended node place analysis with the objective of considering criteria of public transport accessibility in the rebuilding strategy or plan.

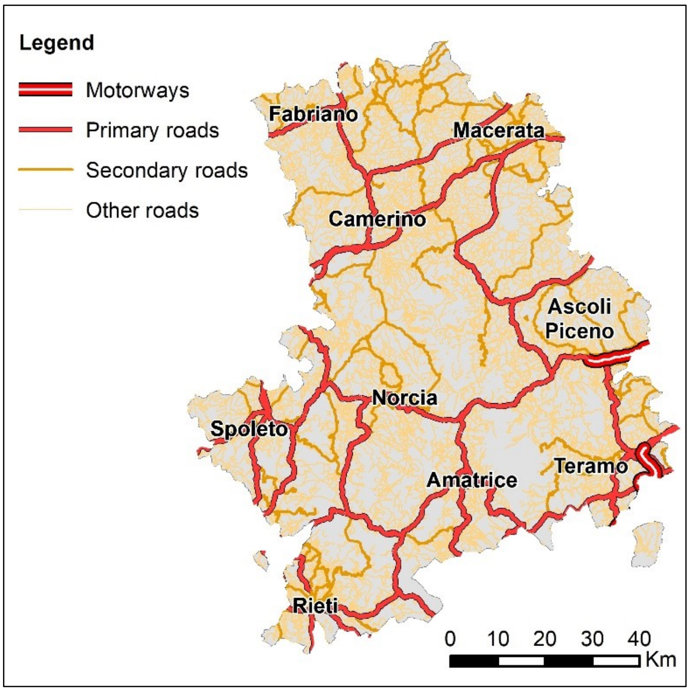


Figure 55. Road network. Source: author's elaboration.

As can be observed in the previous maps, the studied area is mainly occupied by woods and natural lands, with most of the municipalities classified as 'Rural areas' by Eurostat's Degree of Urbanisation (Dijkstra & Poelman, 2014).

The most populous urban centres are located on the fringes of study area; consequently, the region is marginally touched by some railways, mainly local lines, while in the core of the area accessibility is provided by road network, which has been significantly improved during the last decades with the realisation of new 'motorways'.

Data sources

Travel time

As done for Campania study case, the value of average travel time considered is 54.2 minutes, referred to the Italian national context and obtained by ISTAT data about travel time with train as main mode (see Chapter 5).

Access and egress time

As done for the study cases of North Holland and Campania, the value of 12 minutes has been used as acceptable access and egress time, based on the findings about the 'interconnectivity ratio' of multimodal transport chains (Krygsman et al., 2004), as already explained in chapter 4.

Travel speed

In this case, data about travel time are not available for the selected study area, therefore a procedure similar to the one followed for Campania study case has been used, esteeming the speed of car and bus transport mode with the help of Google Maps[105]. The remarkable differences existing in the road network within the studied area – in terms of quality and consequently travel speed – suggested to consider different car routes, respectively referred to 'fast' routes (table 55), and 'slow' routes (table 56). Fast routes rely on primary roads, mostly characterised by separate carriageways, controlled accesses, absence of at-grade intersections and absence of direct accesses to properties.

Route	Distance (km)	Time (min)	Speed (km/h)
Macerata industrial area – Colfiorito via SS 77	61.6	39	94.8
Fossato di Vico – Valtreara via SS 76	26.5	20	79.5
Albacina – Muccia via SP 256	36.5	40	54.8
Colli del Tronto – Rieti via RA 11 and SS 4	117	99	70.9
Average speed	75.0		

Table 55. 'Fast' car routes and corresponding speed. Source: author's elaboration.

Even though motorways network only touches few towns on the edge of study area, like Ascoli Piceno and Teramo, some recently built roads show motorway-like characteristics, e.g. SS

[105] https://www.google.com/maps.

77[106], while many other roads are currently being improved to provide better connections. The average value of 75 km/h has been attributed to 'motorways' and to the sections of 'primary roads' (figure 56) showing motorway-like characteristics.

Route	Distance (km)	Time (min)	Speed (km/h)
Teramo station - town hall	2.2	6	22.0
Spoleto station - town hall	1.4	4	21.0
Macerata station - town hall	3.3	6	33.0
Ascoli - Teramo	49.9	57	52.5
Spoleto station - Norcia town hall	42.4	43	59.2
Camerino - Norcia	79.4	127	54.8
Average speed	40.4		

Table 56. 'Slow' car routes and corresponding speed. Source: author's elaboration.

Slow routes, listed in table 56, mainly refer to connections between stations and town centres or between towns linked by standard roads. The average value of 40.4 km/h, rounded off to 40 km/h, has been attributed to 'secondary roads' and 'other roads' (figure 56).

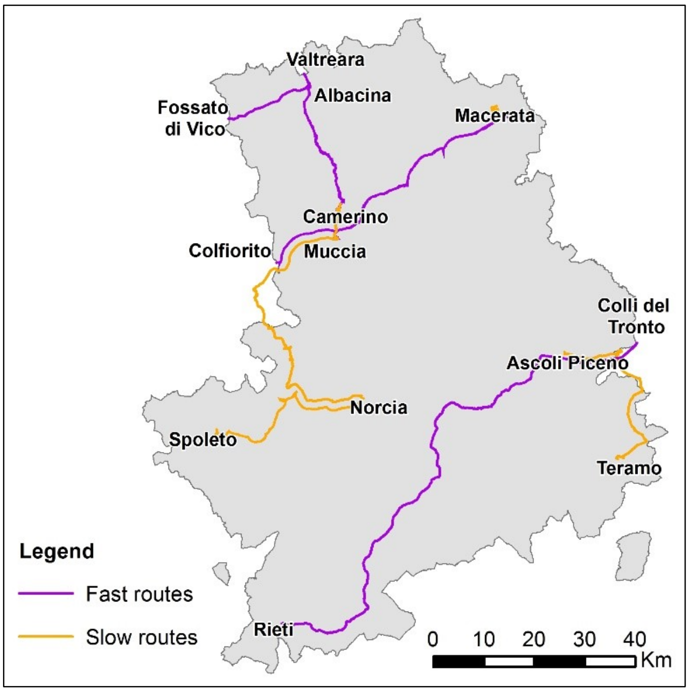


Figure 56. Car routes considered. Source: author's elaboration.

The studied area is generally characterised by low accessibility by public transport, impeded by the impervious geography and by the fact that this region can be seen as a group of different

106 This road has been refurbished with motorway characteristics: https://it.wikipedia.org/wiki/Strada_statale_77_della_Val_di_Chienti . Retrieved on 27/07/2017.

'basins', whit the main infrastructures heading outside the study area itself, while only few of them cross the studied territory.

However, some differences can be found between the southern sector – e.g., the towns of Ascoli Piceno, Teramo, Rieti, and Spoleto are accessible mainly from 'outside' the study area – and the northern sector. The corridor Fabriano – Macerata is the only transport railway corridor crossing the study area, serving the lower Province of Macerata.

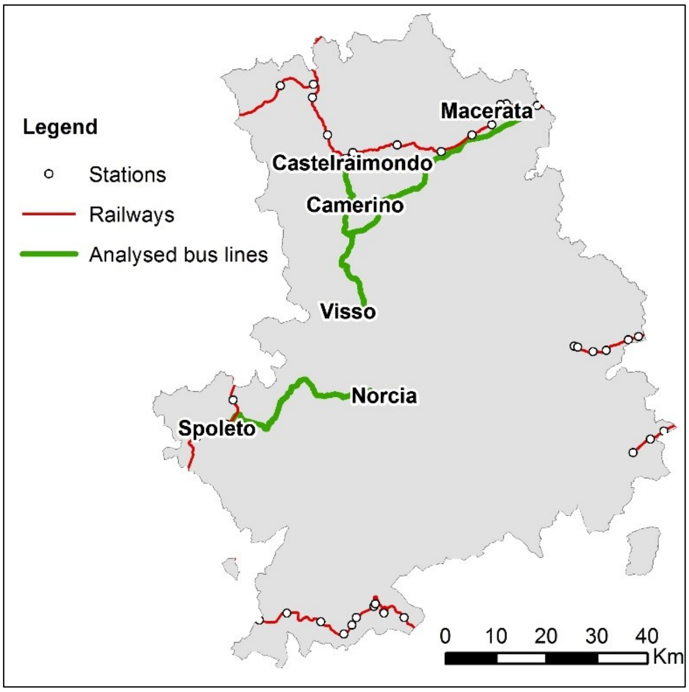


Figure 57. Analysed bus routes. Source: author's elaboration.

The research considered bus lines belonging to the northern and western sector of the study[107].

Route	Distance (km)	Time (min)	Speed (km/h)
Castelraimondo station – Camerino bus terminal	12.5	20	37.5
Macerata - Camerino	49.3	75	39.4
Macerata - Visso	70	148	28.4
Visso - Camerino	30.3	40	45.5
Spoleto station - Norcia town hall	42.4	60	42.4
Average speed	38.6		

Table 57. Bus routes and corresponding speed. Source: author's elaboration.

The found average speed of travels by bus is 38.6 km/h, rounded off to 40 km/h.

[107] Lines for which data are available on the web.

Since the study area is characterised by a remarkable variety in terms of quality of road network, a detailed analysis related to this aspect was conducted. Typologies of roads have been identified, in order to distinguish them on the basis of their ability to sustain different transport modes (e.g. cyclists and pedestrians are not allowed on motorways).

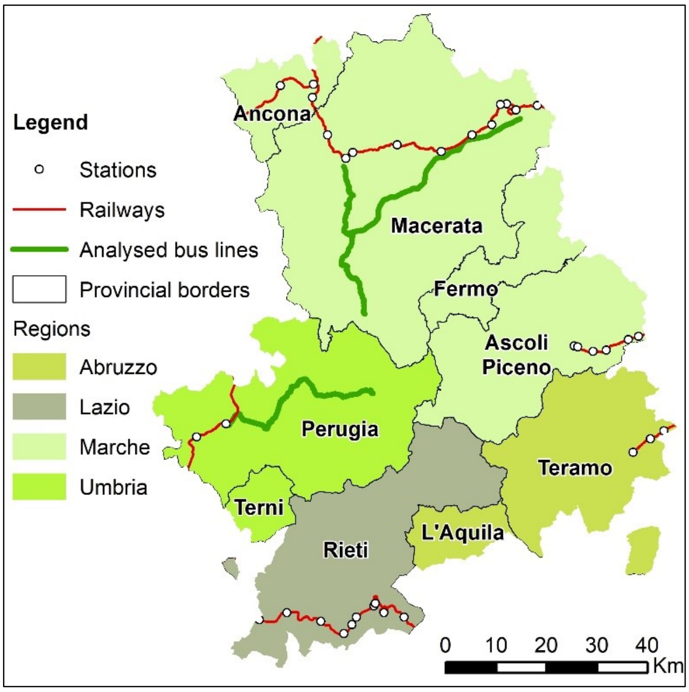


Figure 58. Public transport and administrative boundaries. Source: author's elaboration.

The following table summarises the speed for each transport mode, the typology of roads individuated (see figure 55) and speed values for each transport mode. The speed of bike and walking are supposed to be equal to the values used for the first two study cases.

Road typology	Transport typology: speed			
	Walk	Bike	Bus	Car
Motorways	-	-	40	75
Primary roads	5	12	40	75
Secondary roads / Other roads	5	12	40	40
Bike paths	-	12	-	-
Pedestrian roads	5	-	-	-

Table 58. Transport speed related to the different road typologies. Source: Author's elaboration.

The unavailability of information about the exact itinerary of bus lines forced to consider a 'theoretical' bus catchment area instead of the real one, i.e. a bus catchment area not based on bus network as done for North Holland and Campania study cases, but generically based on road network.

Feeder transport	Average speed (km/h)	Source	Distance covered in 12 minutes (km)
Walking	5	Google Maps	1
Bike	12	CBS (NL)	2.4
Public transport - bus	40	Google Maps	8
Car	from 40 to 75	Google Maps	from 8 to 15

Table 59. Speed of feeder transport modes and corresponding distances. Source: author's elaboration.

In this case, GIS road network database was consulted by the point of view of travel time, rather than distance – as done in the previous study cases – due to the different values of speed referred to car-based transport.

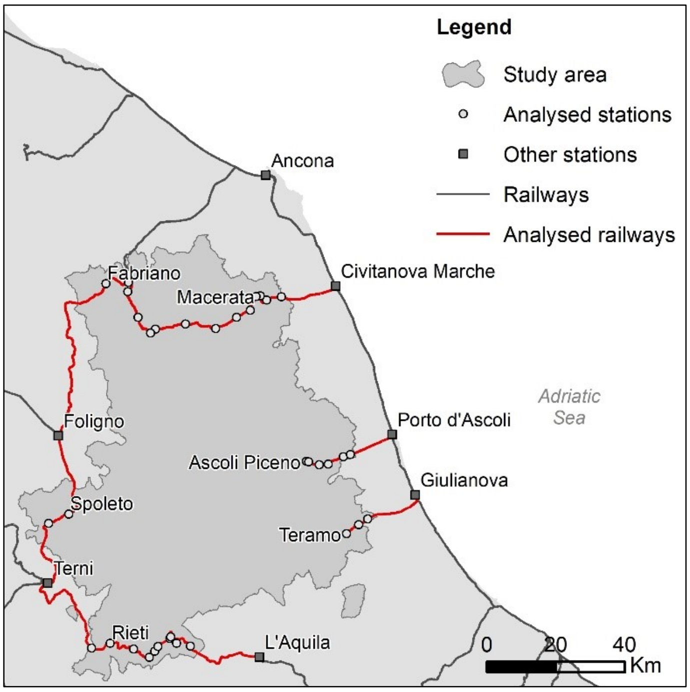


Figure 59. Railway accessibility of study area. Source: author's elaboration.

As can be observed in figure 59, the study area is served by five different railways, mainly running on its borders, while there are not 'transversal' railway connections. This can be explained by the impervious geography of the area, and by the absence of big towns or industries justifying the realisation of railway links. For these reasons, this study case can be subdivided into five sub-cases, listed as follows.

- Railway corridor Fabriano – Macerata, part of the Fabriano – Civitanova Marche line.
- Railway corridor Ascoli Piceno – Porto d'Ascoli.
- Railway corridor Teramo – Giulianova.

- Railway corridor Spoleto – Baiano di Spoleto, part of the Terni – Foligno line.
- Railway corridor Rieti – L'Aquila, part of the Terni – L'Aquila line.

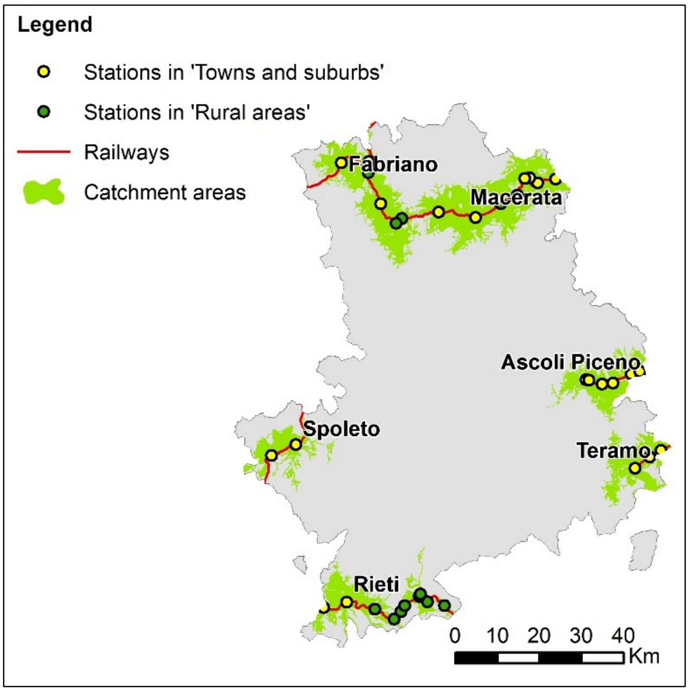


Figure 60. Railway lines, stations and catchment areas. Source: author's elaboration.

These railway lines greatly differ in terms of public transport offer, capacity, relevance and connection role; therefore the following lines sketch a rough distinction. The corridors Fabriano – Macerata and Rieti – L'Aquila correspond to small local railways, mainly linking small and medium towns; both these lines are single-track and non-electrified. The corridors Ascoli Piceno – Porto d'Ascoli and Teramo – Giulianova link the provincial administrative centres of Ascoli Piceno and Teramo to the Adriatic coast, where they join the Adriatic railway, a relevant transport infrastructure connecting north and south Italy; these two short railways are electrified and single-track. The short corridor between Spoleto and Baiano di Spoleto is part of the railway connecting Rome and Ancona, a single-track electrified railway that is currently being improved, with the realisation of the double track. This railway line has an important node in Fabriano station, where it connects to the already mentioned line Fabriano – Civitanova Marche. The following images represent the cited railway corridors, also designing catchment areas.

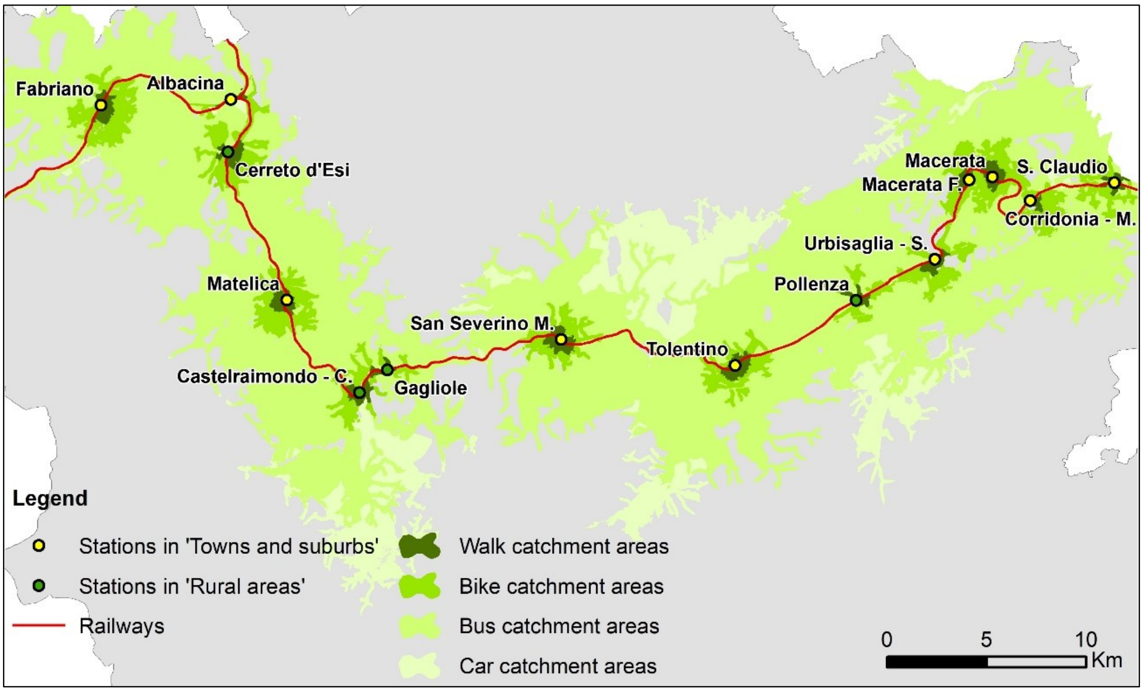


Figure 61. Detail of railway corridor Fabriano – Macerata. Source: author's elaboration.

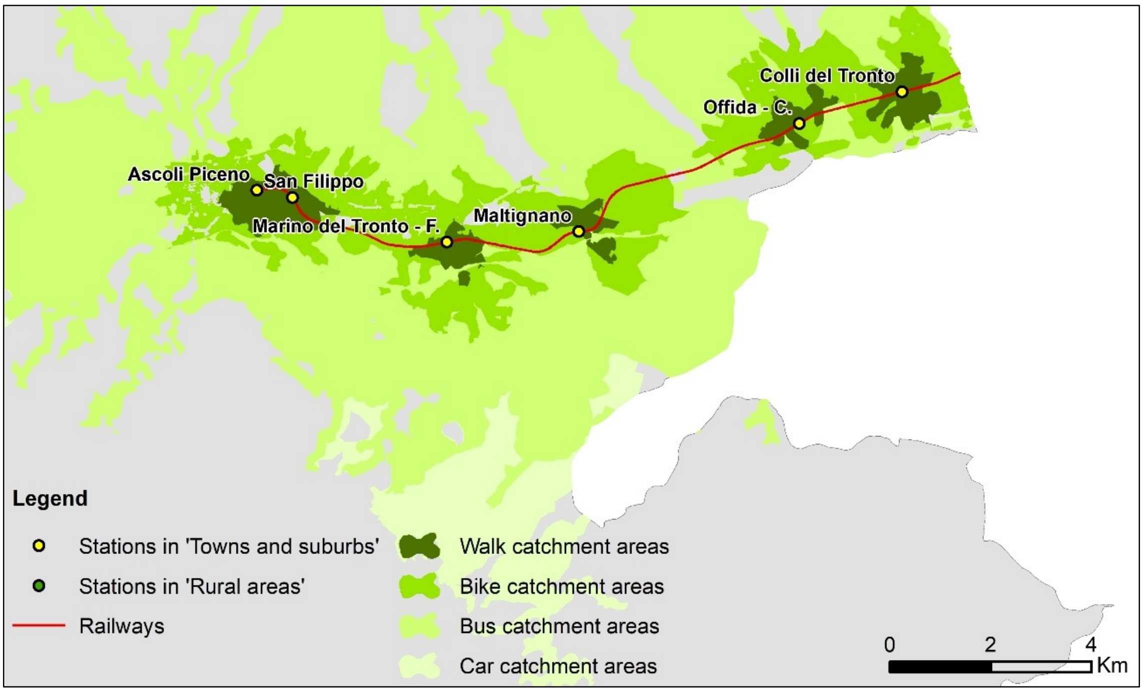


Figure 62. Detail of railway corridor Ascoli Piceno – Porto d'Ascoli. Source: author's elaboration.

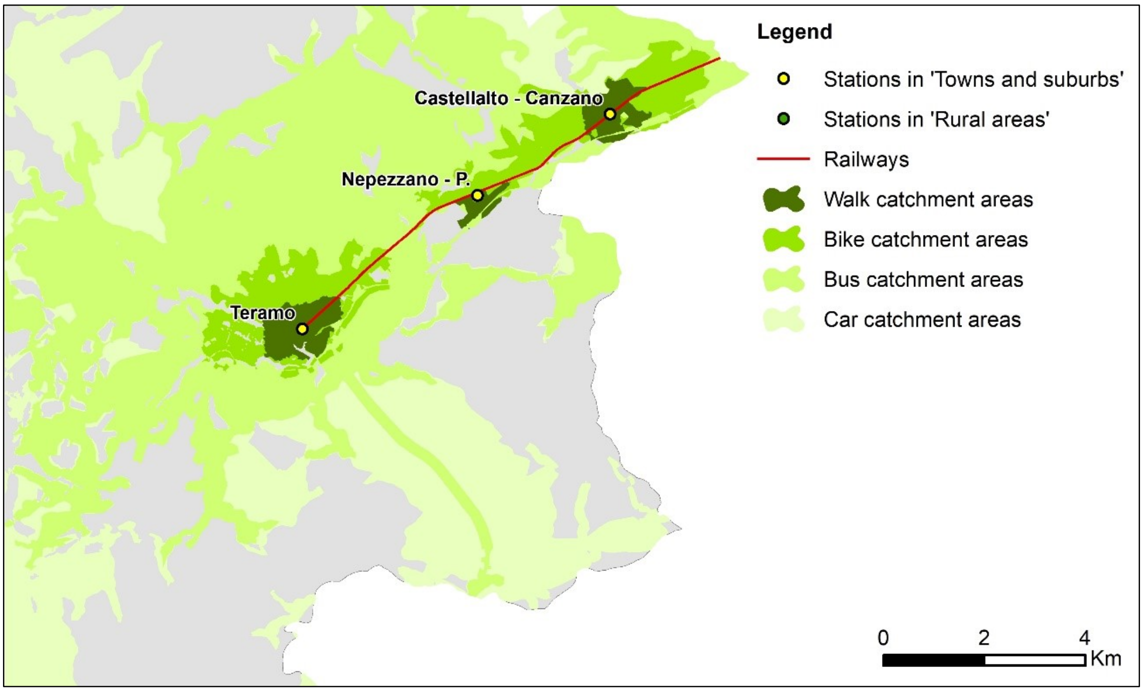


Figure 63. Detail of railway corridor Teramo – Giulianova. Source: author's elaboration.

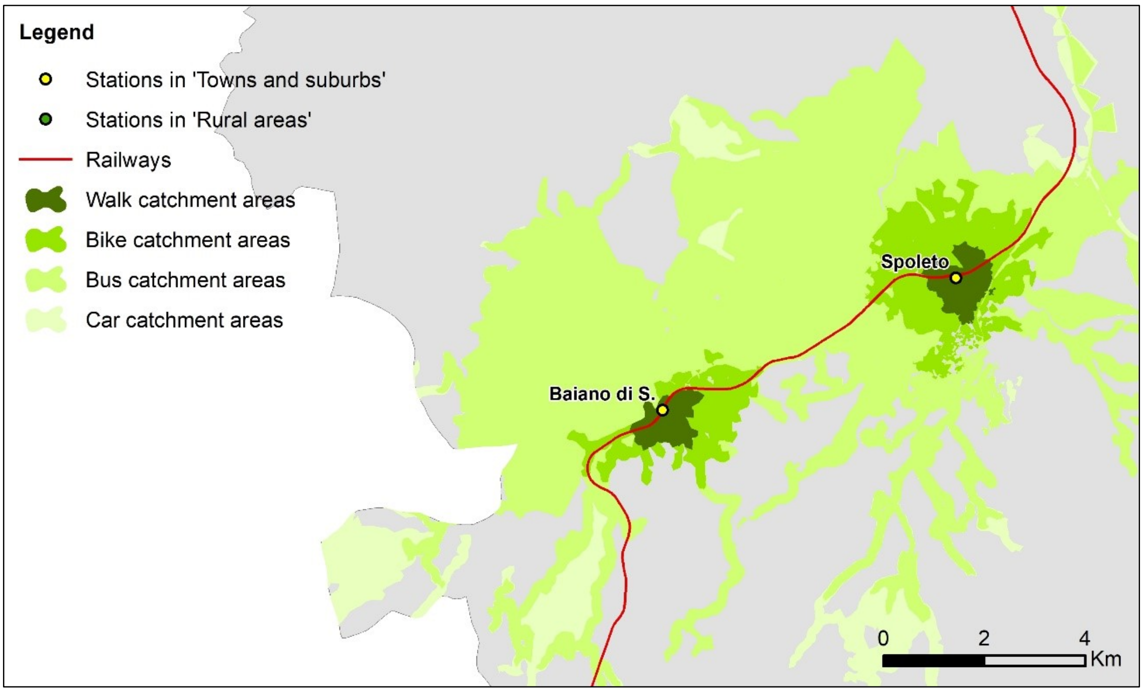


Figure 64. Detail of railway corridor Spoleto – Baiano di Spoleto. Source: author's elaboration.

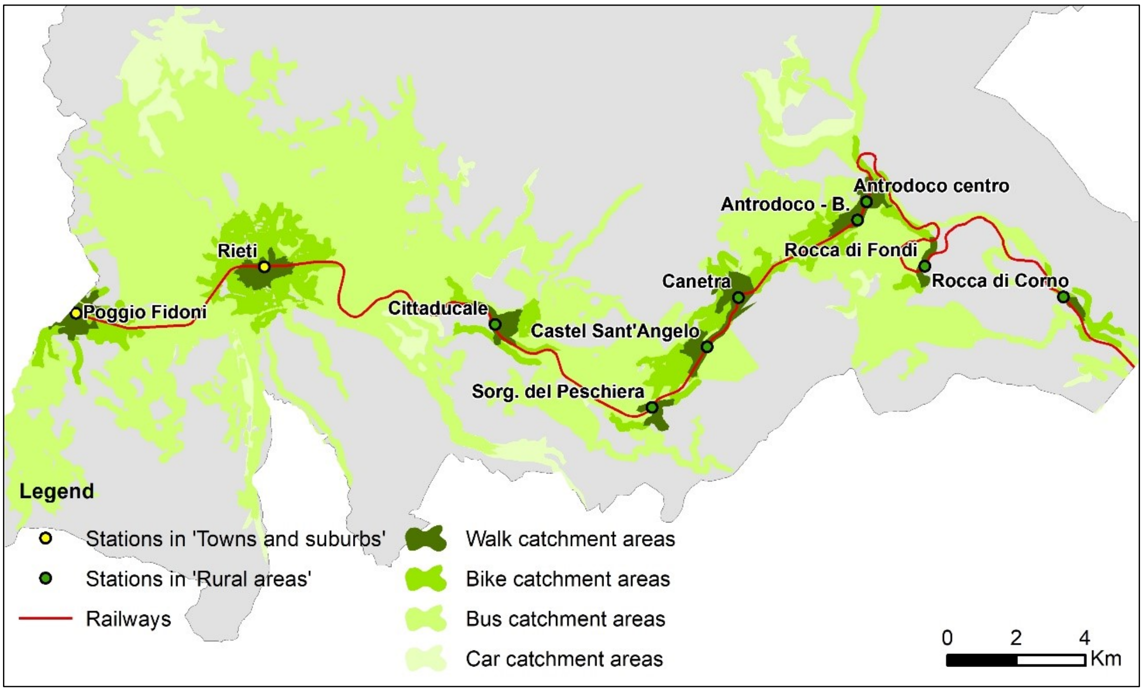


Figure 65. Detail of railway corridor Rieti – L'Aquila. Source: author's elaboration.

Population and workers esteem

As done for Campania study case, ISTAT database was used to find information about population and activities. The latest updates correspond to the 2011 Census of population and the 2012 Census of industry and services[108]. The procedure of calculation of residential and job density, cutting of census tracts and estimation of residents and jobs in catchment areas was used, as already explained in Chapter 5 about Campania study case.

Methodology implementation and results

In this paragraph are summarised the indicators used in this case study. Some differences can be found in comparison with the study cases of North Holland and Campania, since minor adjustments were needed in order to adapt the methodology to the specific context, and to available data, not always exhaustive.

Node indicators

Node indicators are based upon train timetables of 2017; moreover, in this study case as done for Campania, have not been considered data about span – i.e. service time – since this factor does not show great variations among stations with many trains per day and stations where only few trains call, hiding the real differences in terms of service quality[109].

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[108] Census data available at https://www.istat.it/it/archivio/104317#accordions. Retrieved on 22/08/2017.

[109] E.g., some small stations with less than 10 trains per day have a service time similar to main stations where train frequency is five or six times higher.

Main transport	Indicators	Description	Measure unit	Score	Code
Train[110]	Directions	Number of directions served	n	n/MAX value	-
	Frequency (workdays)	Arrivals or departures per day on workdays	n per day	n/MAX value	-
	Frequency (holydays)	Arrivals or departures per day on holidays	n per day	n/MAX value	-
	Node index		-	Average of scores	N

Table 60. Indicators relative to main transport. Source: author's elaboration.

Place indicators

The indicators describing Place qualities are referred to esteemed residential and job density, as done for Campania study case. However, differently from that study case, have not been considered data relative to education facilities.

12-minutes Isochrone area	Name	Measure unit	Score	Code
Walking area	Esteemed residential density[111]	Population / km^2	Density/MAX density	-
	Esteemed job density[112]	Jobs / km^2	Density/MAX density	-
	Walking area average value	-	Average of scores	Pw
Bike area	Esteemed residential density	Population / km^2	Density/MAX density	-
	Esteemed job density	Jobs / km^2	Density/MAX density	-
	Bike area average value	-	Average of scores	Pb
Public transport area	Esteemed residential density	Population / km^2	Density/MAX density	-
	Esteemed job density	Jobs / km^2	Density/MAX density	-
	Public t. area average value	-	Average of scores	Pp
Car-based transport area	Esteemed residential density	Population / km^2	Density/MAX density	-
	Esteemed job density	Jobs / km^2	Density/MAX density	-
	Car-based t. area average value	-	Average of scores	Pc

Table 61. Place indicators referred to the different areas. Source: author's elaboration.

Feeder transport indicators

Walk and bike access are evaluated using qualitative indicators, as done for Campania study case, with the exception of 'Expected vehicular traffic intensity' indicator, that in this study area, considering the low population density, cannot be considered a relevant factor.

[110] All information about train timetables are available at: https://prm.rfi.it/qo_prm/ . Timetables are referred to the period June 2017 – December 2017. Retrieved on 18/07/2017.

[111] Source: ISTAT (Italian Statistical Institute), Population Census 2011. Available at https://www.istat.it/it/archivio/104317#accordions . Retrieved on 22/08/2017.

[112] Source: ISTAT (Italian Statistical Institute), Industry and Services Census 2012. Available at https://www.istat.it/it/archivio/104317#accordions . Retrieved on 22/08/2017.

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 indicator			-	Average of scores	Tw

Table 62. Indicators relative to walk transport and walking area. Source: author's elaboration.

Feeder transport	Indicator	Description	Score		Code
Bike[113]	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	-
	Road size	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	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 indicator			-	Average of scores	Tb

Table 63. Indicators relative to bike transport and bike area. Source: author's elaboration.

Regarding public feeder transport, the unavailability of detailed information about bus lines made impossible to use a more exhaustive set of indicators, as done for North Holland and Campania study cases. The indicator about fare integration corresponds to the ratio of transport companies with ticket integration and all companies serving a transport node[114]; in fact, in this case many transport companies can be found, with some of them that issue integrated train-bus tickets, at least on some lines, while other companies do not allow it at all.

[113] Quality of cycling environment Elements referred to bike areas. The intensity of vehicular traffic, the size and the slope of roads influence the usability of bike as transport mode.

[114] E.g. in the case of Rieti station, there are three transport companies operating: Trenitalia for railway transport, ASM and Cotral for bus transport. It is possible, for passengers, to buy integrated train+bus tickets with Trenitalia and Cotral, thus only 2 transport companies are involved in fare integration policies. Consequently, the score will be 2/3 = 0.667 .

Feeder transport	Indicator	Description	Measure unit	Score	Code
Public transp.[115]	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)	-
	Fare integration	Degree of fare integration	n	n integrated companies / n transport companies	-
Public transport indicator			-	Average of scores	Tp

Table 64. Indicators relative to public transport. Source: author's elaboration.

In the case of car-based transport, every station is linked to road network, thus car access is always possible; however only some stations have car parking or taxi facilities.

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)	-
	Taxi	Taxi service	Y/N	0/1	-
Car-based transport indicator			-	Average of scores	Tc

Table 65. Indicators relative to car-based transport. Source: author's elaboration.

Feeder transport indicators have been put in relation with place indicators. As already done for North Holland and Campania study cases, they have been used as multipliers of Place indicators, thus obtaining four Place indexes referred to each feeder transport mode, as shown in table 66.

Name	Formula
Walk place index	Pw*Tw
Bike place index	Pb*Tb
Public transport place index	Pp*Tp
Car-based transport place index	Pc*Tc

Table 66. Place indexes differentiated by feeder transport modes. They are acquired by multiplying place indicators (Pw, Pb, Pp, Pc) and feeder transport indicators (e.g. Tw, Tb, Tp, Tc). Source: author's elaboration.

[115] Bus transport companies: Contram Mobilità for the Province of Macerata (http://www.contram.it/index.php/orari/); TransFer and Start for the Province of Ascoli Piceno (http://www.trasfer.eu/index.php?action=index&p=422 , http://www.startspa.it/); Staur for the Province of Teramo (http://www.staur.it/orari_home.asp); Busitalia for the Provinces of Perugia and Terni (http://www.fsbusitalia.it/fsb/L'offerta/Linee-regionali/Umbria); ASM and Cotral for Rieti town and Province (http://www.asmrieti.it/index.php/trasporto-urbano/linee-e-percorsi and http://servizi.cotralspa.it/Orari). All websites accessed on 25/07/2017.

General node place analysis

In consideration of the huge number of transport nodes involved, each station has been associated to a number, in order to facilitate reading of the diagrams: the following table contains the names of stations and the relative number.

N.	Station	N.	Station	N.	Station
1	Albacina	13	Corridonia - Mogliano	25	Rieti
2	Antrodoco-Borgo Velino	14	Fabriano	26	Rocca di Corno
3	Antrodoco centro	15	Gagliole	27	Rocca di Fondi
4	Ascoli Piceno	16	Macerata	28	San Claudio
5	Baiano di Spoleto	17	Macerata Fontescodella	29	San Filippo
6	Canetra	18	Maltignano	30	San Severino Marche
7	Castel Sant'Angelo	19	Marino del Tronto-Fol.	31	Sorgenti del Peschiera
8	Castellalto-Canzano	20	Matelica	32	Spoleto
9	Castelraimondo-Camerino	21	Nepezzano-Piano d'Accio	33	Teramo
10	Cerreto d'Esi	22	Offida - Castel di Lama	34	Tolentino
11	CIttaducale	23	Poggio Fidoni	35	Urbisaglia-Sforzacosta
12	Colli del Tronto	24	Pollenza	-	-

Table 67. Numbers and corresponding stations. Source: author's elaboration.

Figure 66 contains the general node place analysis of the 35 transport nodes. As can be observed, several stations show a strong unbalance towards the node index, being placed very close to the y axis, with some of them characterised by very low levels of both indexes (e.g. 15-Gagliole, 23-Poggio Fidoni, 28-San Claudio, 31-Sorgenti del Peschiera)[116]. Few nodes have good or very good levels of accessibility, while place indexes are not so high (14-Fabriano, 32-Spoleto)[117], they correspond to main stations placed along the most important lines and serving medium towns. Some nodes have quite balanced values of both indexes, being close to the bisector line (4-Ascoli Piceno, 25-Rieti).

[116] In fact, this group corresponds to very small stations, with just few trains per day.

[117] Maybe is not by chance that the stations with higher node values are the ones placed along the railway Rome-Ancona, the main railway of the study area and the only one with intercity and fast trains.

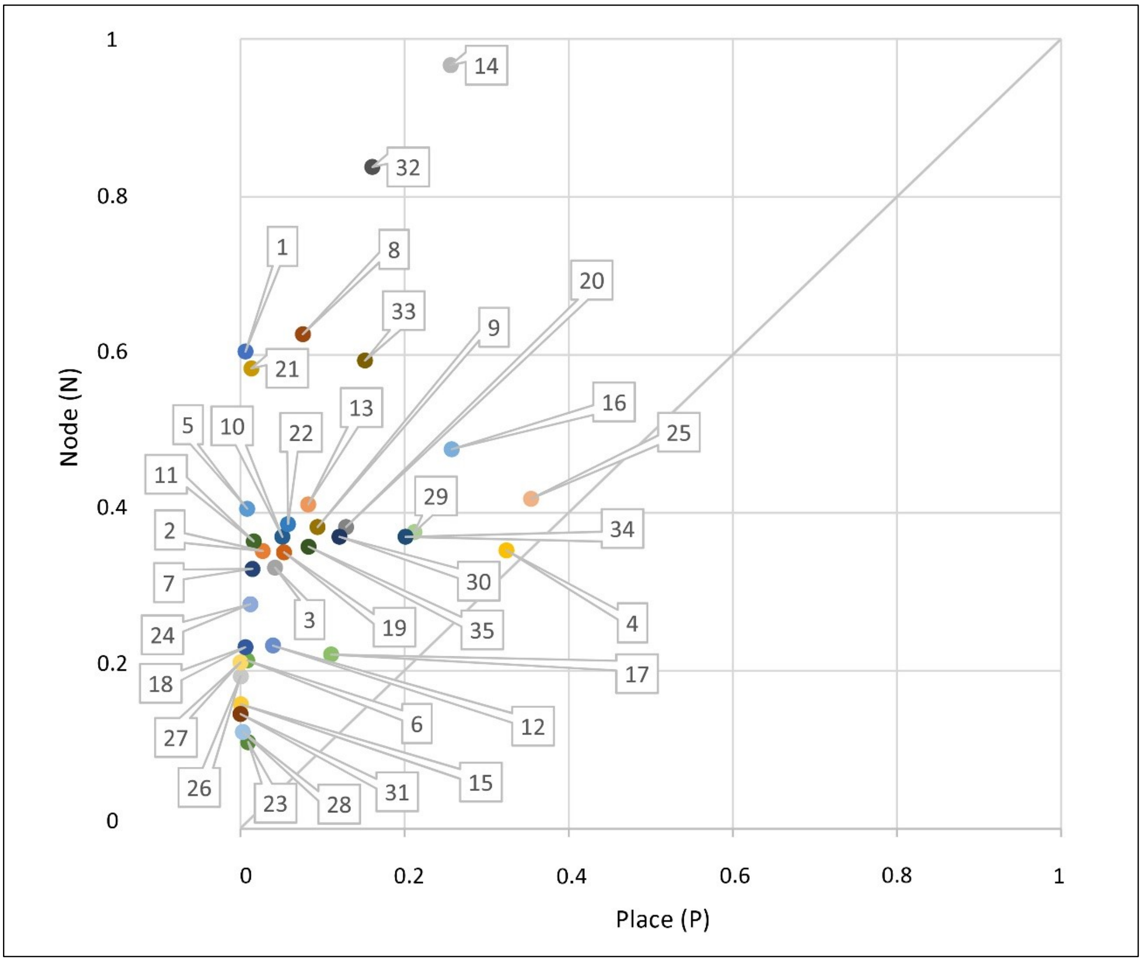


Figure 66. General node place analysis. Source: author's elaboration.

The first step of the analysis underlines how the analysed transport nodes have a low place index, probably influenced by the low urban density of the studied area and the scarce accessibility of railway nodes. On the other hand, railway accessibility shows remarkable differences, even though the majority of nodes are characterised by a low node index, below 0.4.

Detailed node place analysis

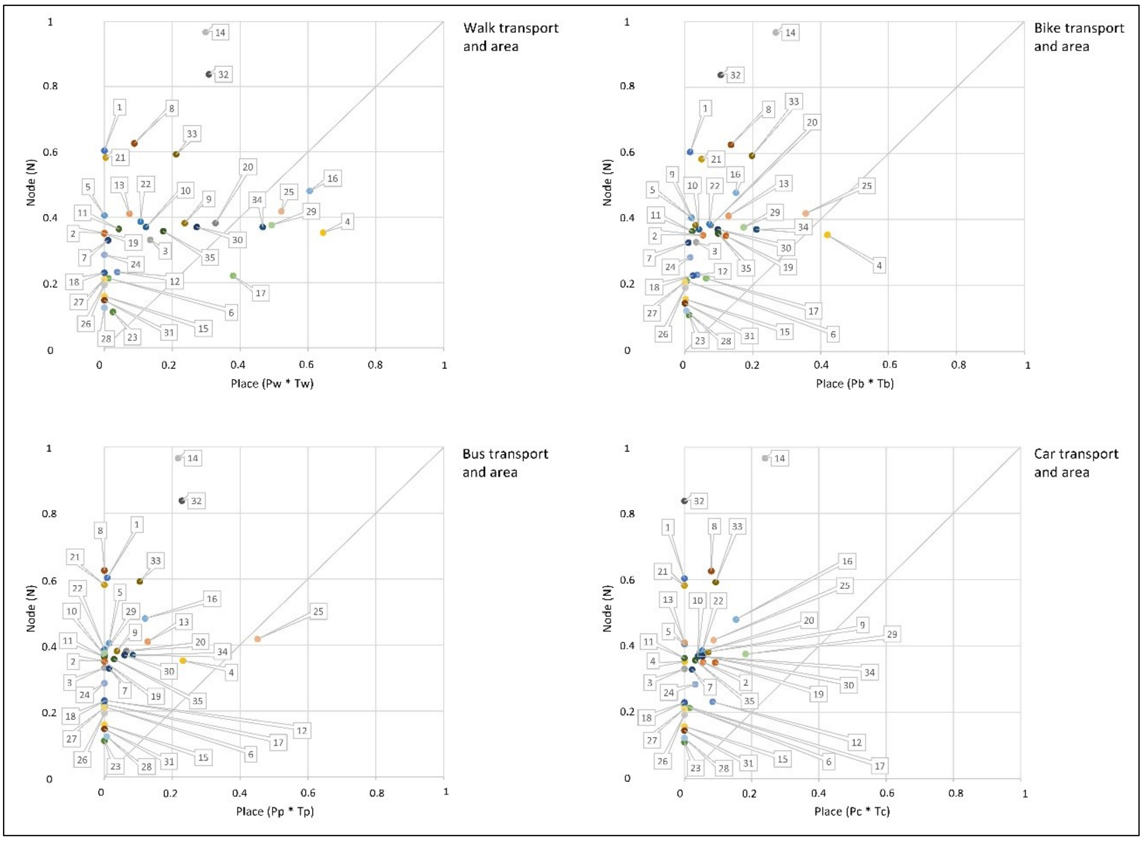


Figure 67. Detailed node place analysis. Source: author's elaboration.

The detailed node place analysis highlights the differences emerging when we consider different access modes to railway stations. In the case of walk transport and area, some points are placed in the right sector of the diagram (4, 16, 17, 25, 29, 34), suggesting the existence of 'unbalanced nodes', in a general framework of remarkable differences in terms of place index. In the case of bike and bus transport and areas, these differences greatly reduce: in both cases, only two stations (4 and 25) are placed close to the bisector line, probably influenced by the good level of accessibility by bike of Ascoli Piceno station[118] and by bus of Rieti station[119].

The diagram referred to car transport and area show how all stations have very low place index, influenced by poor accessibility but also by low urban density.

[118] Ascoli Piceno is one of the few cases in which proper bike lanes can be found.
[119] Rieti station is equipped with a bus terminal for intercity and local buses.

Radar diagrams

The great quantity of transport nodes analysed suggests focusing the third step of the analysis – i.e. radar diagrams – only on few nodes, selecting the most interesting of them on the basis of the results of the general and detailed node place analyses. Figure 68 reports the distinction of nodes into three 'families' of Highly unbalanced nodes, Unbalanced nodes, Balanced nodes (see figure 72).

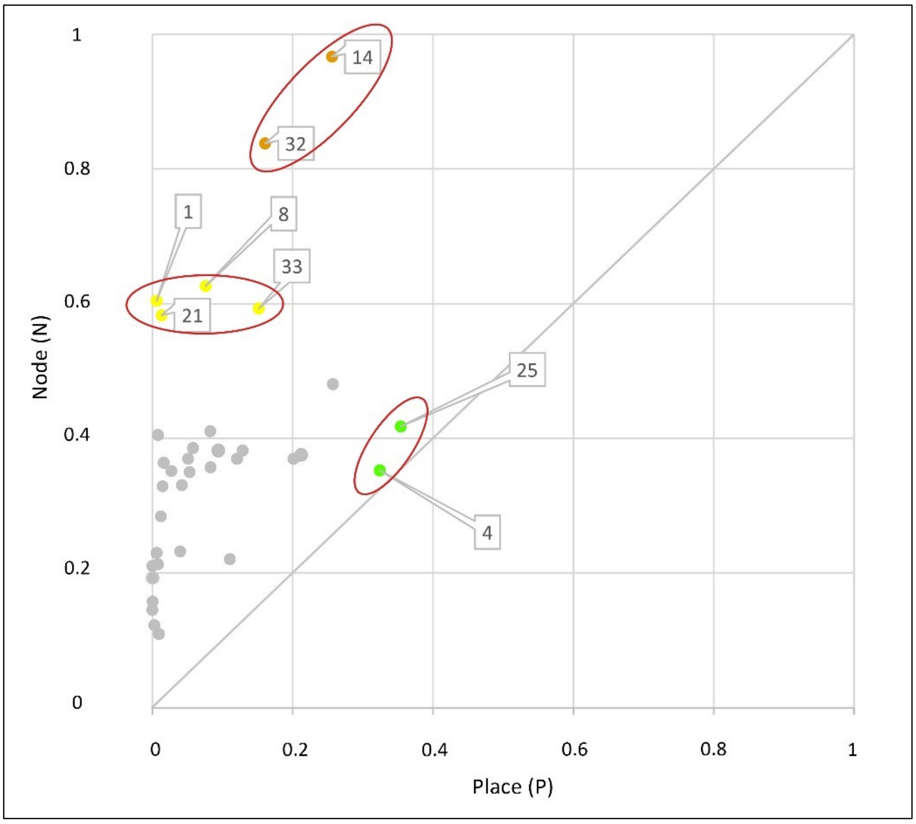


Figure 68. 'Families' of nodes in the xy diagram. Source: author's elaboration.

Therefore, eight nodes have been selected: Fabriano (14), Spoleto (32), Albacina (1), Castellalto-Canzano (8), Nepezzano-Piano d'Accio (21), Teramo (33), Ascoli Piceno (4) and Rieti (25).

Stations 14 – Fabriano – and 32 – Spoleto – are characterised by high node index, not balanced by place index. In fact, as can be observed in the following figure, both Fabriano and Spoleto show medium values of place indicators and feeder transport indicators, influenced by the location of stations, close to urban centres and characterised by a good accessibility with almost every feeder mode. However, as the analysis suggests, the potential increase of urban density should be accompanied by the improvement of accessibility by feeder transport.

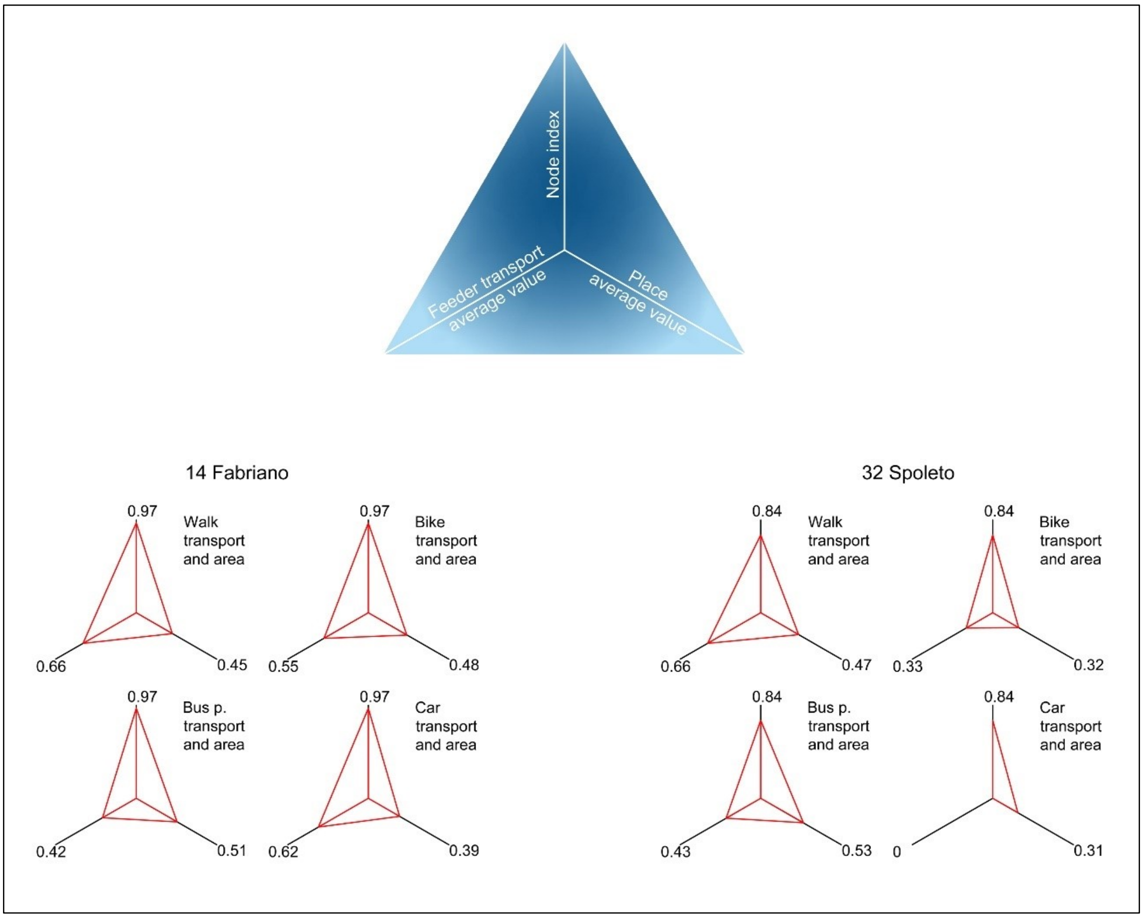


Figure 69. Radar diagrams referred to Fabriano and Spoleto. Source: author's elaboration

Nodes 1, 8, 21 and 33 – respectively Albacina, Castellalto-Canzano, Nepezzano-Piano d'Accio and Teramo – show a good node index and a very low place value; radar diagrams in figure 70 help to explain the reasons behind this unbalance. The station of Albacina represents a quite peculiar situation: since it is placed at the intersection of two railways – respectively leading to Ancona and Civitanova Marche – it has a good service level by train but, at the same time, it is located in a rural area almost without inhabitants and activities. The remaining three stations are located along the line Teramo – Giulianova, a short railway linking the provincial administrative centre of Teramo with the Adriatic coast. In the case of the station of Teramo the unbalance seems to be caused by an insufficient accessibility of the station by feeder modes, especially by bike and bus. Conversely, the stations of Castellalto-Canzano and Nepezzano-Piano d'Accio[120] show a more differentiated situation, in which unbalances are caused by insufficient accessibility – as shown by radar diagrams about bus accessibility – or by low urban density – as in the case of walk areas.

[120] The station of Nepezzano-Piano d'Accio highlights a peculiar situation: in fact, its immediate surroundings have been developed in the last years, mainly with education and commercial facilities. In 2011 – when the National Census has been carried out – these facilities did not exist, not being captured by the Census itself. The station itself has been opened in 2016 (https://it.wikipedia.org/wiki/Stazione_di_Nepezzano-Piano_d%27Accio , retrieved on 27/08/2017).

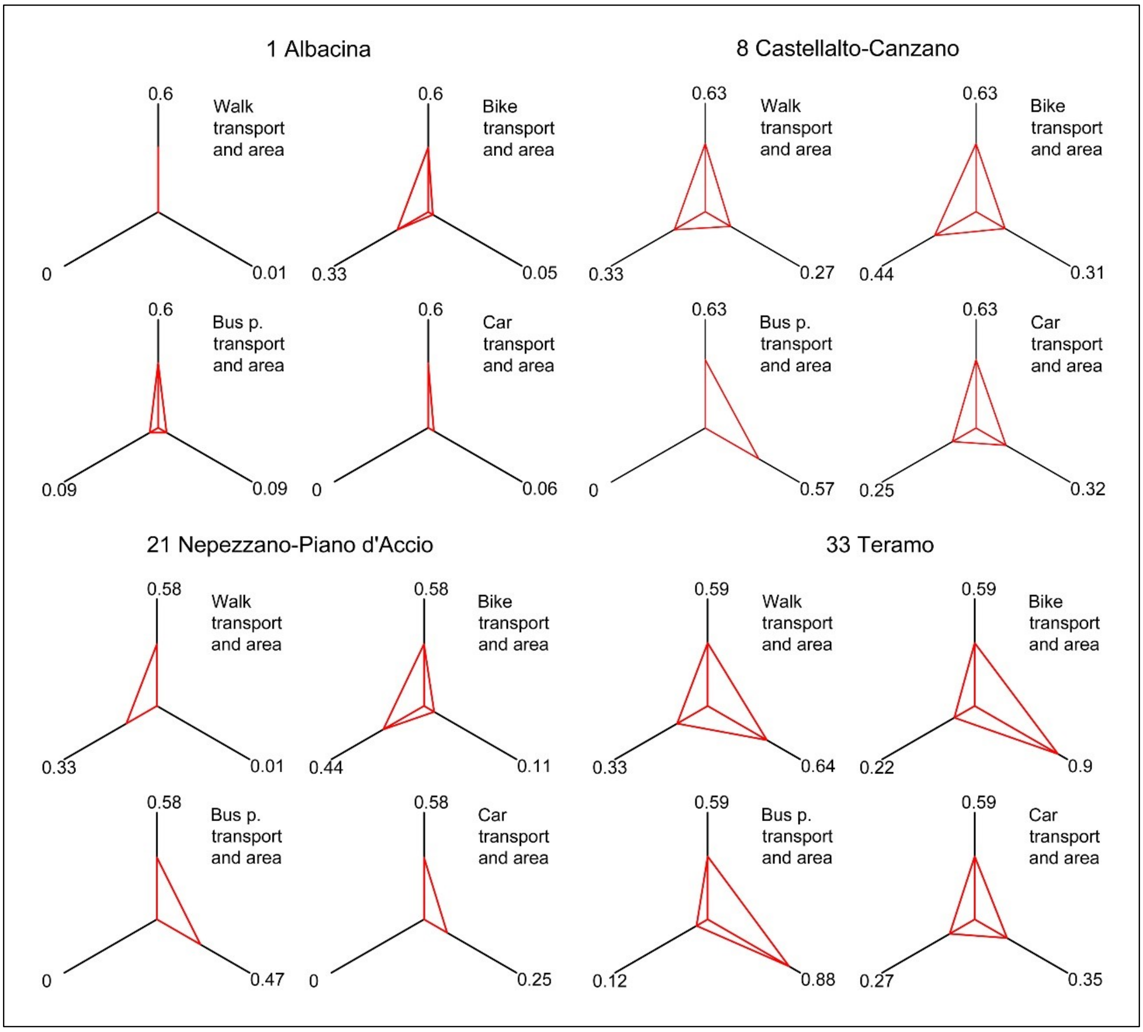


Figure 70. Radar diagrams referred to Albacina, Castellalto-Canzano, Nepezzano-Piano d'Accio and Teramo. Source: author's elaboration.

Nodes 4 – Ascoli Piceno – and 25 – Rieti – are characterised by a good balance between node and place indexes, thus representing examples of good integration between transport and land use. As highlighted by radar diagrams in figure 71, these two stations show a good or very good accessibility by feeder modes, combined with medium or high values of place indicators, corresponding to medium or high urban density. This is probably due to the location of stations, close to town centres, and to a high-quality walking and cycling environment. Moreover, the towns of Ascoli Piceno and Rieti have their main bus terminals in correspondence with train stations, in so easing bus-train interchange.

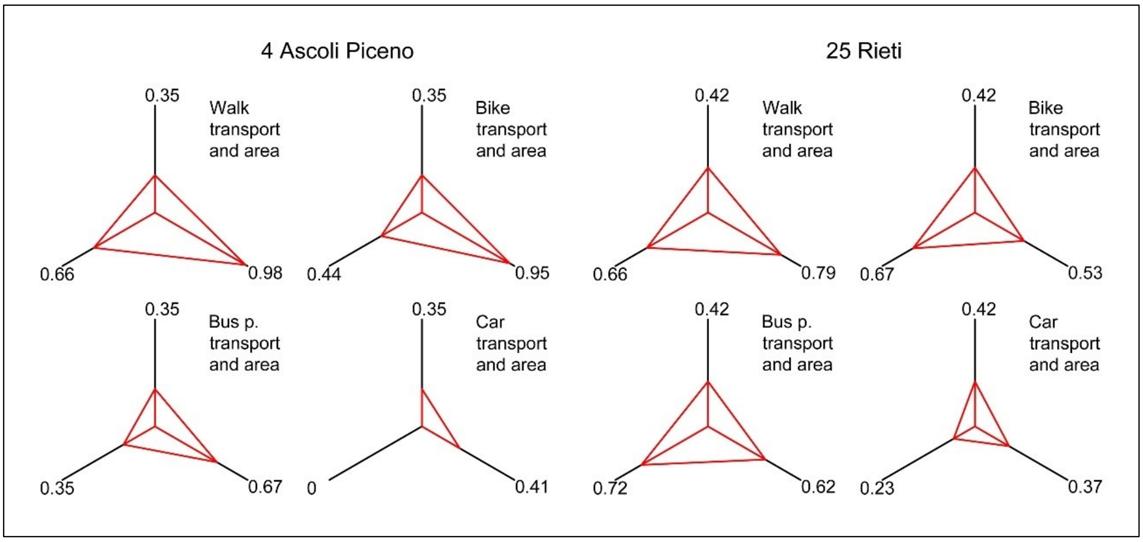


Figure 71. Radar diagrams referred to Ascoli Piceno and Rieti. Source: author's elaboration.

Even though the objective of this study is not to assign a precise category to each transport node, a rough distinction can be made for the stations analysed with the radar diagrams methodology. In this way, it is possible to sketch some 'stations families' based on the position of points representing stations on the XY diagram[121], as done by Bertolini in his node place diagram (2005). In conclusion, the stations of Fabriano and Spoleto can be defined as 'Highly unbalanced nodes', the stations of Albacina, Castellalto-Canzano, Nepezzano-Piano d'Accio and Teramo as 'Unbalanced nodes', while Ascoli Piceno and Rieti are in a situation of 'Balance' (see xy diagram in figure 68 and map in figure 72).

[121] However, it is important to note that in this case the classification is not based on statistical methods.

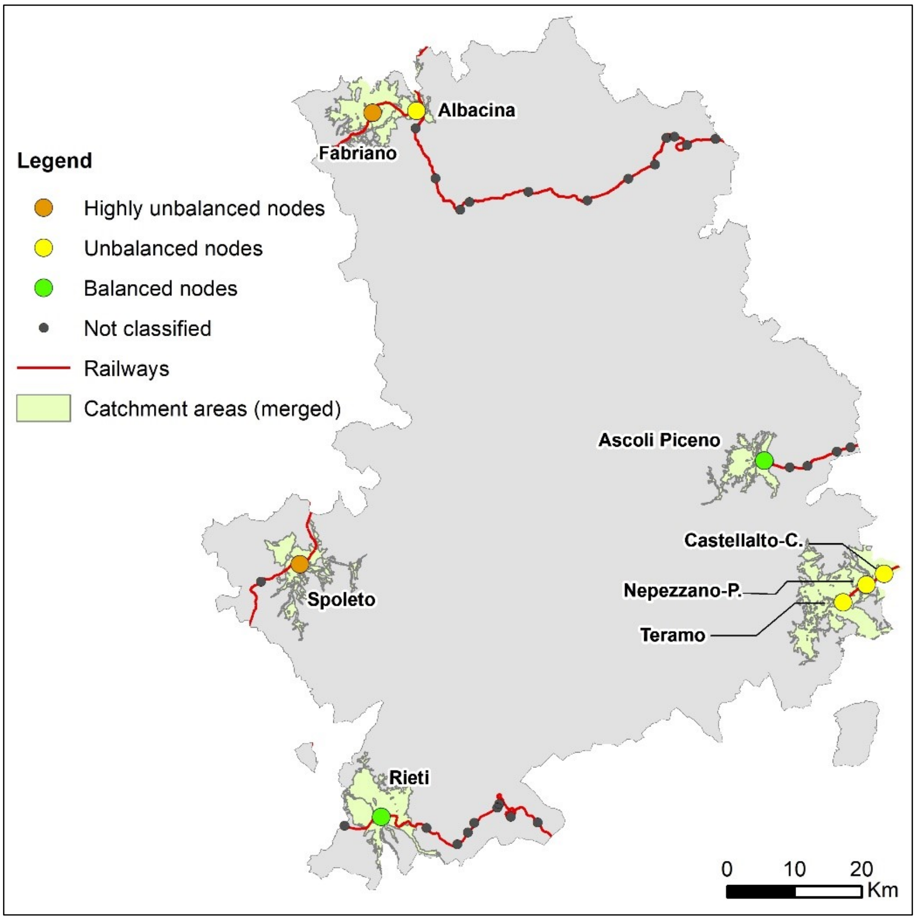


Figure 72. Station families. Source: author's elaboration.

The catchment areas linked to 'Highly unbalanced nodes' and 'Unbalanced nodes' (figure 72) can be considered the ones in which prioritize urban development, in the light of actual accessibility level. The 'Balanced nodes' represent good examples of integration; a slight increase of train service would create the possibility for moderate increases of urban density. In general, the remaining nodes – not classified – have very low node and place indexes, thus, in order to host urban development, they would need substantial improvement of accessibility by train.

It is important to note that data about residential and job density are referred to 2011 – the last update of national census – and could be not very accurate because of their oldness; moreover, the earthquake could have slightly changed the real pattern of residents and jobs – some people and activities could have been temporarily transferred from their original place to provisional locations. However, since the studied areas are located far from the epicentre[122], with only minor disruptions and damages, we can expect that the effects of the earthquake on the distribution of population and jobs is limited. The analysed railway and road infrastructures have suffered only minor damages

[122] Actually, seismologists have recognised four 'main' earthquakes, with their epicentres located in the municipalities of Accumoli (24/08/2016), Castelsantangelo sul Nera (26/10/2016), Norcia (30/10/2016) and Capitignano (18/01/2017). All these municipalities are placed in the inner zone of the study area, so they suffered the worst consequences in terms of victims and damages.

from the earthquake, and they are currently in use; train and bus timetables used to define accessibility refer to 2017.

In comparison to the study cases of North Holland and Campania, this study case is characterised by the higher number of transport nodes, and by the fact that they belong to different railway corridors located within different Regions and Provinces. The aspect of administrative subdivision is relevant since, according to Italian legislation, local railway transport is managed by Regions, and bus transport is managed by Provinces. Therefore, great differences can be found between areas with a good public transport network and areas with scarce connections. Moreover, the availability of data about bus lines greatly varies among the different transport companies, with the impossibility to know the exact itinerary of all bus lines. For this reason, only a 'theoretical' bus catchment area was considered, instead of the 'real' one used for the study cases of North Holland and Campania.

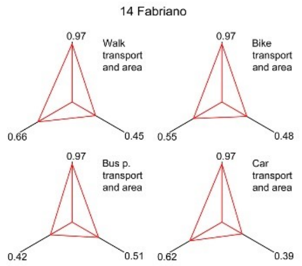
The objective of this case study is to highlight those transport nodes and catchment areas where an increase of population and workplaces is possible, in the light of the actual level of accessibility; this approach can help defining rebuilding strategies, which consider public transport accessibility as a criterion.

In conclusion, the main topic emerging from this study case is the lack of accessibility that characterises the wide central area around the towns of Camerino, Norcia, Amatrice, etc., not reached by railways and with scarce public transport connections. This reflection entails two possible paths that can be followed by the rebuilding strategy: the first one corresponds to a transfer of population and activities towards the areas with better accessibility. The second one would require the realisation of a public transport network able to increase accessibility in the central area. The first option entails the risk of separating and disintegrating local communities, forcing households to move far from their place of origin. On the other side, it is not easy to set up an efficient and effective public transport service in areas with very low demand.

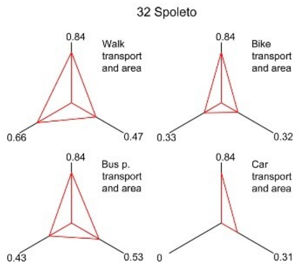
The elaboration of a rebuilding strategy for central Italy can be the opportunity to increase sustainable accessibility through the integration of planning and transport choices; though Italy is periodically hit by earthquakes, a common rebuilding approach cannot be recognised, but each reconstruction follows different approaches depending on the areas involved, political priorities, quantity of damages suffered, etc. As example, the rebuilding strategy elaborated for Campania Region after the earthquake of 1980, caused the relocation of people within the former Province of Naples – today Naples Metropolitan City – in order to solve the problem of housing insufficiency in the city of Naples, and the industrialisation of the Province of Avellino, affected by scarcity of job opportunities (Moccia, 2012a). These strategies, even if resulted in contrasting outcomes, are an example of the possible integration between the objective of reconstruction and improvement of quality of life. In addition, as noted by Sargolini (2014), the topic of accessibility in mountain areas can be governed by the concept of 'self-sustainability of accessibility system', in order to create a co-evolutionary process between inhabitants and territories, able to consider ecological and landscape values.

Actual situation and suggested planning strategies

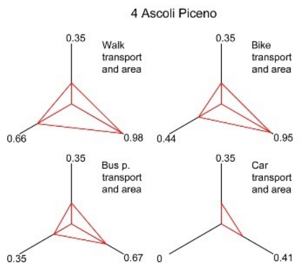
As last paragraph of this chapter, the usual notes to radar diagrams are reported, referred solely to the eight stations analysed in detail.



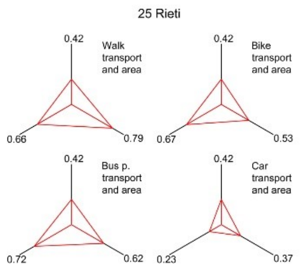
Actual situation:
Fabriano station has a very good quality of train transport, showing good potential for urban density increases in all catchment areas.
Suggested planning strategies:
Considering the actual accessibility by main transport, Fabriano has good potentiality in terms of urban development; nevertheless, the intensification of urban density would require an upgrade of all feeder transports.



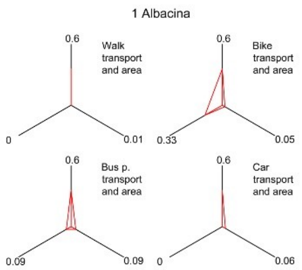
Actual situation:
Like Fabriano, Spoleto is characterised by good accessibility by train, low land use intensity and low quality of feeder transport.
Suggested planning strategies:
Catchment areas linked to Spoleto station can host more residents and activities. The possible increase of urban density would require an upgrade of all feeder transport. Car-based transport needs to be improved, walk environment has good quality, while bike and public transport have to be slightly enhanced.



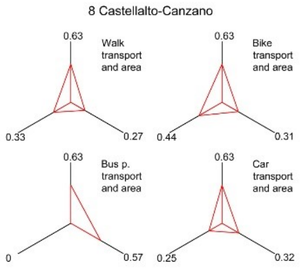
Actual situation:
This station serves the town of Ascoli Piceno, characterised by good urban density, especially in walk and bike catchment areas; accessibility by main and feeder transport is generally poor, with a negative peak in the case of car-based transport.
Suggested planning strategies:
The quality of main and feeder transport should be increased to match the degree of urban density in walk and bike catchment areas. Then, small intensification of land use would be possible within public transport and car-based catchment areas.



Actual situation:
Rieti station is placed close to town centre, in an area with good quality of walking and bike environment, and it is directly connected to the main bus terminal, as witnessed by radar diagrams.
Suggested planning strategies:
In this case, an improvement of main transport is necessary, while catchment areas show some opportunities for urban development, especially within bike area. Car-based catchment area also shows good opportunities for urban development, but an improvement of main and feeder transport is needed.



Actual situation:
Albacina station is characterised by an extreme polarisation on main transport, while values of urban density and accessibility of feeder transports are close to 0.
Suggested planning strategies:
In this case, there is a great potential for urban development, sustained by the necessary improvement of feeder transport. However, it is important to remark that this station is located in a hilly territory whose topography can limit urban development.

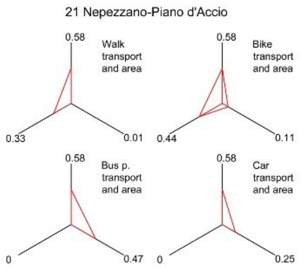


Actual situation:

The station of Castellalto-Canzano shows good accessibility by train and medium values of urban density and accessibility by feeder transport. The station has no connections to bus lines.

Suggested planning strategies:

Increases of urban density are possible in all cases, even though they should be accompanied by a considerable enhancement of feeder transport.

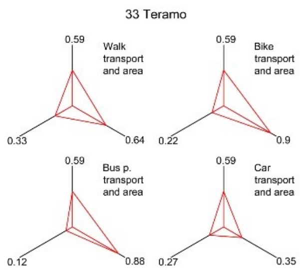


Actual situation:

Walk and bike catchment areas show very low levels of urban density, while an opposite situation can be found within public transport and car catchment areas, where feeder transport quality doesn't match land use intensity. The very low value of place index referred to walk area is influenced by the presence, close to the station, of a shopping centre and a research centre, not captured by census data.

Suggested planning strategies:

Intensification of urban density is possible within walk and bike areas, while public transport and car areas need an upgrade of transport quality.



Actual situation:

Teramo station has medium accessibility by main transport, medium or high levels of urban density and poor accessibility by feeder transport.

Suggested planning strategies:

Actions aimed to increase accessibility by main and feeder transport are needed, especially in the cases of walk, bike and public transport. Urban density can be increased within car transport catchment area, together with an enhancement of car transport.

Appendix

N.	Station	N.	Station	N.	Station
1	Albacina	13	Corridonia - Mogliano	25	Rieti
2	Antrodoco-Borgo Velino	14	Fabriano	26	Rocca di Corno
3	Antrodoco centro	15	Gagliole	27	Rocca di Fondi
4	Ascoli Piceno	16	Macerata	28	San Claudio
5	Baiano di Spoleto	17	Macerata Fontescodella	29	San Filippo
6	Canetra	18	Maltignano	30	San Severino Marche
7	Castel Sant'Angelo	19	Marino del Tronto-Fol.	31	Sorgenti del Peschiera
8	Castellalto-Canzano	20	Matelica	32	Spoleto
9	Castelraimondo-Camerino	21	Nepezzano-Piano d'Accio	33	Teramo
10	Cerreto d'Esi	22	Offida - Castel di Lama	34	Tolentino
11	CIttaducale	23	Poggio Fidoni	35	Urbisaglia-Sforzacosta
12	Colli del Tronto	24	Pollenza	-	-

Node indexes (N)

Node indicators	Value							Score						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Directions	7	3	2	3	8	3	3	0.70	0.30	0.20	0.30	0.80	0.30	0.30
Frequency (workdays)	41	25	25	30	15	10	23	0.63	0.38	0.38	0.46	0.23	0.15	0.35
Frequency (holydays)	13	10	11	8	5	5	9	0.48	0.37	0.41	0.30	0.19	0.19	0.33
N	-							0.6	0.35	0.33	0.35	0.41	0.21	0.33

Node indicators	Value							Score						
	8	9	10	11	12	13	14	8	9	10	11	12	13	14
Directions	8	4	4	3	4	4	9	0.80	0.40	0.40	0.30	0.40	0.40	0.90
Frequency (workdays)	46	22	22	25	12	30	65	0.71	0.34	0.34	0.38	0.18	0.46	1.00
Frequency (holydays)	10	11	10	11	3	10	27	0.37	0.41	0.37	0.41	0.11	0.37	1.00
N	-							0.63	0.38	0.37	0.36	0.23	0.41	0.97

Node indicators	Value							Score						
	15	16	17	18	19	20	21	15	16	17	18	19	20	21
Directions	3	4	4	4	4	4	8	0.30	0.40	0.40	0.40	0.40	0.40	0.80
Frequency (workdays)	4	34	17	14	23	22	40	0.06	0.52	0.26	0.22	0.35	0.34	0.62
Frequency (holydays)	3	14	0	2	8	11	9	0.11	0.52	0.00	0.07	0.30	0.41	0.33
N	-							0.16	0.48	0.22	0.23	0.35	0.38	0.58

Node indicators	Value							Score						
	22	23	24	25	26	27	28	22	23	24	25	26	27	28
Directions	4	2	4	4	2	2	3	0.40	0.20	0.40	0.40	0.20	0.20	0.30
Frequency (workdays)	30	6	15	29	15	16	2	0.46	0.09	0.23	0.45	0.23	0.25	0.03
Frequency (holydays)	8	1	6	11	4	5	1	0.30	0.04	0.22	0.41	0.15	0.19	0.04
N	-							0.39	0.11	0.28	0.42	0.19	0.21	0.12

Node indicators	Value							Score						
	29	30	31	32	33	34	35	29	30	31	32	33	34	35
Directions	4	4	3	10	7	4	4	0.40	0.40	0.30	1.00	0.70	0.40	0.40
Frequency (workdays)	28	22	4	43	46	22	22	0.43	0.34	0.06	0.66	0.71	0.34	0.34
Frequency (holydays)	8	10	2	23	10	10	9	0.30	0.37	0.07	0.85	0.37	0.37	0.33
N	-							0.38	0.37	0.15	0.84	0.59	0.37	0.36

Place average values (Pw, Pb, Pp, Pc)

Place indicators		Value							Score						
		1	2	3	4	5	6	7	1	2	3	4	5	6	7
Walking area	Est. residential density	77	2,011	2,019	6,783	1,027	408	417	0.01	0.30	0.30	1.00	0.15	0.06	0.06
	Est. job density	27	128	457	3,880	87	50	15	0.01	0.03	0.11	0.96	0.02	0.01	0.00
	Pw	-							0.01	0.16	0.20	0.98	0.09	0.04	0.03
Bike area	Est. residential density	230	799	1,114	5,305	737	211	286	0.04	0.15	0.21	1.00	0.14	0.04	0.05
	Est. job density	117	96	212	2,077	86	28	20	0.05	0.04	0.09	0.91	0.04	0.01	0.01
	Pb	-							0.05	0.10	0.15	0.95	0.09	0.03	0.03
Public transport area	Est. residential density	55	251	218	728	178	105	111	0.06	0.29	0.25	0.83	0.20	0.12	0.13
	Est. job density	52	33	40	215	26	13	8	0.12	0.08	0.09	0.51	0.06	0.03	0.02
	Pp	-							0.09	0.18	0.17	0.67	0.13	0.08	0.07
Car-based transport area	Est. residential density	49	1,975	169	682	152	103	205	0.02	1.00	0.09	0.35	0.08	0.05	0.10
	Est. job density	42	140	29	197	41	17	14	0.10	0.34	0.07	0.48	0.10	0.04	0.03
	Pc	-							0.06	0.67	0.08	0.41	0.09	0.05	0.07

Place indicators		Value							Score						
		8	9	10	11	12	13	14	8	9	10	11	12	13	14
Walking area	Est. residential density	1,572	2,213	1,934	1,105	1,227	2,341	2,983	0.23	0.33	0.28	0.16	0.18	0.34	0.44
	Est. job density	1,225	602	352	390	202	427	1,892	0.30	0.15	0.09	0.10	0.05	0.11	0.47
	Pw	-							0.27	0.24	0.19	0.13	0.12	0.22	0.27
Bike area	Est. residential density	1,238	1,004	527	656	804	596	2,526	0.23	0.19	0.10	0.12	0.15	0.11	0.48
	Est. job density	879	224	208	168	158	808	1,126	0.38	0.10	0.09	0.07	0.07	0.35	0.49
	Pb	-							0.31	0.14	0.10	0.10	0.11	0.23	0.31
Public transport area	Est. residential density	439	137	147	291	289	520	419	0.50	0.16	0.17	0.33	0.33	0.59	0.48
	Est. job density	273	31	52	85	56	313	233	0.64	0.07	0.12	0.20	0.13	0.74	0.55
	Pp	-							0.57	0.11	0.15	0.27	0.23	0.66	0.51
Car-based transport area	Est. residential density	323	166	151	286	347	504	420	0.16	0.08	0.08	0.14	0.18	0.26	0.21
	Est. job density	196	55	55	107	66	303	233	0.48	0.13	0.13	0.26	0.16	0.74	0.57
	Pc	-							0.32	0.11	0.10	0.20	0.17	0.50	0.39

Place indicators		Value							Score						
		15	16	17	18	19	20	21	15	16	17	18	19	20	21
Walking area	Est. residential density	293	5,668	5,298	1,000	865	3,023	96	0.04	0.83	0.78	0.15	0.13	0.44	0.01
	Est. job density	136	4,061	1,502	194	447	853	31	0.03	1.00	0.37	0.05	0.11	0.21	0.01
	Pw	-							0.04	0.92	0.57	0.10	0.12	0.33	0.01
Bike area	Est. residential density	103	2,426	3,628	196	1,888	1,105	701	0.02	0.46	0.68	0.04	0.36	0.21	0.13
	Est. job density	51	1,044	1,050	164	861	308	210	0.02	0.46	0.46	0.07	0.38	0.13	0.09
	Pb	-							0.02	0.46	0.57	0.05	0.37	0.17	0.11
Public transport area	Est. residential density	39	604	767	137	732	213	600	0.04	0.69	0.87	0.16	0.83	0.24	0.68
	Est. job density	14	236	225	81	268	68	110	0.03	0.56	0.53	0.19	0.63	0.16	0.26
	Pp								0.04	0.62	0.70	0.17	0.73	0.20	0.47
Car-based transport area	Est. residential density	38	603	688	141	521	208	509	0.02	0.31	0.35	0.07	0.26	0.11	0.26
	Est. job density	13	236	204	83	193	67	98	0.03	0.57	0.50	0.20	0.47	0.16	0.24
	Pc	-							0.03	0.44	0.42	0.14	0.37	0.13	0.25

Place indicators		Value							Score						
		22	23	24	25	26	27	28	22	23	24	25	26	27	28
Walking area	Est. residential density	3,333	941	529	4,801	29	191	292	0.49	0.14	0.08	0.71	0.00	0.03	0.04
	Est. job density	628	61	168	3,553	26	0	19	0.15	0.01	0.04	0.87	0.01	0.00	0.00
	Pw	-							0.32	0.08	0.06	0.79	0.01	0.01	0.02
Bike area	Est. residential density	1,758	345	201	2,844	36	116	108	0.33	0.06	0.04	0.54	0.01	0.02	0.02
	Est. job density	251	23	75	1,217	13	0	14	0.11	0.01	0.03	0.53	0.01	0.00	0.01
	Pb	-							0.22	0.04	0.04	0.53	0.01	0.01	0.01
Public transport area	Est. residential density	470	114	179	629	11	11	50	0.54	0.13	0.20	0.72	0.01	0.01	0.06
	Est. job density	82	7	65	225	4	0	8	0.19	0.02	0.15	0.53	0.01	0.00	0.02
	Pp	-							0.36	0.07	0.18	0.62	0.01	0.01	0.04
Car-based transport area	Est. residential density	455	112	183	558	10	11	50	0.23	0.06	0.09	0.28	0.01	0.01	0.03
	Est. job density	80	7	76	190	3	0	8	0.19	0.02	0.18	0.46	0.01	0.00	0.02
	Pc	-							0.21	0.04	0.14	0.37	0.01	0.00	0.02

Place indicators		Value							Score						
		29	30	31	32	33	34	35	29	30	31	32	33	34	35
Walking area	Est. residential density	5,307	3,661	35	3,134	5,188	6,804	2,040	0.78	0.54	0.01	0.46	0.76	1.00	0.30
	Est. job density	2,892	1,162	16	1,920	2,110	1,679	915	0.71	0.29	0.00	0.47	0.52	0.41	0.23
	Pw	-							0.75	0.41	0.00	0.47	0.64	0.71	0.26
Bike area	Est. residential density	2,518	1,414	21	1,771	4,230	2,601	819	0.47	0.27	0.00	0.33	0.80	0.49	0.15
	Est. job density	1,314	397	9	708	2,285	634	460	0.57	0.17	0.00	0.31	1.00	0.28	0.20
	Pb	-							0.52	0.22	0.00	0.32	0.90	0.38	0.18
Public transport area	Est. residential density	877	194	25	510	862	309	158	1.00	0.22	0.03	0.58	0.98	0.35	0.18
	Est. job density	424	64	5	204	333	114	80	1.00	0.15	0.01	0.48	0.79	0.27	0.19
	Pp	-							1.00	0.19	0.02	0.53	0.88	0.31	0.18
Car-based transport area	Est. residential density	902	142	29	441	510	290	159	0.46	0.07	0.01	0.22	0.26	0.15	0.08
	Est. job density	411	47	6	163	181	103	72	1.00	0.11	0.01	0.40	0.44	0.25	0.18
	Pc	-							0.73	0.09	0.01	0.31	0.35	0.20	0.13

Feeder transport average values – walking (Tw)

Indicators	Value							Score						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Quality of walking environment	-	-	-	-	-	-	-	0.00	0.00	0.66	0.66	0.00	0.33	0.33
Tw	-							0.00	0.00	0.66	0.66	0.00	0.33	0.33

Indicators	Value							Score						
	8	9	10	11	12	13	14	8	9	10	11	12	13	14
Quality of walking environment	-	-	-	-	-	-	-	0.33	1.00	0.66	0.33	0.33	0.33	0.66
Tw	-							0.33	1.00	0.66	0.33	0.33	0.33	0.66

Indicators	Value							Score						
	15	16	17	18	19	20	21	15	16	17	18	19	20	21
Quality of walking environment	-	-	-	-	-	-	-	0.00	0.66	0.66	0.00	0.00	1.00	0.33
Tw	-							0.00	0.66	0.66	0.00	0.00	1.00	0.33

Indicators	Value							Score						
	22	23	24	25	26	27	28	22	23	24	25	26	27	28
Quality of walking environment	-	-	-	-	-	-	-	0.33	0.33	0.00	0.66	0.00	0.00	0.00
Tw	-							0.33	0.33	0.00	0.66	0.00	0.00	0.00

Indicators	Value							Score						
	29	30	31	32	33	34	35	29	30	31	32	33	34	35
Quality of walking environment	-	-	-	-	-	-	-	0.66	0.66	0.00	0.66	0.33	0.66	0.66
Tw	-							0.66	0.66	0.00	0.66	0.33	0.66	0.66

Feeder transport average values – bike (Tb)

Indicators	Value							Score						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Bike lanes	-	-	-	-	-	-	-	0	0	0	0.33	0	0	0
Road size	-	-	-	-	-	-	-	0.66	0.66	0.33	0.33	0.33	0.33	0.66
Road slope	-	-	-	-	-	-	-	0.33	1	0.33	0.66	0.33	0.33	0.33
Tb	-							0.33	0.55	0.22	0.44	0.22	0.22	0.33

Indicators	Value							Score						
	8	9	10	11	12	13	14	8	9	10	11	12	13	14
Bike lanes	-	-	-	-	-	-	-	0	0	0	0	0	0	0
Road size	-	-	-	-	-	-	-	0.66	0.33	0.66	0.33	0.66	0.66	0.66
Road slope	-	-	-	-	-	-	-	0.66	0.33	0.66	0.33	0.33	1	1
Tb	-							0.44	0.22	0.44	0.22	0.33	0.55	0.55

Indicators	Value							Score						
	15	16	17	18	19	20	21	15	16	17	18	19	20	21
Bike lanes	-	-	-	-	-	-	-	0	0	0	0	0	0	0
Road size	-	-	-	-	-	-	-	0	0.66	0.33	0.66	0.33	0.33	0.66
Road slope	-	-	-	-	-	-	-	0.33	0.33	0	0.66	0.66	1	0.66
Tb	-							0.11	0.33	0.11	0.44	0.33	0.44	0.44

Indicators	Value							Score						
	22	23	24	25	26	27	28	22	23	24	25	26	27	28
Bike lanes	-	-	-	-	-	-	-	0	0	0	0	0	0	0
Road size	-	-	-	-	-	-	-	0.66	0.33	0.33	1	0.33	0	0.33
Road slope	-	-	-	-	-	-	-	0.33	0.66	1	1	0.33	0	0.66
Tb	-							0.33	0.33	0.44	0.67	0.22	0	0.33

Indicators	Value							Score						
	29	30	31	32	33	34	35	29	30	31	32	33	34	35
Bike lanes	-	-	-	-	-	-	-	0	0	0	0	0	0.33	0
Road size	-	-	-	-	-	-	-	0.66	0.66	0	0.66	0.33	0.66	0.66
Road slope	-	-	-	-	-	-	-	0.33	0.66	0.33	0.33	0.33	0.66	1
Tb	-							0.33	0.44	0.11	0.33	0.22	0.55	0.55

Feeder transport average values – public transport (Tp)

Indicators	Value							Score						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Feeder transport	Y	N	N	Y	Y	N	Y	-	-	-	-	-	-	-
Feeder lines	1	-	-	7	4	-	1	0.08			0.54	0.31		0.08
Bus stop accessibility	80	-	-	50	100	-	50	0.20			0.50	0.00		0.50
Fare integration	0/2	-	-	0/2	0/2	-	0/2	0	-	-	0	0	-	0
Tp	-							0.09	0	0	0.35	0.10	0	0.19

Indicators	Value							Score						
	8	9	10	11	12	13	14	8	9	10	11	12	13	14
Feeder transport	N	Y	N	N	N	Y	Y	-	-	-	-	-	-	-
Feeder lines	-	6	-	-	-	1	10		0.46				0.08	0.77
Bus stop accessibility	-	50	-	-	-	50	50		0.50				0.50	0.50
Fare integration	-	0/2	-	-	-	0/2	0/2	-	0	-	-	-	0	0
Tp	-							0	0.32	0	0	0	0.19	0.42

Indicators	Value							Score						
	15	16	17	18	19	20	21	15	16	17	18	19	20	21
Feeder transport	N	Y	N	N	N	Y	N	-	-	-	-	-	-	-
Feeder lines	-	1	-	-	-	6	-		0.08				0.46	
Bus stop accessibility	-	50	-	-	-	50	-		0.50				0.50	
Fare integration	-	0/2	-	-	-	0/2	-	-	0	-	-	-	0	-
Tp	-							**0**	**0.19**	**0**	**0**	**0**	**0.32**	**0**

Indicators	Value							Score						
	22	23	24	25	26	27	28	22	23	24	25	26	27	28
Feeder transport	N	N	N	Y	N	N	Y	-	-	-	-	-	-	-
Feeder lines	-	-	-	13	-	-	1				1			0.08
Bus stop accessibility	-	-	-	50	-	-	50				0.50			0.50
Fare integration	-	-	-	2/3	-	-	0/2	-	-	-	0.667	-	-	0
Tp	-							**0**	**0**	**0**	**0.72**	**0**	**0**	**0.19**

Indicators	Value							Score						
	29	30	31	32	33	34	35	29	30	31	32	33	34	35
Feeder transport	N	Y	N	Y	Y	Y	Y	-	-	-	-	-	-	-
Feeder lines	-	6	-	7	2	4	6		0.46		0.54	0.15	0.31	0.46
Bus stop accessibility	-	50	-	50	80	50	100		0.50		0.50	0.20	0.50	0.00
Fare integration	-	0/2	-	n[123]	0/2	0/2	0/2	-	0	-	0.25	0	0	0
Tp	-							**0**	**0.32**	**0**	**0.43**	**0.12**	**0.27**	**0.15**

[123] In this case, the two transport companies involved (Trenitalia and Busitalia) allow integrated train-bus tickets but only on some bus lines. For this reason, the value of 0.5/2 has been used, resulting into the score of 0.25.

Feeder transport indicators – car-based transport

Indicators	Value							Index						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Car parking	0	500	0	0	0	1,000	1,000		0.25				0.5	0.5
Car parking accessibility	-	100	-	-	-	50	50		0.00				0.50	0.50
Taxi service	N	N	N	N	N	N	N		0.00				0.00	0.00
Tc	-								0.08				0.33	0.33

Indicators	Value							Index						
	8	9	10	11	12	13	14	8	9	10	11	12	13	14
Car parking	500	1,500	1,300	0	2,000	0	1,300	0.25	0.75	0.65		1		0.65
Car parking accessibility	50	80	50	-	50		80	0.50	0.20	0.50		0.50		0.20
Taxi service	N	Y	N	N	N	N	Y	0.00	1.00	0.00		0.00		1.00
Tc	-							0.25	0.65	0.38		0.50		0.62

Indicators	Value							Index						
	15	16	17	18	19	20	21	15	16	17	18	19	20	21
Car parking	0	1,100	0	0	500	1,100	0		0.55			0.25	0.55	
Car parking accessibility	-	50	-	-	50	50	-		0.50			0.50	0.50	
Taxi service	N	N	N	N	N	N	N		0.00			0.00	0.00	
Tc	-								0.35			0.25	0.35	

Indicators	Value							Index						
	22	23	24	25	26	27	28	22	23	24	25	26	27	28
Car parking	500	0	400	1,000	0	0	0	0.25		0.2	0.5			
Car parking accessibility	50	-	50	80	-	-	-	0.50		0.50	0.20			
Taxi service	N	N	N	N	N	N	N	0.00		0.00	0.00			
Tc	-							0.25		0.23	0.23			

Indicators	Value							Index						
	29	30	31	32	33	34	35	29	30	31	32	33	34	35
Car parking	500	1,500	0	0	600	900	500	0.25	0.75			0.3	0.45	0.25
Car parking accessibility	50	100	-	-	50	80	50	0.50	0.00			0.50	0.20	0.50
Taxi service	N	Y	N	N	N	N	N	0.00	1.00			0.00	0.00	0.00
Tc	-							0.25	0.58			0.27	0.22	0.25

Conclusions and research prospects

In an age of increasing awareness of the impacts of human activities on the natural environment, interventions on transport sector can play a key role in reducing those effects. According to the principles of sustainability applied to mobility of people, transport modes with lower environmental impact should be privileged. This means that public transport – train, bus, tram, shared cars, etc. –, individual non-motorised modes – walking and bike – should have the priority on individual motorised modes, while urban and regional development strategies should consider the degree of 'sustainable' accessibility as key elements in evaluating the feasibility of urban development.

The management of transport is inevitably intertwined with the geographical location and the characteristics of places where people live, work, spend their free time, etc. Actually, it is widely accepted the concept that land use and transport have deep connections, with these two systems mutually influencing each other (Wegener & Furst, 1999). Therefore, many authors claim the advantages of co-ordinating these two systems, and the potential benefits in terms of 'sustainability'.

Based upon these findings, studies about land use and transport integration have flourished in the last decades, sometimes grouped under the label of TOD – Transit Oriented Development – as defined by Calthorpe (1993). In the wide landscape of studies and discourses about transport integration, as shown in the chapter about literature review, many different approaches can be recognised. Probably influenced by some pioneering studies – like the well-known research made by Newman & Kenworthy (1996) – most authors focus their attention on the key factors of 'high urban density' and 'high capacity transport'. This approach 'naturally' leads to point the attention on core districts of metropolitan areas, main transport nodes and infrastructures, where intense demographic and economic development can be expected.

Several developing countries are now facing the challenges linked to an impetuous car-oriented urban growth; therefore, they could apply the 'standard' TOD principles. On the other hand, some European and North-American territories are experiencing phenomena of 'shrinking' population and economies, where intense urban development cannot occur and the realisation of high-capacity public transport infrastructures is hampered by their economic and environmental cost. Moreover, the classic TOD scenario, with urban development concentrated in very limited areas around transport nodes, could not correspond to local population's desires or could conflict with the instances of preservation of historical heritage or natural sites. At the same time, as underlined in the first chapter, mobility is becoming one of the distinctive characteristics of our societies in their entirety, not only referred to people living within urban and metropolitan areas.

All these factors considered, what is missing in the actual literature about land use and transport integration are specific studies referred to the achievement of land use and transport integration when one – or both – of the two abovementioned 'key factors' is missing. One of the objectives of this research is, thus, to start place-specific discourses about land use and transport integration, in particular to implement it in geographic contexts with medium or low urban density.

In order to achieve this goal, the methodology of transport nodes' evaluation was used, that is recognised by the academic literature (Kamruzzaman et al., 2014) as one of the most promising, even though underexplored, branches of land use and transport integration.

A methodology able to consider the elements of access to transport and 'network' qualities of public transport has been elaborated, while the application to three study cases, referred to similar geographical contexts, gave the opportunity to test it, highlighting some limitations and sketching future research prospects.

In conclusion, the rationale behind this research stems from the identification of an existing gap – both in the academic literature and practice – in land use and public transport integration field, and from the awareness that the quality of public transport network can play a crucial role in increasing the attractiveness of public transport itself, as concretely proved by real experiences (Mees, 2010; Walker, 2012). The quality of public transport, its ability to act like a network is believed to be a 'key factor' – actually underexplored – that has to be explicitly taken into account by the assessment of transport nodes.

Outcomes

Based on the evaluation of transport nodes known as 'node place model' (Bertolini, 1999), a tool able to assess 'node' and 'place' quality has been elaborated. In Bertolini's model, 'node' corresponds to quality of main transport service, while 'place' describes population and activities density, presence of services and functional mix. This research, innovated the 'place' factor, explicitly considering different access modes to transport node, recognizing that good or poor quality of access to transport can represent a decisive element in 'multimodal transport chains'. More in general, the goal is to build a context-based approach, as highlighted by Qvistrom (2015), adapting the concept of accessibility – and policies aimed to improve it – to local peculiarities.

The outcomes of the implementation, summarised by node place diagrams, radar diagrams and maps, should be considered 'suggestions' about integrated land use and transport management strategies, rather than strict rules. These suggestions are directed to urban and regional planners, public decision makers, transport authorities, which can acquire knowledge about the following factors.

- Areas where increases of density are more or less convenient.
- Transport nodes where transport offer is insufficient.
- Transport nodes where access to transport is insufficient.
- Transport nodes/areas where increases of density are possible only if accompanied by improvements of transport offer and/or access to transport.

The involved actors can discuss the results, with the positive 'side effect' of encouraging the dialogue between them and overcoming one of the obstacles to land use and transport integration.

Used indicators

The following table gives an overview of indicators in each of the three study cases. The table allows a quick comparison between the study cases: the one referred to North Holland is the most accurate from the point of view of indicators, since it uses the most complete statistical and travel database; the analysis of North Holland and Campania study cases has been helped by field trips.

	Indicators	Description	North Holland	Campania	Central Italy
Node indicators	Directions	Number of directions served	x	x	x
	Frequency (workdays)	Arr./dep. per day on workdays	x	x	x
	Frequency (holydays)	Arr./dep. per day on holidays	x	x	x
	Span (workdays)	Service time on workdays	x		
	Span (holydays)	Service time on holidays	x		
	NS stand. / Ticket service	Ticket machine	x	x	
Place indicators	Residential density	-	x	x	x
	Esteemed job density	-	x	x	x
	N. of students	-		x	
Feeder tr. indicators: walking	Sidewalks	Quality of sidewalks	x	x	x
	Pedestrian streets	Quality of pedestrian streets	x		
Feeder tr. indicators: bike	NS standards	Unguarded cycle storage	x		
		Self Service bike storage	x		
		Bike rental	x		
		P. t. bike (ov-fiets)	x		
		Bike repair shop	x		
		Bike locker	x		
	Bike lanes	-	x	x	x
	Exp. vehicular traffic int.	-		x	
	Road size	-		x	x
	Road slope	-		x	x
Feeder tr. indicators: public transport	Feeder transport	Presence of at least one line	x	x	x
	Feeder lines	Number of lines	x	x	x
	Frequency (workdays)	Departures per day on workdays	x	x	x
	Frequency (holydays)	Departures per day on holidays	x	x	
	Span (workdays)	Service time on workdays	x		
	Span (holydays)	Service time on holidays	x		
	Fare integration	Degree of fare integration	x	x	x
	NS standards / Passenger facilities	Waiting room	x	x	
		Restaurants/kiosks	x	x	
Feeder tr. indicators: car-based transport	NS standards	Park and ride	x		
		NS zone taxi	x		
		Taxi service/Taxi rank	x		x
	Car parking	Car parking area	x	x	x
	Car parking accessibility	Dist. station – nearest car parking		x	x

Table 68. Indicators: comparison between study cases. Source: author's elaboration.

The presence of several education facilities in Campania study case suggested considering the number of students as additional indicator, since census data do not consider this parameter.

In some cases, the choice on the use of specific indicators has been influenced by the relevance of them in the specific context: e.g., the study cases refereed to Italy are characterised by very poor dotation of bike facilities, so it did not seem correct to use the same set of indicators referred to North Holland. A remark follows about the use of indicators: some authors underline that not all the qualities of transport have the same relevance (Cascetta & Cartenì, 2014). However, this research, acknowledging the impossibility to define the relative relevance for each indicator, gives to all of them – i.e. all qualities of transport – the same relevance.

The adopted methodology – evaluation of transport nodes – entails some imprecisions related to the nature and availability of data and, more noticeably, it naturally tends to consider one – or more – transport nodes as 'benchmark', in so establishing the 'maximum' values of node and place indexes[124]. Actually, it is not possible to assess an 'ideal' or 'maximum' value of indexes and indicators, therefore the results of 'node place' classification have to be considered as only a partial description of the complexity of urban and transport systems (Lee, 1973; Te Brömmelstroet, Pelzer, & Geertman, 2014). Thus, the aim of this research is not to establish the 'right' balance of node and place, but to suggest virtuous pattern of integration.

It is important the phase of selection of transport nodes, in fact, the choice of nodes radically different – from the point of view of transport quality etc. – could 'hide' most of the differences. This criticism is partially limited by the choice, as study cases, of territories with homogeneous characteristics, as done in the illustrated study cases where the Eurostat's Degree of urbanisation was used.

Finally, this methodology can be further developed and adjusted in order to pursue different and more ambitious objectives. One of the possible developments is the comparison between Euclidean and isochrone-based catchment areas, to highlight opportunities of extension of the isochrone-based catchment area. Another potentiality of the explained methodology is, probably, the evaluation of land use plans in the light of actual – or future – accessibility by public and sustainable transport.

The comparison between the illustrated study cases can highlight the effectiveness of transport system in different geographical contexts, underlining their strengths and weaknesses. North Holland seems to benefit from a better integration of different transport modes and from its geographical and urban pattern, with stations usually placed at the core of urban areas, with good walking connections, a thin bike network, bus terminals usually placed near railway stations, presence of bike and car parking. The classification of transport nodes in 'families' indicates which catchment areas are the most suitable for urban development, and which need improvement of transport service. Campania study case shows a medium or low quality of – main and feeder – transport, and remarkable potential for urban development: in this case, there is an undeniable need for transport improvement, and some opportunities for urban development; however, the main goal, suggested by the analysis, is to provide better sustainable transportation for existing urban settlements. Central Italy study case shows different characteristics, since it involves a territory with

[124] E.g. if the maximum of 'place' index corresponds to 3,000 inhabitants/km^2, this will become the value against which all other values of density will be evaluated. However, we cannot exclude a priori that higher values are possible.

lower population density. In this case, the 'extended' node place analysis can be used not only to assess existing transport nodes, but also to evaluate potential demand of new transport infrastructures or lines, evaluating their capacity to catch transport demand through 'multimodal transport chains'.

Thesis evaluation

This paragraph summarises the comments received from the referees, acknowledging the limitations and deficiencies of this research.

This research aims to investigate the relationship and mutual influence of 'sustainable' mobility and land use patterns. To do this, a methodology able to capture characteristics and quality of transport and land use was elaborated, with the necessary reductions of reality's complexity, influenced by the availability of data. In the analysed study cases, 'place' characteristics originate from residential density and workplaces density, with the only partial exception of Campania study case, where is added, as third indicator, the number of high school and university students.

As highlighted by the reviewers, the absence of a systematic analysis of the activities not detected by census data can represent a criticism. This research uses census data in order to quantify 'place' indicators; so facilities linked to education, healthcare, culture, sport, leisure, tourism can be overlooked, since census data usually refer to inhabitants and workplaces only. However, the abovementioned activities can entail a remarkable impact on mobility demand, and not considering them could affect the result of the analysis.

Figures about different urban functions can be integrated in the methodology, as partially shown by the Campania study case, where a 'place' indicator referred to the number of students has been used. Indeed, the model used by this research is susceptible of improvement using indicators referred to various activities, as long as proper data are available. Therefore, it is possible to build a more complex set of 'place' indicators, but the availability of data still plays a crucial role. Both CBS and ISTAT databases – respectively used for the Dutch and the Italian study cases – contain data about residents and workplaces, at different scales of detail. Therefore, the presence of a high school with hundreds of students or a museum with thousands of visitors per day is not detected by census data and, consequently, by the described methodology. To remedy to this deficiency, indicators focused on specific topics can be added, based on evaluations made by the researcher. As example, in the already mentioned study case of Campania, the relevance for that area of the accessibility of education facilities[125] suggested to consider them, beside residential and job density. This 'flexible' approach can be replicated if specific accessibility issues – not considered by census data – emerge, and if a consistent database is available.

A possible variation of this research's methodology would be to consider commuting flows instead of residential and job density, in order to evaluate the 'attractiveness' of each catchment area. This approach can be extended to 'node' indicators, currently based on transport offer (frequency, service time, etc.), thus considering the number of passengers using a station. However,

[125] The relevance is witnessed by the comparison of figures about University students (about 34,000) and total inhabitants of the study area (about 65,000 in the five municipalities considered according to the 2011 Census).

it must be remarked that these typology of data are often hard to obtain because authorities and transport companies do not collect them, or they are not willing to give information to the public.

In conclusion, these aspects should be seen as research's prospects rather than limitations, since their refinement and implementation can give the spur to other researches, in the hope of giving a fertile contribute to the scientific debate and a useful tool to decision-makers.

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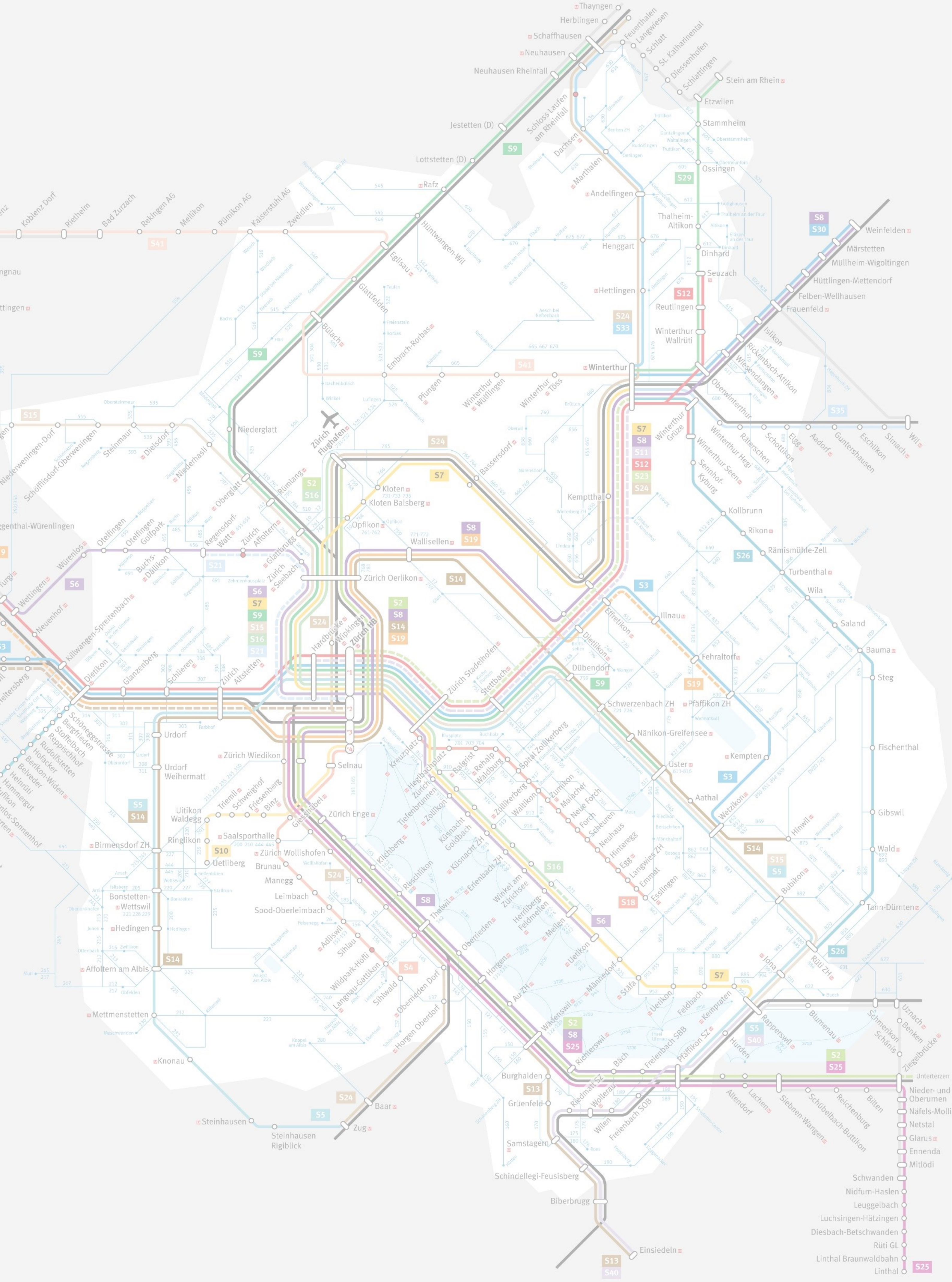

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Etzwilen
Stammheim
Jestetten (D)
Schloss Laufen am Rheinfall
Dachsen
Lottstetten (D)
Marthalen
Ossingen
Rafz
Andelfingen
Thalheim-Altikon
Dinhard
Henggart
Hüntwangen-Wil
Eglisau
Seuzach
Hettlingen
Reutlingen
Winterthur Wallrüti
Glattfelden
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Weinfelden
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Winterthur Seen
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Gibswil
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Niederweningen-Dorf
Schöfflisdorf-Oberweningen
Steinmaur
Dielsdorf
Niederhasli
Oberglatt
Rümlang
Döttingen-Würenlingen
Otelfingen
Otelfingen Golfpark
Buchs-Dällikon
Regensdorf-Watt
Zürich Affoltern
Glattbrugg
Zürich Seebach
Würenlos
Wettingen
Neuenhof
Killwangen-Spreitenbach
Dietikon
Glanzenberg
Schlieren
Zürich Altstetten
Zürich Oerlikon
Hardbrücke
Wipkingen
Zürich HB
Zürich Stadelhofen
Stettbach
Dietlikon
Effretikon
Illnau
Fehraltorf
Pfäffikon ZH
Dübendorf
Schwerzenbach ZH
Nänikon-Greifensee
Uster
Kempten
Aathal
Wetzikon
Hinwil
Bubikon
Rüti ZH
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Blumenau
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Benken
Schänis
Ziegelbrücke
Urdorf
Urdorf Weihermatt
Zürich Wiedikon
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Zürich Enge
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Adliswil
Sihlau
Wildpark-Höfli
Langnau-Gattikon
Sihlwald
Kreuzplatz
Hegibachplatz
Zürich Tiefenbrunnen
Zollikon
Küsnacht Goldbach
Küsnacht ZH
Erlenbach ZH
Winkel am Zürichsee
Herrliberg-Feldmeilen
Meilen
Uetikon
Männedorf
Stäfa
Uerikon
Feldbach
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Balgrist
Rehalp
Waldburg
Spital Zollikerberg
Zollikerberg
Waltikon
Zumikon
Maiacher
Neue Forch
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Scheuren
Neuhaus
Hinteregg
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Kilchberg
Rüschlikon
Thalwil
Oberrieden
Horgen
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Horgen Oberdorf
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Richterswil
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Pfäffikon SZ
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Burghalden
Grüenfeld
Samstagern
Wollerau
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Freienbach SOB
Schindellegi-Feusisberg
Biberbrugg
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Altendorf
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Siebnen-Wangen
Schübelbach-Buttikon
Reichenburg
Bilten
Unterterzen
Nieder- und Oberurnen
Näfels-Mollis
Netstal
Glarus
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Nidfurn-Haslen
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Diesbach-Betschwanden
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