Literature Review

On Indicators for Urban Node Accessibility

DRAFT

RAISE-IT Activity 1 team

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1. Introduction

The performance of railway stations has been traditionally discussed with reference to transport related issues such as passenger frequency and the number of train services. However, stations have been increasingly playing multifunctional roles, not only in arriving and departing trains and transferring trains, but also in facilitating interchanges for wider travel networks between different transport modes and in creating public realm beyond the public transport provision (Figure 1). Van Egmond and van Hagen (2016) maintained that Interchanges exist in all public transport networks and they represent places where public transport modes, and private or alternative forms of travelling (e.g. walking, cycling, private car use, car sharing, and carpooling) all come together. Railway stations are important gateways to their cities and 'symbol of longing, nostalgia, farewell and reunion' (Peters and Novy, 2012: 6). They have been often recognised as landmark buildings because of eye-catching design (Edwards, 1997). Furthermore, in the post-industrial era the role of railway has been rediscovered in providing a better access to the city centre, that is one of the key missions of 'urban renaissance' which aims to create attractive places for working, living and visiting in urban centres. Whereas, over the last two decades stations have been acting as a catalyst for boosting economic activities and changing the image of place through the regeneration of station and its surrounding areas.

Activity 1 of the RAISE-IT project will focus on the improvement of urban node accessibility in order to optimise access and travel time within and to/from a node (i.e. railway station). It will address a range of infrastructure and operational aspects such as station, wayfinding, integrated ticketing and facilities for transferring passengers and any other users. Furthermore, the design of station will be considered in terms of the integration of all the urban travel modes, including walking, cycling, private car and public transport as well as the relationship with its surrounding areas.

Figure 1. Frankfurt Haptbahnhof as multimodal interchange

Source: Endemann, 2005

1.1 Task 1 Objectives

Task 1 of the Activity 1 aims to present state of criteria and indicators for assessing the performance of a railway station and its adjacent areas. Since a large number of indicators already exist and have been applied to assess the quality of stations in previous projects, it is important to provide an overview of relevant criteria and indicators to RAISE-IT. Results from this literature review will be utilised when a tailor made benchmark for examining six railway stations will be developed in Task 2. The six stations to be investigated for this study are Arnhem, Nijmegen, Düsseldorf, Frankfurt am Main, Karlsruhe and Genova.

1.2 Methodologies

Methodologies for this literature review are based on the analysis of previous work such as research projects, academic literature, policy documents and best practice. In order to compile relevant information, a series of key word search has been carried out using database platforms like Web of Science1, Google Scholar, eur-lex.europa.eu, and so on. Key words used for the search are 'urban node', 'railway station', 'interchange', 'indicators', 'accessibility', 'connectivity', 'feeder modes', 'intermodality', 'wayfinding', 'safety', 'security', and so on. Due to different challenges and opportunities the six urban nodes will be investigated based on three different goals: 1) develop the concept of multimodal 'mini-hub' (Genova); 2) analyse key issues and explore solutions at roundtables (Nijmegen, Düsseldorf, and Frankfurt am Main); and 3) introduce good practices for the purpose of developing benchmark indicators and guidelines (Arnhem, Karlsruhe). To this end, the present literature review will include state of the art concerning criteria and indicators which evaluate the urban node accessibility at station and its surrounding areas, and multi-modal connections at urban scale. A detailed description of the concept of multimodal 'mini-hub' is provided in the document "Literature Review: Mini-hub concept".

1.3 Structure of the review

This report will start with discussing the definition of 'urban nodes' by TEN-T Regulations (EU, 2013) and identifying what types of 'urban node accessibility' in relation to railway station will be the target of Activity 1 (Chapter 2). Then, a review of existing indicators for examining the performance of node (i.e. rail station) and its surrounding areas will be presented (Chapter 3). It will be followed by an overview of indicators concerning the multi-modal accessibility to/from station at urban scale (Chapter 4). Finally, the report will conclude with directions for the next step, that is the development of tailor-made benchmark indicators for RAISE-IT (Chapter 5).

[1] Web of Science is an online subscription-based scientific citation indexing service originally produced by the Institute for Scientific Information (ISI).

2. Definition of Urban Nodes

2.1 What is 'urban node'?

According to the European Commission (EU, 2013: 7), the term 'urban nodes' is defined as:

'…an urban area where the transport infrastructure of the trans-European transport network, such as ports including passenger terminals, airports, ***railway stations***, logistic platforms and freight terminals located in and around an urban area, is connected with other parts of the infrastructure and with the infrastructure for regional and local traffic.'

TEN-T Regulations see 'urban nodes' as the starting point or final destination for passenger and freight moving on the trans-European network. They are also considered as points of transfer within or between different transport modes. For passenger transport 'urban nodes' are areas for catering the interconnection between rail, road, air and inland waterway and maritime infrastructure (EU, 2013).

In Activity 1 of this study the term 'urban node' refers to an urban area where the railway station is located, while 'node' means railway station.

2.2 Accessibility at/within node

Node accessibility in Activity 1 will be examined at three levels of spatial contexts: 1) accessibility at/within a node (i.e. railway station); 2) access relationship between a node and its surroundings areas; and 3) accessibility to and from a node at local scale.

The quality of node is primarily concerned with traditional transport functions such as platforms for arrival and departure, operational safety and passenger security as well as passenger circulation and capacity within a station. Furthermore, information provisions like wayfinding, signage, and real time information have become more important since ease and speed of transfer at the multimodal interchange has been expected due to the growing number of urban public transport networks. In order to offer an efficient and comfortable accessibility to passengers within a node, it is crucial to address architectural and urban design aspects of station buildings and open spaces. This is because design related elements such as configuration, material and colour scheme, public space and station facilities (e.g. restaurants, shops, toilets, waiting area, ticket office, left luggage) largely influence the quality of station and the interchange performance. Non-rail related activities such as property and retail development have become prominent, given an increasing demand for generating supplementary revenue through additional facilities and activities.

Once a well-designed station is created, it is very important to have a clear and long-term plan on station management involving various stakeholders and day-to-day maintenance to keep cleanliness and repairs. Finally, resource management and energy consumption of station premises is a critical aspect in terms of the adaptation to climate change and sustainability, which is also related to the mitigation of air and noise pollution in urban node.

2.3 Access relationship between node and its surroundings

To examine the access and spatial relationship between a node and its surrounding areas, it is essential to establish a working definition for physical proximity meant by 'surrounding areas'.

Station areas concerned by Transit Oriented Development (TOD) (See detailed in Sec. 3.2.3) are often described as ‘a mixed use place, with a certain urban density and high-quality walking environment located within half-mile (800 m), i.e. 10 minutes’ walk of a transit stop (Vale, 2015: 70)’. This figure is also used by the concept of Mobility Oriented Development (MODe) which has been developed by a Dutch consultant, ARCADIS and their idea was inspired by the ‘node-place’ mode of Bertolini (1996). ARCADIS (2016) argue the quality of a station environment is based on four domains (connectivity, urban environment, social placemaking and economic development) and data are collected within a radius of 800 m, around the station (Figure 2).

Although the difficulty in distinguishing the target area between a TOD and a transit-adjacent development (TAD) is pointed out (Vale, 2015) and the availability of data within a radius of 800m around the station is questioned (ARCADIS, 2016), the Activity 1 considers an area within 10 minutes’ walk of a station for ensuring physical proximity and thus a radius of 800 m is defined as ‘surrounding areas’ for this study.

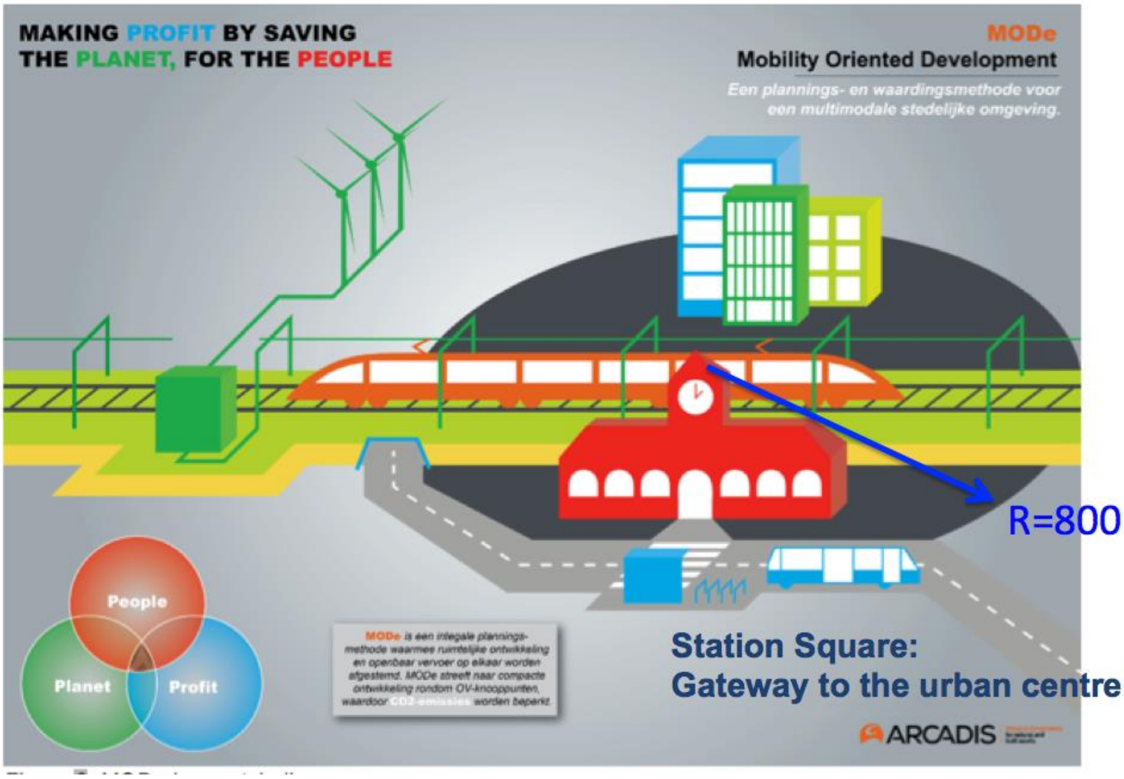

Figure 2. Station and its surrounding area (R=800)

Source: ARCADIS (2016, adopted by Otsuka, 2017)

2.4 Accessibility to and from node at urban scale

A working definition of “accessibility to and from node” is also necessary for the purpose of the present work.

Rail trips rarely start and end at the railway station. They are usually part of a trip chain that includes the journey to and from the station, at the beginning and end of the rail trip respectively. Givoni and Rietveld (2007) suggest that getting to and from the station is an important part of a rail journey and the ‘integration of these components is essential to achieve a continuous travel, door-to-door when using the rail, and in order to make the railway a viable and attractive alternative to the car'.

Following the definition of connectivity[2] provided by the UK Government's Department of Transport (2015a), 'how well different places are connected to each other using the transport system', accessibility to and from the node within the framework of the present work refers to the ease of access to and from a railway station with the different modes of transport.

Figure 3. Rail as part of a trip chain

Source: ATOC 2010 (adopted in Galiza and Charles, 2013: p2)

In Activity 1 accessibility to and from the node is going to be evaluated at urban scale, that is within the town/city boundaries where the node is located, without considering the area surrounding the node, since this is subject of study under the "*Access relationship between node and its surroundings*" (see Sec 2.3) nor the node hinterland beyond the city/town, which is going to be studied in Activity 2 "*Seamless Connection from the Nodes*".

[2] In the present work connectivity is used as a synonym of accessibility

3. Indicators and Criteria at Node

3.1 Introduction

In this chapter the relevant indicators and criteria for analysing the node performance are discussed with reference to academic literature, policy documents and previous EU co-financed projects (e.g. CIVITAS, CLOSER, CODE24, GUIDE, KITE, LINK, MEDIATE, MIMIC, ORIGAMi, PIRATE, SWITCH and Trendy Travel). The introduction of EU projects is heavily drawn upon the literature review carried out by the NODES project (Van der Hoeve, et al. 2013) since they provided useful summary of relevant projects up to 2013. Their review on state of the art was really comprehensive covering 18 previous EU co-financed projects, ten policy frameworks and guidelines and 32 base practices.

In addition to review of previous literature, authors' interpretation resulting from observation of the six rail stations have been added together with pictures taken by the authors.

The following five criteria have been decided to provide headings for discussing a number of indicators. The chapter starts with strategic integrated planning and mixed land use at and around node (3.2), and then detailed design aspects of node (i.e. railway station) are explained (3.3). Thirdly, pedestrian access and information provision are presented (3.4), that are followed by review on management and business provision (3.5). Finally, issues related to environment and climate change are summarised (3.6).

3.2 Strategic integrated planning and mixed land use at/around node

In recent years station has been expected to act as a key node for obtaining accessibility benefits through the improvement of the interchange performance. Furthermore, the opening of HSR stations have brought enhanced accessibility and fostered changes in the configuration of the land-use system of the urban area near the station, and its immediate surroundings (Monzon et al., 2013). Station has been playing a catalyst role in regenerating the urban area in its immediate surroundings, and the strong link between railway station mega-projects and the re-making of inner cities in the European context were discussed by previous literature (Vickerman, 2015; Peters and Novy, 2012; Germendia et al. 2012). Many of the area development projects typically show a dense mixture of office, retail, leisure and housing and are located around highly accessible places such as main railway stations (Bertolini et al., 2012). Having observed the evolving roles of stations, it is clear that fulfilling only traditional station roles from the rail service perspective is not sufficient any more and a boarder planning approach integrating the station building and its surrounding area is required.

Although main features related to train services such as safety, reliability, network connectivity and speed are still important, once they have reached an acceptable level, how passengers experience their journey at node should be taken into account. Passengers are nowadays addressed as 'customers', and their satisfaction with total travel service beyond a basic public transport provision should become the main issue in improving the interchange performance. However, most of the previous research underestimates the importance of the 'satisfier' aspect of the transport services, that is, to what extent customers appreciate the overall services offered (van Egmond and van Hagen, 2016).

Concerning the area planning of a station and its surrounding areas, it is important to pursue not only the integrated planning approach to land use and public transport function, but also specific needs of individual public transport customers. They are the key actors using an interchange and thus the quality of station in terms of well-functioning interchanges (design, operation, management, etc.) should be considered particularly from the user's perspectives. As prerequisite conditions for discussing the performance of rail station, the next sections introduce the classification of stations (3.2.1) and the types of different user groups (3.2.2). Then the mainstream approach to integrating land-use planning and infrastructure planning is explained with a particular focus on Transit Oriented Development (TOD) (3.2.3).

3.2.1 **Classification of stations**

Traditionally the classification of railway station has largely relied on the indicators such as 'passenger frequencies' and 'the number of rail network services', in which focus is placed on transport related issues. The early attempt beyond the transport provision was introduced by Bertolini (1996), and his 'node-place model' classified stations based on the relationship of network connectivity and land use planning in the catchment area. Bertolini's concept has been used by the Dutch railways to coordinate the strategies with their business unit (passengers, station services, and real estates) (Zemp et al., 2011a) as well as an adaptation of his model was applied to compare over 1600 Swiss railway stations (Reusser et al., 2008).

Zemp et al (2011a) argue that classifications can contribute to strategies transport and land-use planning in three ways:

- to provide comparable situations in terms of management and operation for infrastructure companies; and to enable the identification of comparative opportunities and challenges for local planning authorities;
- to carry out comparisons and performance assessments within the station classes for the purpose of establishing successful benchmarks; and
- to support the identification of general development potentials and future adaptations with reference to classes.

They maintained that the classification system for strategic planning should focus on the demand and conditions of stations in order to make the railway station more functional and user friendly. Contexts and environment of the railway station (e.g. size, environmental constraints, and characteristics of place such as workplaces, leisure and shopping) refer to the demand and conditions under which a station functions (i.e. how to link the catchment population with transport networks), that consequently determine structures and operation of the railway stations (e.g. layout, design and operation of platforms, station facilities, opening hours, etc.). The development of railway station is highly context-dependent and Juchelka (2002, cited in Zemp et al., 2011b) described his view on the classification of stations from the perspective of urban development potentials in its surrounding urban areas. His approach was echoed by Vale (2015) who provided the classification of 'station area' in three different aspects: land use, transportation, and walkability conditions.

The study led by Transportation Research Board in U.S.A (Kittelson and Associates, 2012) introduced station typologies which illustrate general characteristics for stations, including land use intensity, feeder transit connections, parking availability, and the quality of the pedestrian network. They have reviewed stations according to eight categories:

- **Housing density** in the area around the station;
- **Scale** in terms of average building height in the area surrounding the station;

- **Distance from Central Business District** (CBD), which is European equivalent to the city centre;
- **Supporting transit networks**, the level of transit connectivity other transit services;
- **Pedestrian/ Bike access,** a measure of the completeness and attractiveness of the pedestrian and bicycle networks around the station;
- **Surrounding land uses**, mixed land use in stations adjacent area;
- **Parking facilities**, the level of off-street parking at station;
- **Access/ Egress**, the primary role of the station in the transportation system.

These categories have been often referred to the assessment of station performance in the previous literature, and the rest of literature review will take them into consideration when discussing criteria and indicators.

3.2.2 Different user groups

As a growing number of people living in urban areas in European cities and many public transport users are required to combine several modes of transport to reach their destination, it is necessary to consider user's requirements when discussing the efficiency and competitiveness of urban transport interchanges (Hernandez and Monzon, 2016). The modern railway station has a variety of users such as tourists, commuters, salesmen, retailers, train spotters and homeless people (Edwards, 1997)

The Netherlands Railways developed a tool called 'Station Experience Monitor (SEM)' which is designed to quantify the customer experiences at interchanges and assist station managers in determining the basic quality level and monitoring change over time. Using SEM, all 406 train stations in the Netherlands have been monitored with a particular focus on customer's experiences (van Hagen and van Egmond, 2015, See more detailed in Sec.3.3.5). Through periodical monitoring in different time of the day (e.g. day time and night time; peak and off-peak, and seasonal difference, etc.), SEM has accumulated enough evidence in identifying different types of users. The users can be categorised with reference to their 'freedom of choice' and 'their travel motive' (must travellers or lust travellers) which tend to be influenced by their personality and personal circumstances. 'Must travellers' refer to commuters and users on business trip, while 'lust travellers' mean by users for pleasure such as shopping and holiday. Depending on the nature of their travel and time of the day each user has different ways of using a station. There are indeed users who do not make use of the transfer function, but come to use the secondary services such as shopping, restaurants and meeting points (van Egmond and van Hagen, 2016).

A previous EU funded project, PIRATE (Promoting Interchange Rationale, Accessibility and Transfer Efficiency, 1998-1999), which sought rationale for promoting interchanges in terms of accessibility and transfer efficiency, identified three groups of interchange users (Van der Hoeve, et al. 2013: 13):

- People who work in an interchange (including managers, vehicle drivers and subcontractor service staff);
- People who use an interchange for travel, shopping or social purposes, categorised as walk and ride users; park and ride/ kiss and rider users; bike and ride users; and ride and ride between the same or different public transport modes;
- People who are non-users or potential users.

In addition to van Egmond and van Hagen's (2016) categorisation, PIRATE is concerned with workers at interchanges as well as potential users. Furthermore, Bertolini et al (2012) looked into profile and life style of users with reference to recent demographic and economic trends which seem to favour highly accessible locations like station areas. Ageing society, the increase in double income householders, and the emergence of more flexible, and mobile working arrangements are calling for stations and their surroundings to be more accessible and convenient for daily activities.

3.2.3 **Land use planning and infrastructure planning**

There has been a tendency for railway stations to be placed in the centre of large-scale urban redevelopment projects, thus they are playing a strategic role in restructuring the post-industrial urban cores and in connecting station areas with city centres (Vickerman, 2015; Peters and Novy, 2012; Germendia et al. 2012). Banister and Hall (1993) maintained 'Railway Renaissance' in the post-industrial era when city centres are being rediscovered as an attractive site for working, living, visiting and for entertainment in European countries. Over the last two decades, the steady expansion of HSR rail networks in Europe have triggered new development opportunities around station areas by placing station premises as a part of city centre extension (Bertolini et al., 2012; Apostol, 2013; Germendia et al. 2012). Enhanced accessibility between stations and city centres has become one of the selling points in city centre regeneration programmes. The importance of stations has been explicitly noted in National Government's' policy documents, and for example, the UK government's most recent housing white paper stated railway stations as key anchors for the next generation of urban housing development (Biggs, 2017).

The refurbishment of both the railway stations and their surroundings ensures convenient and seamless access for non-motorised users and public transport (e.g. tram, bus) on the surface, where station squares and pedestrian areas have been redesigned to provide a better accessibility and safer crossing. In addition to the enhanced pedestrian accessibility, new commercial entertainment functions have been integrated into the physical environment inside the station as well as adjacent areas. Monheim (2009, quoted in Peters and Novy, 2012) pointed out the above aspects together with good practice examples in smaller and medium-sized cities in Germany and Switzerland (e.g. Karlsruhe, Siegburg, Basel). Concerning the integration of land-use planning and infrastructure planning, the rest of this section explains two key planning tools: Transit Oriented Development (TOD) and Sustainable Urban Mobility Plans (SUMPs) (Rupprecht Consult, 2014).

First of all, TOD is a planning approach to station area projects which aims at the re-centring of entire urban regions around rail transport and making urban areas for pedestrian friendly (Bertolini et al., 2012). More walkable spaces and transit oriented mixed-use patterns are the key ingredients of TOD and the integration of land use and transport planning is essential in implementing a TOD-led project. TOD has assisted in creating an urban environment with high densities, mixed and diverse land uses, which is located within an easy walkable area around a transit stop (Singh et al., 2014). Planners and policy makers have promoted TOD as a key solution to a range of urban problems such as traffic congestion, air pollution, social integration and urban poverty. They argue that mixed-use developments in high density urban areas near transit stations can enhance access to jobs and various urban activities for those living within walking distance of a transit stop (Dawkins and Moeckel, 2016). In this respect, TOD is being actively promoted as an urban design model for areas round the railway network (Vale, 2015).

Furthermore, this concept is now dominating urban growth planning paradigm as a tool for promoting urban development along rail networks as well as achieving cohesive territories and sustainable urban development (Papa and Bertolini, 2015). There is no doubt to say that TOD is a public policy driver from the perspective of promoting sustainable urban mobility which would encourage people to opt for public transport and non-motorised modes (Bertolini et al., 2012). A number of previous research projects have examined the linkages between TOD and travel behaviour as well as measuring TOD levels and rail-based accessibility (Papa and Bertolini, 2015; Singh et al., 2014) and area developments around railway station (Vale, 2015), acknowledging the prominent role of TOD in creating pedestrian friendly and sustainable urban centres.

Secondly, through the CIVITAS initiatives (Cleaner and better transport in cities, 2002- on going) the European Commission have introduced the idea of Sustainable Urban Mobility Plans (SUMPs) which have three goals (Van der Hoeve, et al., 2013: 34):

- to promote and implement sustainable, clean and (energy) efficient urban transport experiments;
- to demonstrate integrated packages of technology and policy actions in a structured process comprising eight steps (status analysis; vision building; objective and target setting; policy and measure selection; active communication; monitoring and evaluation; and the identification of lessons learnt) (Rupprecht Consult, 2014);
- to build up critical mass and markets for innovation by transferring good practices to other European cities.

The EU published the guidelines for introducing the SUMPs concept and how to benefit from using them as a new planning paradigm, and SUMPs is defined as ‘a strategic plan designed to satisfy the mobility needs of people and businesses in cities and their surroundings for a better quality of life. It builds on existing planning practices and takes due consideration of integration, participation and evaluation principles (EU, 2013: 8)’. One of the key missions in SUMPs is to replace sectorial planning approach which is largely model-focused and dominated by traffic engineers with an inter-disciplinary policy planning with inter-disciplinary experts.

3.3 Design of node: station

Traditionally, the planning and development of most stations are based on a functional design. How to operate trains and transport passengers from A to B as well as the circulation planning of passengers for transfer trains and walk out/in a station has been recognised as the most important factor when designing railway stations. Structural engineers, traffic engineers and architects are the key actors to lead the physical and infrastructural design of stations, while the place making of stations as a public space seems to be set aside.

In recent years, previous research has unveiled the lack of taking user’s travel and waiting experiences into account and the importance of undertaking customer satisfactory survey of station users is emphasised by previous EU funded projects (van der Hoeve, et al., 2013). The aforementioned Station Experience Monitor (SEM) (van Hagen and van Egmond, 2015) was developed to guide interchange designers and operation managers to create a user-oriented station by putting their efforts to deliver a more pleasant and attractive interchange for users. In addition to the physical design elements of interchange infrastructure, the place is also determined by environmental and atmospheric conditions such as colour, brightness, sound, and smell. Hernandez and Monzon (2016) aimed to identify key factors for an efficient urban transport interchange from user’s perspectives, and their literature review pointed out that most of previous work identified ‘information and accessibility’ as the most relevant functional features, while ‘safety, security and comfort’ as the most important psychological aspects, concerning the design, operation and management of passenger multimodal transport stations.

In the following the design of node is discussed with five aspects: architectural and urban design (3.3.1); station facilities (3.3.2); access facilities catering for intermodal connections (3.3.3); ease of transfer within a station (3.3.4), and finally liveability and comfort from user's perspective (3.3.5).

3.3.1 **Architectural and urban design**

In his book, entitled *The Modern Station: New approaches to railway architecture,* Edwards described that:

> 'the design of railway station is one of the more challenging and rewarding fields of practice today. The opportunity to enhance the public realm and to balance engineering with more practical considerations results in a building type of particular relevant and visual complexity. As a typology the railway station employs a distinctive architectural language of large-span roof, grand entrance halls, interior concourses and wide public entrances (Edwards, 1997: ix).'

The image of a station is most likely influenced by the architectural design of buildings, streetscapes, trees and other greenery, public arts and street furniture, and these features play a critical role in adding value to the quality of an interchange and in facilitating more opportunities to cultural, social and economic activities through private sector investments (van der Hoeve, et al., 2013). Stations should be comprehensively designed in response to different occasions and needs. The important factor is that physical experiences and psychological reactions of station users are extensively affected by the design and operation of interchanges (Hernandez and Monzon, 2016).

In terms of urban design, when considering the spatial relationship between a station and its surrounding area, many stations tend to have two distinctive faces (Figure 3). According to Peters and Novy (2012), station areas are typically divided into 'two incongruent, and socially segregated environments'. There is often a representative station square in front of the building, which would be leading to tree-lined boulevards with expensive hotels and business establishments, providing the connection to the older parts of the city centre. In contrast, the back of the station would typically exhibit a mix of less desirable uses which had been occupied by noisy and highly polluting factories and workshops alongside low quality rental accommodation and commercial facilities for their workers that typically included red-light districts. Since the deindustrialisation in the 1960s and 1970s the inner city neighbourhoods on the backside of station have further deteriorated into an undesirable and derelict quarter, distinctively segregated from the buoyant shopping districts in the city centre. However, the recent movement of 'Railway Renaissance' has provided excellent opportunities to the regeneration of the back of the station area and a masterplan has attempted to link the neglected area with the station front premises and the rest of the city centre.

Since the 1990s there have been a number of architectural design competitions on station building which often include a masterplan for its surrounding area, and impressive new stations have been opened and they have become a new symbol of city (e.g. Arnhem, Rotterdam Central, Kings Cross, Berlin Hauptbahnhof, Torino Porta Susa, Madrid Atocha, etc.). These projects tend to prioritise the visual architectural design of the building, while the functionality might play a secondary role. Some negative factors such as poorly situated ticket offices as well as lack of lifts, ramps and waiting areas were mentioned by a previous European project, MIMIC (Mobility, intermodality and interchanges, 1996-1997). The functionality of the station building should be primarily concerned together with station layout and interior design in response to accommodating station facilities for users.

Figure 3. Two faces of the Mannheim station

Source: Otsuka, 2017

3.3.2 **Station facilities**

In terms of the configuration and layout of station, Edwards (1997: 59) identified six main elements for the railway engineers and station designers to address when designing and planning railway stations:

- railway track and signalling;
- the platforms;
- circulation areas;
- ticket sales and retail spaces;
- post and parcel areas; and
- station forecourt.

Of those, this section focuses on discussing station facilities with reference to ‘platforms’; ‘ticket sales and retail space’; and ‘post and parcel areas’. Railway track and signalling is out of scope in Activity 1 of this project, while circulation areas will be explained in the next section (3.3.4. Ease of transfer) and station forecourt in Sec. 3.4.1 (Walking to station).

Trendy Travel, a previous European project (2007-2010) examined how sustainable travel can be made more attractive by fulfilling people’s emotional needs. They clarified two distinctive types of user experience at a railway station: fast and slow. The fast area corresponds with the transfer area where users need to move round efficiently, faster and easier, and therefore predictability and being recognisable is the two key factors in their experience. In this respect the layout of shops and food stalls, seasonal events (e.g. Christmas markets etc.) and cafes should be carefully located in order not to obstruct people’s movement in concourses. For example, the authors have witnessed that shops and food stalls located within the concourse of Frankfurt Hauptbahnhof are clearly blockades for the circulation of people since crowd getting off from trains is struggling to go through narrow walkways between the commercial establishments (Figure 4).

Figure 4. Layout of shops and narrow entrance at Frankfurt Hauptbahnhof

Source: Otsuka, 2017

On the other hand, the slow area needs to offer users a useful, comfortable and pleasurable experience to spend their waiting time. The Trendy Travel project attested that when they have a pleasant social interaction in a well-designed waiting area where a setup of benches is planned to encourage eye contacts, the perceived waiting time could be shortened. Another EU project, GUIDE (Group for urban interchanges development and evaluation, 1998-1999) also emphasised the importance of matching the design and layout to user's needs.

KITE (A knowledge base for intermodal passenger travel in Europe, 2007-2009) mentioned the importance of weather protection in walkways and waiting areas. Poor protection from sun, wind and rain on the platforms would make waiting time unpleasant. Such aspects as waiting areas and shelter function are not directly related to transport services themselves, but they are key ingredients for improving user experiences in the waiting time. Other services, which would bring added value to an interchange, are noted by LINK (The European forum on intermodal passenger travel, 2007-2011):

- clean toilets and sanitation;
- good luggage handling facilities (e.g. left luggage office, lockers, lost and found, luggage trolleys that are simple and safe to use);
- communication services (fax, telephone, internet);
- business facilities (meeting rooms, W-LAN zone);
- a variety of retail offers and food (restaurants, bars, food stalls, automatic vending machines).

In addition to services emphasised by the LINK project, the author's observation has suggested the following facilities:

- Cash points and exchange of currencies;
- Post office and parcel services;
- Kids clubs as nursery function and assistant services for disabled people;
- Police station or security office.

These additional services should ensure the diversity of offers and prices and it is necessary to determine the adequate capacity in response to the changing demand from passengers and non-train users. Furthermore, the Trendy Travel project emphasised the effectiveness of applying a personal and distinguishing touch in the design of street furniture in the waiting areas and platforms (e.g. bench, light fitting, signpost, etc.), and the same principal should be adopted to the above additional facilities.

Finally, the location of ticket office and the placement of ticket vending machine should be planned carefully since these are one of the first facilities that users look for on their arrival. Nowadays, the purchase of online tickets makes it possible for users to avoid queues in front of ticket counters or machines, but these are still one of the most important facilities in the station.

3.3.3 **Intermodal and access facilities**

Debrezion et al. (2009) explained that two types of factors influence the user's choice of departure station: factors related to the accessibility of station, and factors related to rail services provided at the station. Users tend to select easily accessible railway stations as their departure points. In addition to widely recognised indicators on railway services (e.g. the frequency of train services, network, connectivity and coverage, etc.), the presence of other supplementary facilities such as the availability of parking spaces, the park-and-ride possibility, bike stands and sharing, carpooling and well-accessible taxi bay also increase the attractiveness of a station as a departure station. The GUIDE project highlighted the importance of a comprehensive approach when designing access to the interchange by all relevant modes, including walk, cycle, taxi and car.

With reference to previous European projects, key elements of intermodal and access facilities are now summarised. Firstly, CLOSER (Connecting Long and Short-distance networks for Efficient transport, 2010-2012) pointed out the necessity of putting more effort on enhancing bicycle use. The MIMIC project provided some reasons for why cyclists often find it difficult to use their bikes in stations. These obstacles are, for example, the lack of cycle lanes leading to stations, handling a bike because of steps and staircases within station buildings, and unsafe and unpleasant cycle parking areas. A sufficient number of cycle stands and safely lockable stands are urgently required in many stations. Lockable stands are also very useful from a design perspective since it makes possible to store more number of bicycles in line (Figure 5). In addition, due to the presence of a growing number of bike-sharing systems, the design of bicycle stands and the accessibility of cyclists should be reconsidered from the perspectives of two types of cyclists (private use and share).

The LINK project examined transport-related infrastructure in terms of intermodal access to stations. There are different types of car parking facilities for different kinds of vehicles (e.g. park and ride, kiss and ride, taxi bay for travellers and waiting space for taxi drivers, public transport stops, car-rental, car-sharing, carpooling and private car parking). The quality of intermodal related infrastructure is determined by various elements such as number and location of the parking facilities, distances to the platforms and the connecting paths between the parking facilities and the station concourse. MIMIC identified some negative aspects, for example, the inadequate capacity of parking areas at park-and-ride interchanges and no dedicated area for dropping off and picking up of passengers (kiss-and-ride). Furthermore, CLOSER proposed to explore the possibility to take cycles into vehicles, which calls for the appropriate physical connections between car parking and cycle parking. In terms of transport-related rental services (i.e. car-rental, bike-rental and car sharing), LINK noted that the attractiveness of such services are highly dependent on the quality and diversity of existing offer and the price and the modalities of utilisation.

Figure 5. Unlockable cycle stands for bike-sharing system, at Frankfurt Hauptbahnhof (left) and lockable stands in Dusseldorf Hauptbahnhof (right)

Source: Otsuka, 2017

Finally, according to ORIGAMI (Optimal Regulation and Infrastructure for Ground, Air and Maritime Interfaces, 2011-2013), when intermodal facilities are designed, managed and equipped to a sufficient standard, users can connect between different modes safely, quickly and comfortably.

3.3.4 **Ease of transfer**

According to van Egmond and van Hagen (2016), safety, reliability, speed and ease are the basic requirements when people need to move round in a public space like railway station. They emphasised that Interchange maps are a vital component of a modern interchange. When maps are sophisticated, interactive with users and providing the both dynamic and static nature of information, they can significantly assist users in wayfinding, and especially non-frequent users can benefit from such maps. When the configuration of an interchange is more complex as a result of serving a range of travel modes, the usefulness of such maps would be significantly increased. Station maps will be referred later as part of information provision in Sec.3.4.2.

Transfer times and distance to the platforms are another critical factor examined by the KITE project. As a practical example, on the page of ‘travel plan’ of their website Deutsche Bahn (DB) suggests at least 10 minutes for passengers to transfer from one train to another or between different public transport modes (DB, 2017). As the MIMIC project noted, many routes between different modes require level changes, with often no ramps, escalators or lifts available or being placed in hidden corners of the platforms. Such obstacles to seamless movement should be removed through the introduction of soft change in levels and the clear signage for finding lifts and escalators. As noted in the previous section (3.3.2) shops and food stalls can also become the main blockage when many people have to move between a narrow walkway (Figure 4).

In particular, there are some social groups who need special assistance in moving round at stations (e.g. disabled, elderly, mother with small children on pushchair, etc.). The ORIGAMI project raised concern about people with restricted mobility. There seem to be many cases that steps and staircases are placed without a careful consideration on the accessibility of those vulnerable groups. Furthermore, the lack of guided routes for blind people makes it difficult for them to travel independently. The release of these barriers is essential to increase the physical accessibility of all kinds of users. In addition, MEDIATE (Methodology for Describing the Accessibility of Transport in Europe, 2008-2010) maintained that the ease of transfer for elderly and disabled people when travelling by public transport should be concerned with not only the physical accessibility between transport modes, but also the access to useful information and ticketing system.

3.3.5 **Liveability and comfort**

This section presents the soft elements of node design with reference to the NODES project (2012-2015) which aimed to develop new tools for design and operation for urban transport interchanges. One of the tools is the Station Experience Monitor (SEM) (NODES, 2015) that is evidence based research executed on behalf of the Netherlands Railways and tested with 406 railway stations in the Netherlands as well as those in other European countries such as Italy, Hungary, Spain and the UK (NODES, 2015; Van Hagen and van Egmond, 2015, also see Sec. 3.2.2). The purpose of SEM is to measure, monitor and compare customer experiences in stations at a European level. The research team called interchange users as customers and their key mission was to explore how to provide the customers with a high level of satisfaction and they argue that customer's satisfaction is determined by good experience and comfort. Also customer's emotional needs are often influenced by various atmospheric elements of stations. This point was echoed by the Trendy Travel project which recommended making sure to keep intangible atmospheric elements (such as music, scent, visual and art, green, and TV screen) at an optimal simulation level. The optimal level should be detemined per station and per target groups although such a tailor made approach is often extremely difficult to realise, given a limited costs invested in soft elements as well as the problematic nature of addressing individual preferences and perceptions.

To develop SEM it was important to examine how people's behaviour is influenced by stimuli which are present in their environment. Environmental stimuli such as sound, temperature, colour, brightness and smell, are often perceived unconsciously even though they extensively influence people's emotion and behaviour (NODES, 2015). Van Egmond and van Hagen (2016) clarified that all the positive and negative behaviour can be provoked by the environment, which can be divided into two distinctive behaviours: 1) approach behaviour (wanting to explore and stay, feeling connected to the place, wanting to return) and 2) avoidance behaviour as opposing to the approach behaviour. It is clear that moving area and staying area (i.e. the fast area and the flow area defined by Trendy Travel, see Sec. 3.3.2 for more details) require different quality of the environment. Since people's emotion has a strong influence on the ways in which they evaluate the performance of interchanges (van Egmond and van Hagen, 2016), these stimuli play an important role in the development of criteria and indicators for measuring customers' liveability and comfort at stations.

In the SEM, the following six themes of the station experience have been monitored (van Egmond and van Hagen, 2016, *points highlighted italics added by the authors*).

- Ambience (warm appeal, colourful, attractiveness, etc.)
- Comfort (shops, *bars and restaurant*, shelter, waiting, etc.)
- Access (find station easily, pleasant environment, etc.)
- Orientation (information, signage, overview,)
- Safety (*light, security, maintenance, etc.)* and Cleanliness (*clean, fresh, smell, etc.)*
- Staff (visible, professional, *attentiveness, availability*)

Survey by the NODE project identified six themes of customer experience (ambience, comfort, access, orientation, safety and cleanliness, and staff) and the relative importance of the six themes on the overall score of the surveyed stations is presented (Table 1). The themes that scored the highest importance (25%) were ‘comfort’ and ‘safety and cleanliness’, followed by the themes of ‘ambiance’ and ‘access’ (20%). Surprisingly, the importance of staff was not significant in the investigated stations and they were left out from the table below. From the NODES study, it is evident that ‘ambience’ and ‘comfort’ are very important themes when concerning the performance of stations.

Table 1 Relative importance of six themes on the overall score of stations in SEM

Six themes	Train
Ambience	20 %
Comfort	25 %
Access	20 %
Orientation	10 %
Safety and Cleanliness	25 %
Staff	-

Source: Adopted from NODES, 2015: 2.

3.4 Pedestrian access and information provision

Making a transfer at interchange stations is inevitable for multimodal travel and this is a considerable drawback compared with private cars offering door-to-door seamless transport. Van Egmond and van Hagen (2016) see the transfer barrier as an unwelcome journey interruption and it impacts on the three decisive factors for modal choice: budget, time, and physical and mental effort. In the development of SEM their key mission was to reduce customers’ constraint, especially concerning the value of their time. Beyond the traditional approach to time saving (e.g. increasing the frequency of services and providing integrated real-time information), they argue that additional services and facilities at a station such as shopping, business and leisure activities (see more detailed in 3.3.2) could compensate time loss caused by a transfer. The previous section (3.3) was concerned with how to reduce the transfer barriers through a better design of node.

This section focuses on factors influencing the accessibility to multimodal interchanges when users are accessing a station from its surrounding areas as well as how they find their way out to their final destination after arriving by train. The majority of previous work on multimodal transfer included some aspects of ‘accessibility’ and ‘information’ and thus these two can be considered as crucial indicators. The next section is concerned with walking to station (3.4.1), while access by other transport modes (e.g. public transport, cycling, private car, sharing modes) will be discussed in Chapter 4. Then, information provision for intermodal connections is explained (3.4.2).

3.4.1 **Walking to the station**

Walking can be considered as the primary access mode to transport interchanges if the station is within one km of the departure point, and Galiza and Charles identified benefits of walking:

> ‘All forms of travel regardless of the main mode of transport employed have a walking component. Walking is regarded as the most basic travel mode and indeed the most sustainable way of accessing the station. Walking also produces some health benefits

together with environmental, social and economic benefits (Galiza and Charles, 2013: 23)'.

There are many conditions influencing user's decision on whether they opt for walking to a station or taking other transport modes. First of all, the distance people walk to access stations and bus stops plays a fundamental role in the ultimate use made of public transit (García-Palomares and Gutierrez, 2013). However, short proximity does not always guarantee people's choice since walking in some locations can be inconvenient, unpleasant or unsafe especially with circuitous routes, poor footpath conditions, heavy traffic, and dark or isolated corridors (Galiza and Charles, 2013). This issue is also highlighted by the MIMIC project and pedestrian access to interchanges frequently involves difficult access over busy roads or through unpleasant (often unsafe) areas (Figure 6). In many cases walking to the platforms requires longer distances than it was anticipated when they started walking. Along with the distance to the station, physical quality of the urban environment, transportation facility conditions, time, cost, and characteristics of travellers affect user's choice to walk to a transit station (Loutzenheiser, 1997, cited in Galiza and Charles, 2013).

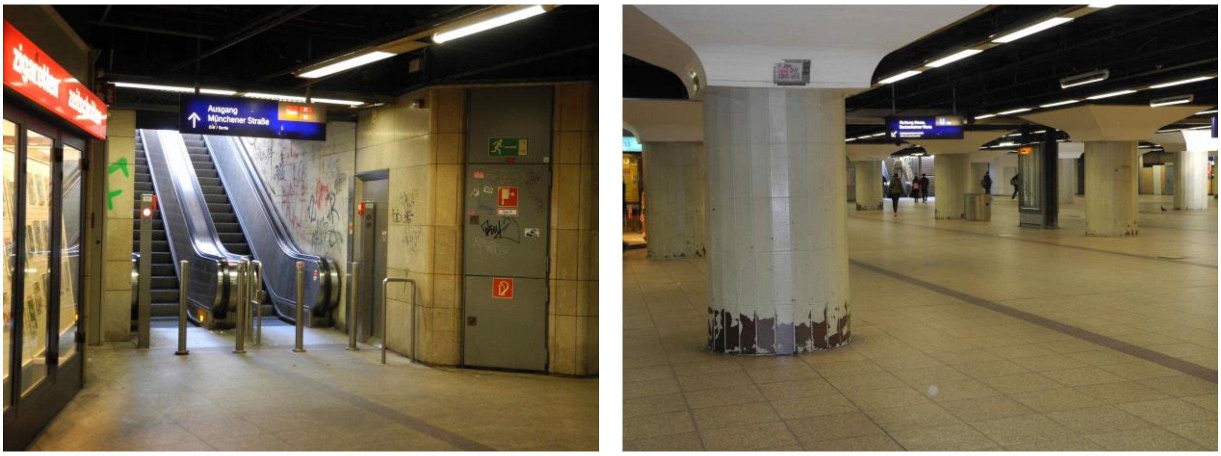

Figure 6. Unpleasant underground access to Frankfurt Hauptbahnhof

Source: Otsuka, 2017

Street network and configuration is an important factor in order to improve the accessibility to the station. One of TOD indices is to design urban space with a particular reference to the suitability of streetscape for walking and cycling, especially in street crossing points (Singh et al., 2014). The private transport system is based on a street network, which should be planned to cater to the free and individual movement of pedestrians, bicycles and cars, constitutes the public space structure of urban environment and represents the main interface with other urban systems (Gil, 2014). The design of public place affects the choices people could make, and 'where people can go and where they cannot is the quality called 'permeability' (Bentley et al., 1985:9). It also impacts on 'how easily people can understand what opportunities it offers', that is the quality called 'legibility' (Bentley et al., 1985: 9). Although station users are able to consider a number of alternative walking routes to a station, the access with the high degree of 'permeability' and 'legibility' help them reach a station fast in a direct way.

In addition to the network and configuration, it is crucial to ensure detailed arrangement of street infrastructure such as kerbs, pedestrian guardrails, crossing and step-free accesses by ramps and lifts, according to the GUIDE project. Street furniture should be facilitated to create straight-line pedestrian access and well-lit streets during night time. Furthermore, concerning the accessibility of disabled people from the surrounding areas to the station, as explained in the section of ‘Ease of transfer’ (3.3.4), special attention should be paid to fulfil the needs of people with mobility problems.

Finally, in terms of types of users, García-Palomares and Gutierrez (2013) calculated distances walked by different population groups using case studies from Metro stations in Madrid. Their survey found that the majority of transit users accessing metro stations on foot are young people and adults, men, and immigrants who are less sensitive to the effect of distance. In addition, those groups are less likely affected by walking conditions on access routes such as the presence of barrier free facilities and unsafe atmosphere. The findings of their study indicated that the improvement of accessibility to stations should also be addressed from a social exclusion viewpoint, in other words, it is necessary to guarantee citizens equal opportunities to accessing transit networks. Although some people decide to walk as a sustainable travel choice or for their own health benefits (Morency et al., 2011), people’s choice for walking to the station is largely influenced by infrastructure planning and design on the street layout and configuration. Research by Reyer et.al. (2014) applied the Walkability-Index and the Walk Score to map out high and low walkability areas in the city of Stuttgart, and investigated the association between urban form and active transportation of residents using a household survey. These tools can be useful for the examination of walkability in the surrounding areas of station.

3.4.2 **Information provision for intermodal connections**

According to the literature review of the NODE project on previous EU-funded projects (van der Hoeve, et al., 2013), ten out of 18 reviewed projects focused on information and intermodality. Providing easy wayfinding, real-time information and different means of information provision is essential to ensure smooth connections between different modalities. With reference to summaries of these ten projects prepared by the NODES project, information provision for intermodal connections can be categorised into the four key aspects: 1) Wayfinding and signage; 2) real time and static information; 3) means of information and staff; and 4) information for special cases (i.e. people requiring assistance and emergency occasions).

1) Wayfinding and signage
GUIDE maintained that users need to recognise the existence of the station from some distance and key station facilities such as ticket office, information and platform entrances should be ideally placed as to become visible from their main accessing points. Transport-related information services at the interchanges are necessary throughout the whole process of journey, including pre- and after-trip information, that was identified by LINK, ORIGAMI and SWITCH (Sustainable workable intermodal transport choices, 1999-2000). When users arrive in the station by train or from outside or form intermodal stops (e.g. underground, bus, tram), they firstly need to locate themselves so that they can quickly move to the next destination. Information about personal navigation includes sign-posting to and within the station, station maps showing locations of the platforms and other facilities, and availability of localisation information (near site information, hotels and events) (CLOSER, GUIDE, KITE, LINK). Signage should be clear, standardised, and understandable to everyone (Figure 7), and amount, design and placement of signage are the three important elements to be considered as the GUIDE project maintained.

Figure 7. Italian station's standardised signage system in Genova (left) and DB's red cup staff (right) at Frankfurt Hbf.

Source: Otsuka, 2017

2) Real time and static information

There are two types of information required at the station: dynamic and static. Dynamic and real time information relates to real time scheduling for the arrival and departure of trains and intermodal connections. Although the MIMIC project pointed out 20 years ago the rare availability of real time information at interchanges, nowadays most of the large stations provide this type of information as well as track systems of running trains can be checked online anytime. In contrast, static information is, for example, line diagram and map of network services at the station, train timetable, and fare system descriptions (i.e. ticket prices and zoning system). In coordination with the placement of timetable, the visibility of clocks in the station concourses and platforms should be carefully considered. Finally, ticket vending machines are often complicated for non-locals and foreigners to use, and thus simplified ways of the payment or advice on purchasing tickets should be facilitated (MEDIATE).

3) Means of information and staff

Information can be provided through staffed information facilities or screens (real time digital displays or interactive screens). The availability of information about ticket sales, network services and destination information should be ensured ideally at staffed information desk or ticket office. In addition, DB has an interesting scheme of 'red cup staff' (Figure 7) that is walking round platform entrances or station concourses to be standby for answering user's questions on request. Although MIMIC criticised the level of staff training for providing adequate information in face-to-face situations, means of information provision has been extensively diversified over the last two decades due to the improvement of online information systems. However, it should be noted that many people would still find it difficult to read maps and timetables, especially foreigners, local ethnic minorities and people with learning difficulties.

4) Information for special cases

Further aspects on the information provision include special assistance required for disabled people (e.g. acoustic signals and braille maps for visually impaired). For example, Sala Blue of Trenitalia and Bahnhof Mission of DB are situated within all their bigger stations which aim to provide special assistance for disabled people. Both Principe and Brignole stations in Genova offer information boards targeting at blind people which are guided by tactile floor tiles, as the authors have found them during the observation.

Finally, emergency alert systems for traffic related accidents, severe weather or terrorist attacks were mentioned by previous projects (LINK, MEDIATE), and they would become more and more important due to increasing cases of terrorist related incidents in public spaces and severe weather warning in recent years.

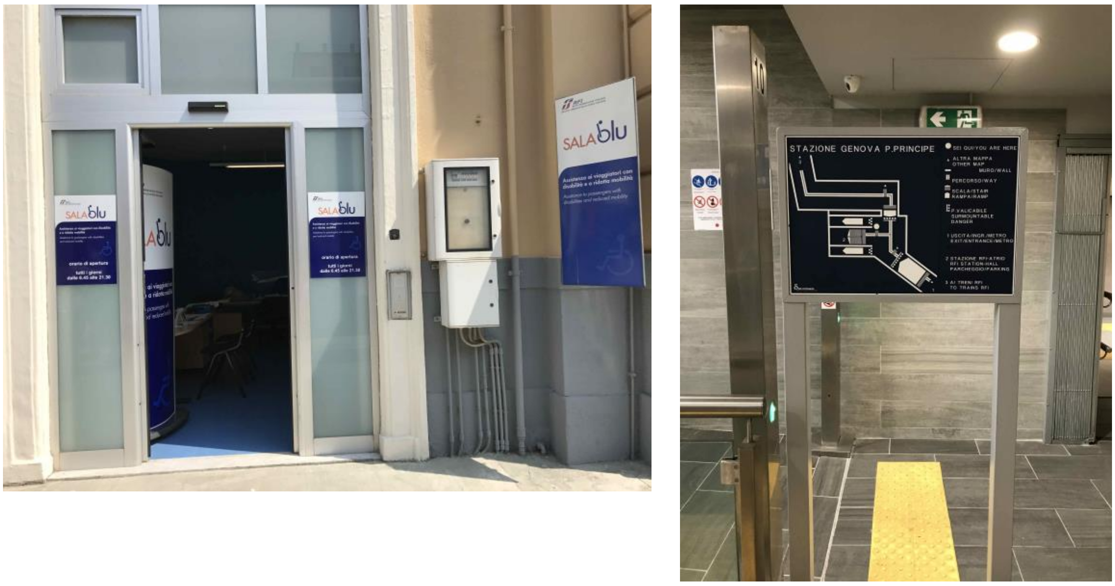

Figure 8. Sala Blue (left) and Signboard for blind people (right) in Genova Principe Station

Source: Otsuka, 2017

3.5 Management and business provision

So far the planning and design elements of the node have been discussed with reference to literature and previous EU-funded projects. Once a well-designed station is thoughtfully created and a good accessibility within and to/ from the station is ensured, it is necessary to take into account a long-term management of the station and its future business opportunities (e.g. revenues from retail, restaurants and hotels, property development in the adjacent areas, etc.), which are beyond transport related services.

This section starts with explaining services and station management (3.5.1) and then literature on property development and local economy is reviewed (3.5.2). For the purpose of keeping the station environment at high standard and economically buoyant, to provide safety and security of users is of paramount importance. Thus the final section is dedicated to this aspect (3.5.3).

3.5.1 **Services and station management**

The management of stations presents a very problematic nature since a public space is utilised by different socio-economic groups who have distinctive needs and expectations. Furthermore, the type of users vary depending on the time of a day or a week and even seasons (3.2.2), and thus every station requires flexible management strategies in order to fulfil requirements from various types of users on a case-by-case basis. In addition to so-called customers as defined by SEM, there are a number of people working in shops and restaurants as well as train operators' staff. The delivery routes of food and retail goods and back offices for those workers should be integrated in the station building and it is necessary to develop service and management systems in a holistic way.

According to van Egmond and van Hagen (2016), there are cases that stations are suffering from mismanagement when interchange managers and operators have not obtained the correct impression according to the different features of a public transport trip on the overall quality. The presence of a sufficient number of competent staff would bring a positive influence on customer satisfaction, and especially when different personnel (e.g. conductors, ticket sales, information desk, platform managers, service and security officers) have a clear understanding of their respective role and demonstrate a helpful attitude to customers, their journey experiences will become more positive and pleasant.

Also it should be noted that the presence of other customers would affect the experiences of the users. Station is a dynamic public space and it can be seen too empty or too busy depending on a different day and time and holiday seasons. When large crowds gathering before or after a major event in the city, some extent of disruption to services (e.g. long queues and overcrowding) is unavoidable, and to this end the station management team needs to develop a comprehensive management mechanism and to monitor the situation of platforms and concourses on a day-to-day basis. Madrid TIP (Madrid transport Interchange Plan, 2009) emphasised that it is essential to create points for addressing customers' complaint and suggestion due to the large number of passengers who use the transport interchange station daily. Furthermore, concerning the management of a large public space, planning for a day-to-day maintenance of janitorial work (e.g. cleaning of floors and toilets, empty rubbish bins, repair of damaged areas and street furniture, etc.) is extremely important to sustain the quality standard of stations (Otsuka, 2004).

Concerning services and management provisions, the station involves multiple stakeholders, who have different goals and requirements as well as multiple functions exist simultaneously, and they might conflict with each other. Both experts (e.g. regulators, station manager, operators, planners, local authorities, businesses, scientists; those groups are often described as professionals) and users (e.g. customers, local residents; often described as laypeople) are considered as important stakeholders (Zemp et al., 2011b). Although CLOSER called for the cooperation of transport operators for shared terminals and coordination of schedules, MIMIC identified the difficulty in unlocking institutional and organisational barriers in the decision making process. In addition to such barriers within the station premise, there is an increasing need to coordinate with its surrounding areas and even the city centres since the station has become the key anchor of rejuvenating a new image of the city centre. A holistic long-term management is the key to success for the station area and city centre regeneration.

3.5.2 **Property development and local economy**

The enhanced accessibility offered by transit proximity can often attract private investment into business and commercial activities around the railway station. Singh et al. (2014) noted that one of the TOD indices is private investment in the station area which can be measured with indicators such as number of business establishments, tax earnings of local authorities as well as unemployment levels.

With reference to the largest cities in the Netherlands, Bertolini et al. (2012) pointed out the fact that multi-modal locations have been experiencing the most intense property dynamics of the whole urban area. Another work using Dutch case studies also provided evidence in positive influence of HSR expansion on office location choices, and the availability of HSR services can contribute to the attractiveness of a location for offices, especially those for international firms which clearly value HSR stations for good international accessibility (Willigers and van Weer, 2011). In fact, the advent of new HSR lines often creates a catalyst effect on economic and residential activities of general interest. In many cases the realisation of new HSR stations significantly bring an increasing demand for space in their surrounding area, and it results in an increase in property values compared to the other parts of the urban area (Gargiulo and Ciutiis, 2010).

Due to the privatisation of rail industry transport infrastructure and service providers have sought several ways to recapture the accessibility advantage and to develop commercial activities within stations, or to redevelop land above or around stations (Bertolini et al., 2012) as a package of regeneration projects. For example, if there is underused space or any empty room in the station building, it can be rearranged for business usage such as meeting rooms and conference facilities. The study by Debrezion et al (2007) examined the influence of railway station proximity on property value in the Netherlands, and found that the effect on commercial property value takes places at short distances from stations: their survey results showed that commercial properties within 1/3 mile are 12.2% more expensive than residential counterparts. This is because retail activity is one of the key components of mixed-use development encouraged by TOD which generated more pedestrian flow. This situation obviously boosts retail business opportunities and brings fiscal benefits to local authorities through generating more business tax incomes (Schuetz, 2015).

While a number of positive factors on property value and local business have been discussed by previous literature, the increased accessibility also brings some disadvantages. Gentrification and the rise of crime and disorder are the two issues frequently mentioned by previous research. Dawkins and Moeckel (2016) introduced the term ‘transit-induced gentrification’ which causes the displacement of the low-income populations who lived in former industrial areas near the station. New transit investments tend to target housing development for higher socio-economic groups which often triggers the dramatic increase in housing prices in the station area. With regard to crime and disorder, Debrezion et al (2011) sees the growing retail business opportunities may attract pickpocketing, luggage lifting and drug misuse in the immediate location of station. The rise of crime and disorder often results in the degradation of urban environment and has a negative impact on residential, commercial and any other related demand (Gargiulo and Ciutiis, 2010).

3.5.3 **Safety and security**

Functional and operational aspects of the station are concerned with the improvement of the physical movement and convenience of users, while psychological aspects such as public safety and comfort is more closely related to user’s experience of a station as a public space (Hernandez and Monzon, 2016). As the comfort of users has been discussed in the previous section (3.3.5), this section focuses on safety and security of users.

Regarding personal security, the GUIDE project looked into design features and staffing elements which are effective to tackle crime and disorder as well as to reduce user’s fear of crime. They clarified the importance of visible staff presence as well as other attributes improving the sense of personal security, that can be enhanced by horizontal and vertical transparency in the station building, short and wide passageways as well as access to all areas with clear lines of visibility and eliminating blind spots. In particular, creating brightly lit space is really important, especially at night (Edwards, 1997), and the brightness can be secured through strong, but sympathetic lighting (GUIDE).

PIRATE identified certain characteristics that make users feel unsafe and unpleasant at stations. These are surveillance, toilets conditions, cleanliness of public space, and security against theft and vandalism, all of which have a close link with user's security concern. MIMIC stated that 'fear of crime is generally a serious deterrent to using public transport for most people' (van der Hoeve, et al., 2013: 69). There are different types of fear, for example fear of physical attack and violence from drunk people or drug-misusers, the danger of bicycle and car thefts and pickpockets, and these are problems people have experienced at most interchange stations. However, fear is often greater in the adjacent areas than within the station itself since casual surveillance from other passengers and staff is not available outside the building.

With regard to operational safety, GUIDE listed the following points (van der Hoeve, et al., 2013: 52)

- Movement of people and their waiting in normal or abnormal operating conditions;
- Provisions to control overcrowding;
- Sizing and treatment of surfaces, concourse, ramps, escalators, etc.;
- Suitability of escalators, lifts, conveyors;
- Number and size of exits, halls, etc.;
- Ventilation, lighting, etc.

Finally, an efficient traffic control system should be in place in order to secure passengers' safety when they are walking to the station entrance. There are many cases that users have to cross over busy roads or tramways, and also passenger drop-off and pick-up areas lack designated pedestrian access routes.

3.6 Environment and climate change

In spite of the growing awareness of issues related to climate change and environmental concerns, NODES revealed in their literature review that almost none of previous projects paid serious attention to energy-efficiency and environmental friendliness in the interchange premises (van der Hoeve, et al., 2013). ORIGAMI is one of the few projects which raised environmental concerns through reflecting user's expectations on transport companies and operation to take some actions to minimise the environmental impact by using low emission vehicles and clean energy. The European Commission has supported the CIVITAS initiative since 2002 with the aim of fostering a significant change towards a sustainable urban mobility by promoting sustainable, clean and energy efficient experiments. However, most of actions were centred on the technological side of testing clean vehicles and fuels or developing a mechanism for reducing air pollution through the application of congestion charge. Also CODE24 (Corridor Development 24 Rotterdam – Genoa, 2010-2015) examined a better system for rail freight and inland waterways and their capacity analysis in order to shift a large amount of goods transport from road transport.

The European Commission set up a clear target on delivering the minimum 60% reduction of GHG emission from transport needed by 2050 (EC, 2011: 17). Given the fact that urban transportation is responsible for one fourth of the total GHG emissions by the transport sector which accounts for approximately 7 % of the total GHG emissions in the EU, it is vital to promote the use of integrated, accessible and environmentally friendly public transport system (Gonzales-Gil et al., 2015). However, station has not been the main focus of previous research and EU projects in response to SUMP and other policy documents on the climate change adaptation, despite there are a number of issues which can be dealt with in the station premises. Van der Hoeve, et al. (2013) listed the following solutions from the perspectives of climate change adaptation, resource management and energy efficiency.

In terms of climate change adaptation strategic plans and designs for adapting to extreme weather such as high temperature and flooding should be in place. For example, 'overheating is effectively dealt with by a combination of fixed external shading on the south and west sides and the air currents of passing trains, which provide effective and regular cooling (Edwards, 1997, xi)'. Also evidence of local biodiversity (e.g. living roofs and walls) has been noticed and adequate plans for protecting biodiversity and ecosystem is required within stations, while environmental hazardous living and spices such as rats, mice, cockroach, pigeons and weed should be controlled (Van der Hoeve, et al., 2013).

There are a number of ways of pursuing effective resource management. Examples are grey water recycling, use of recyclable materials and goods, flow control of water on fixtures and fittings in toilets. A mechanism for water management should be set up in each station in order to monitor regular water use during operation and construction. Waste management such as recycling options for rubbish collection needs to be considered together with the operational aspects of janitorial work. Energy efficiency can be improved through lighting control, energy monitoring, plan for low & zero GHG emissions through passive heating and cooling as well as solar water heating system. Building form has a potential to contribute to saving energy when building orientation, the use of natural light, air tightness and thermal mass are carefully designed as noted above (Van der Hoeve, et al., 2013).

Finally, it is important to increase public awareness of the use of resources and energy and outreach strategies are especially required.

4. Accessibility to and from node

4.1 Introduction

The important role of accessibility to and from TEN-T corridor nodes in enhancing transport flows, intermodal and sustainable mobility, and the reduction of air and noise pollution is widely recognised by the European Commission (European Commission, 2013; European Union, 2013). In addition, different studies suggest that the journey to and from the rail station can influence both passenger numbers and passenger satisfaction with rail travel (Bros, et al. 2009; Givoni and Rietveld, 2007; Semler and Hale, 2010; Monzon et al., 2016; La Paix and Geurs, 2016). Therefore, accessibility to and from railway stations is a key element that needs to be considered when planning for a European green and seamless door-to-door transport, and improvements in higher speed connections between nodes should be accompanied by improvements in urban accessibility to and from nodes (Rietveld, 2000).

According to Geurs and Van Wee (2004) there are four important components for measuring accessibility:

- **land use**: considering opportunities (i.e. jobs, shops, etc.) at destinations and the demand for these opportunities at origins;
- **transportation**: describing the transport system, expressed as the disutility for an individual to cover the distance between an origin and a destination using a specific transport mode;
- **temporal**: reflecting temporal constraints, i.e. the availability of opportunities at different times of the day;
- **individual**: including the needs, abilities, and opportunities of individuals.

Although the importance of all four components is acknowledged, the transportation component was considered the most significant for the purpose of the present work, which aims to explore the transport connectivity between the node and the urban area where it is located. As a result the literature review was focused on transport related indicators. In addition, it was decided to concentrate on disaggregated indicators rather than a composite one, since they:

- better describe reality as their value is not influenced by weights, unlike composite indicators;
- are more effective in identifying discrepancies, underlying issues and whether specific objectives have been met;
- are more durable in time as single indicators can be easily used for future monitoring of specific aspects.

Accessibility does not in principle favour certain modes over others (Venter, 2016) and, in relation to railway stations, it is usually examined for four transport modes: walking, cycling, public transport and car (driver and passenger) (Semler and Hale 2010). Nonetheless, the present section will focus only on three transport modes:

- public transport
- cycling
- sharing mobility (bike sharing and car sharing).

Walking is a dominant mode for accessing railway stations for short distances and therefore is closely related to the characteristics of the area surrounding the node. As such, it is examined under "*Indicators and Criteria at Node*"(see Sec. 3.4).

Car transport on the other hand was not taken under consideration for the following reasons:

- an already high level of car accessibility in European urban areas, thanks to urban planning practices until recent years;
- adoption of SUMPs by an increasing number of local authorities with the aim to promote alternatives to car transport;
- EU targets and objectives for a more sustainable and less polluting transport sector, i.e. reduction of carbon emissions in transport by 60% by 2050 (EC, 2011).

Nonetheless, the present work recognises the importance of car transport in node accessibility and therefore this mode is examined in relation to the node and its surrounding area, with a particular focus on station facilities catering car transport (see Sec. 3.3.3).

Finally, the analysis included sharing mobility, and in particular bike sharing and car sharing[3], due to the growing popularity of the phenomenon and the existing collaboration between railway and sharing mobility operators (e.g. SBB with Mobility Car Sharing in Switzerland). However, carpooling is not included in the assessment of accessibility to and from the node because:

- it is assumed that the road network in urban areas offers a high level of accessibility for this mode of transport;
- there are already well known web/mobile applications available throughout Europe enabling carpooling (e.g. BlaBlaCar);
- the presence of parking spots dedicated to carpoolers at the station is examined under Sec. 3.3.3.

With the aim to develop a methodology for reviewing accessibility to and from the node and enhancing node access planning, the following sections will provide an outline of existing indicators for the assessment of node accessibility at urban level. Factors affecting the different modes of transport and relevant indicators are going to be presented, starting with the description of context elements affecting all modes of transport (4.2) and followed by a section on public transport (4.3), one on cycling (4.4) and another on sharing mobility (4.5). A final section (4.6) is examining additional factors influencing node accessibility that are common among the different modes.

It should be noted that elements of the node and its surrounding area affecting node accessibility by different transport modes (e.g. bike parking facilities, public transport bus stops) have already been examined under section 3 "*Indicators and Criteria at Node*" and are not part of this section.

4.2 Accessibility to and from node – context

The first elements to be examined provide context information on railway stations and are not related to specific modes of transport, nonetheless, they offer a preliminary indication of their level of accessibility.

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[3] Car sharing (car clubs in the UK) is a model of car rental where people rent cars for short periods of time, often by the hour. It should not be confused with carpooling which refers to the sharing of a car journey so that more than one person travels in a car.

Distance

Distance and the corresponding travel time are the main parameters used for analysing the impediment of travelling between an origin and a destination.

Distance of a node from residential areas, jobs and key trip attractors/generators provides a first indication of its accessibility. It is a key factor that determines the mode of choice used for accessing a node. For example, Givoni and Rietveld (2007) indicate that there seems to be a trade-off between bicycle and walking when distances to railway stations are short and a trade-off between bicycle and public transport when distances are longer. Therefore, the location of a node and its distance from the urban core is an important context factor that influences what constitutes a successful use of the node (Kittelson and Associates, 2012). For example, the low level of walking access would be a failure for a station located close to the city centre whereas it would not be viewed as such for a station located outside the city.

It appears that distance also influences railway use, in fact, a study in the Netherlands has determined that frequency of railway use tends to decline as the distance between residence and railway station increases (Keijer and Rietveld, 1999, cited in Rietveld, 2000).

Example of Distance Indicators:

- Proximity:
  - Euclidean distance (as the crow flies) between an origin and a destination (and the corresponding travel time)
  - Definition of the shortest path on the transport network that connects an origin and a destination and estimation of its distance and travel time (SiTI, 2007)

Access Opportunities

The opportunities available for accessing a railway station are determined by the variety and type of transport modes serving it. Accommodating for different transport modes at a node could present difficulties due to limited land availability and possible conflicts between them, nonetheless a variety of transport options is recommended as it offers higher flexibility of movement and, therefore, higher accessibility.

A good assessment of the overall accessibility of the node should address all the available modes separately.

Example of Access Opportunities Indicators:

- Number of modes serving the node (Malicet et al. 2013)

Catchment Area

Catchment areas serve for estimating the potential number of travellers and it can be estimated for each mode serving the node separately.

There are different methods for assessing catchment areas, the simplest one being the buffer approach that estimates the number of travellers in an area defined by a fixed radius from the node under consideration (Andersen and Landex, 2008). It can also be based on travel time contours, considering elements such as network and service speed, and land use intensity (SNAMUTS, 2016).

It can be expressed either as a number or as a proportion of the entire population and jobs present in an area.

Example of Catchment Area Indicators:

- The proportion of the population living within a given distance of the destination able to access it within a specified time. (Department for Transport, 2015a)
- Population reach at xx minutes (e.g. 10, 20, 30, 45 and 60 minutes) travel by any mode from the interchange (Albecoa et al, 2013)
- Circular buffer: estimation of the potential number of travellers for a PT stop considering the number of inhabitants and workplaces in a Euclidean distance from the stop. (Andersen and Landex, 2008)
- In the case of PT, catchment area can be estimated along a bus route by defining the area of influence for each bus stop, and the merging of all bus routes can provide an overall bus catchment area (Galiza and Charles, 2013).
- Catchment size of xx-minute (e.g. 30-minute) travel time contour. It determines the number of residents and jobs within the walkable catchment areas of activity nodes[4] that can be reached within a kerb-to-kerb public transport travel time of up to xx minutes from the reference node. This indicator is expressed as a percentage of the total number of metropolitan residents and jobs and is shown as an average for each node. (Curtis et al. 2012; SNAMUTS, 2016)

Modal Split

Modal split, that is the percentage of travellers using a particular type of transportation for reaching a destination, a railway station in this case, offers a clear picture of the actual use of the different modes when accessing a node. It is thus a useful input for station managers that wish to improve accessibility to and from the station and, in particular, when certain modes are to be favoured over others.

Modal split is determined by the surrounding land use types and densities, as well as the availability and level of service of the different modes, e.g. frequency and coverage of PT, existence and quality of a cycling network, walking connectivity, presence of park and ride service etc. (Kittelson and Associates, 2012). Attention should be given to the fact that railway users tend to have access to private modes (i.e. car, bicycle) mainly at the home end of the trip, therefore, it might be appropriate to differentiate between the modal split of access and egress to the station.

A comparison between the modal split of node access and that of all trips in the municipality is also advisable, since it offers a baseline for measuring the performance of the different modes. For example, the share of cycling as access and egress mode of train passengers in the Netherlands is around 23%, which appears rather high when compared to other European countries, however, it is not particularly high for the Netherlands where the share of cycling in all trips is around 28% (Rietveld, 2000).

[4] They refer to the list of higher-order activity centers across a metropolitan area (Curtis et al. 2012)

4.3 Public transport

Public transport represents an important feeder service for railway stations as it (Semler and Hale, 2010; Kittelson and Associates, 2012; Galiza and Charles, 2013):

- increases the catchment area, especially for longer distances where walking and cycling do not represent a valid alternative, or when it is difficult to access the node with these modes (e.g. presence of luggage);
- offers access to the node for the elderly, disabled, people that do not have access to a car, and it, therefore, contributes to a more equitable transport system;
- places less pressure to the local road network and the area surrounding the node than the car;
- is less land demanding compared to park-and-ride, which is of great importance especially for nodes located in areas where there is limited land availability and land costs are high (i.e. cities).

In addition, public transport is an important transport mode for the last mile of the trip chain, where node users do not have access to private modes, i.e. car, bike.

Nonetheless, the use of public transport for the trip to and from the station is influenced by a number of factors, such as the availability of the service at the trip origin and destination, duration of the trip, frequency of the service, etc.

The literature collects various indicators for the evaluation of public transport services, a collection of which is presented below.

Public Transport Supply

Public transport supply indicators are used for monitoring the quantity of public transport lines that feed a destination.

Example of Public Transport Supply Indicators:

- Number of rail lines, bus lines, metro lines, and tramway lines that serve the node (Christiansen and Andersen, 2013; Albecoa et al., 2013; Grafl et al. 2008 - KITE)

Travel Time (or Access Time)

Travel time together with public transport frequency (see below) are probably the most common indicators used for monitoring and evaluating public transport accessibility for reaching a destination. Travel time indicates the time necessary for travelling from origin to destination and, in the case of PT, it often integrates the walk time to PT access points (i.e. bus stops) at the origin.

The UK Department for Transport in its transport connectivity statistics is also proposing a weighted travel time indicator, which in addition to the travel time measure accounts also for the importance of a destination (e.g. size of transport node). However, this approach appears to be more useful when evaluating the overall connectivity of an area (Department for Transport, 2015a).

In all cases the lowest the travel time the highest the accessibility between origin and destination with PT.

Example of Travel Time Indicators:

- Access time from a zone to the selected location calculated on the shortest path (SiTI, 2007). It provides the minimum travel time from origin to destination
- Average travel time from origins to destinations. It provides a measure of actual travel times (Department for Transport, 2015a)
- Network closeness centrality: average of minimum travel times from the node to all other transport nodes in the network (Albecoa et al, 2013)
- Representative travel times for arrival at 8am, arrival by 8:30am and arrival by 9am with early arrival of up to 30 minutes in all three half hour periods (Department for Transport, 2015a)
- Weighted indicators for access to destinations (for origin areas): it provides a measure of travel time from origin to destination, accounting for the importance of the destination (for example, size of airport). They measure the opportunities available from a given origin. (Department for Transport, 2015a)

Frequency and Waiting Time

Frequency describes how often a PT service is provided at a location (per direction) and is usually measured for a specific period of time (e.g. 8:00am - 9:00am), since service frequency can vary during the day according to transport demand. Attention is also paid to the day of the week frequency is measured since there can be variations between different days (e.g. there are often frequency variations of public transport services between weekdays and weekends),

Example of Frequency Indicators:

- Number of departures per hour per direction between two nodes (Curtis, et al, 2012)
- Number of transit vehicles per hour and its reciprocal (headway - time interval between transit vehicles) (Galiza and Charles, 2013)

The frequency indicator can also be expressed as the time users have to wait at PT access points for the service (waiting time). In this case, the punctuality of the service can also be taken into consideration.

Example of Waiting Time Indicators:

- Schedule waiting time (SWT) for each route at each service access point is based on service frequencies in a reference period (e.g. 8:15-9:15) on a weekday. SWT(minutes) = 0.5*(60/frequency) (Transport for London, 2015)
- Average waiting times (in minutes) for each route at each service access point equals the schedule waiting time plus a reliability factor (in minutes). The reliability factor varies by mode of transport. It reflects the fact that actual waiting times can be longer because services do not arrive in an entirely regular manner (Transport for London, 2015)

Transfers and Centrality

The number of transfers separating the node from a destination is often used to indicate the directness of a trip and the centrality of the node in relation to the transport network. Another measure of the directness of a trip is the presence of shuttle buses between a node and major trip attractors/generators (Galiza and Charles, 2013; Kittelson and Associates, 2012), which indirectly evaluates the lack of transfers. Nonetheless, it should be noted that higher directness of a trip does not necessarily translate into higher accessibility, since transfers are a necessary component of the public transport system and they can lead to similar travel times and higher accessibility of the overall area.

Centrality, on the other hand, it can also be measured in terms of the extent to which a node is located 'at the crossroads' of public transport supply (SNAMUTS, 2016) and, therefore, how central it is with reference to the network. The more central a node is the easier it is to access it.

Example of Transfers and Centrality Indicators:

- Number of transfers carried out during the shortest path trip between origin and destination. (SiTI, 2007)
- Average Necessary Transfers: it represents the average value of necessary transfers on the shortest path from the node to all other transport nodes in the network (Albecoa et al, 2013)
- Degree of centrality: a topological network indicator, measuring the minimum number of transfers between each pair of activity nodes. It is calculated as an average for each activity node. Lower values indicate greater centrality (Curtis et al., 2012; SNAMUTS, 2016)
- Network betweenness centrality: it calculates the number of times (and %) an interchange is included within the optimal routes (e.g. shortest path) from every transport node to all others in the network (Albecoa et al, 2013)

Comparison of PT with Car Travel

Indicators comparing PT with car travel can be really useful, especially when the aim is to promote a modal shift towards PT, since they can provide an insight regarding the performance of PT against the most popular mode of transport, and can highlight areas of the service that require improvement.

Example of Comparison of PT with Car Travel Indicators:

- Ratio of car and public transport travel time (Venter, 2016)
- Relative affordability: cost of bus fare per mile relative to equivalent petrol cost and taxi fare (on fixed O/D relations) (Abley and Halden, 2013)

Information Availability

Accessibility with PT is also influenced by the availability of information on existing services as they facilitate the use of PT services and alleviate uncertainty on the reliability of the service. There are different channels that can be used for providing PT information to the public and vary from the most traditional ones, such as service timetables displayed at the bus stop, to more technological ones, like mobile applications providing real-time information on the service.

Example of Information Availability Indicators:

- Access to information: number or % of bus stops with travel information displays (Abley and Halden, 2013; Christiansen and Andersen, 2013)
- Quality of real-time information and other system-navigation aids for passengers (Semler and Hale, 2010)
- Availability of information/services (e.g. ticket purchase) accessible through mobile devices (PDA, PC, smartphone, tablet, etc.) (Malicet et al. 2013)
- Door-to-door information, pre-trip/on-trip information, real time information, information system of interchanges - access to relevant information (timetables, fares) in different languages via internet, cell phone, etc. (Kuhnimhof et al 2007-KITE)

4.4 Cycling

Cycling is an economic and flexible mode of transport, that is increasingly recognised at urban level as a key feeder and distributor mode for public transport, especially in Northern European countries (La Paix and Geurs, 2016). Being more flexible than PT and faster than walking, it is a convenient means of transport for access to railway stations, especially for intermediate distances that are too long for walking but too short for public transport (Martens 2007; Galiza and Charles, 2013).

Railway station access data from the Netherlands confirms the importance of cycling. According to Givoni and Rietveld (2007) in 2005 38% of the trips to railway stations (at the home end) was carried out by bike, followed by PT (27%) and walking (20%) (see Figure 9 below).

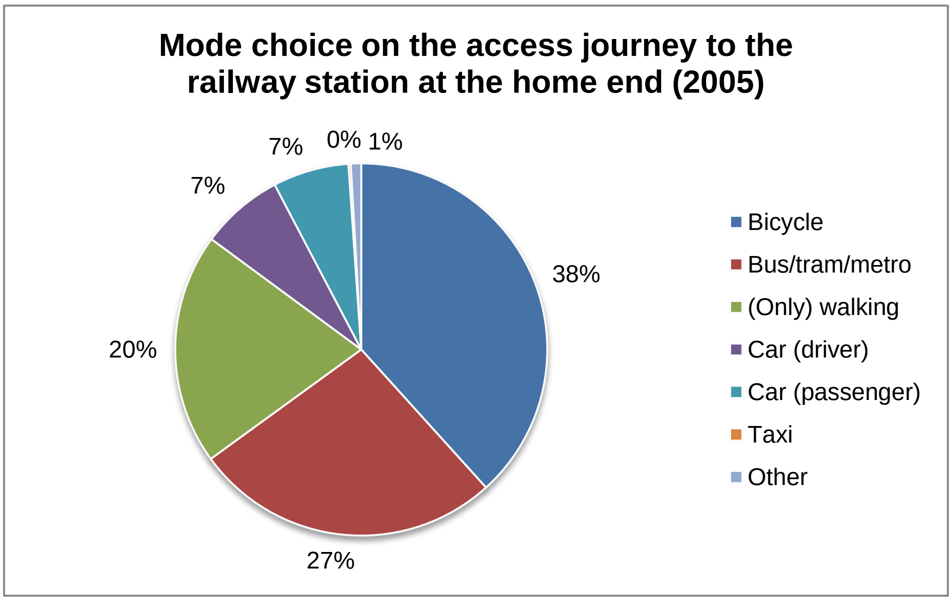

Figure 9: Modal choice in access to the railway station at the home end in the Netherlands

Source: Givoni and Rietveld, 2007 (graph elaborated by SiTI)

It should be noted that access to railway stations by cycling is more likely at the home end of a trip since bicycles are usually privately owned and, therefore, are available at home. The possibility and ease of taking bikes into the train can greatly influence the accessibility to and from the railway station by bike at the activity end. The presence of bike sharing (see section 4.5) and bike rental services at railway stations can also have a positive impact to the use of this means of transport for trips to and from the node (Rietveld, 2000).

Cycling accessibility to and from the station is influenced by factors such as bicycle network connectivity, traffic volume and speed, topography, climate, bike-and-ride facilities at the station, as well as general level of cycling (Galiza and Charles, 2013; Semler and Hale, 2010). It is evident that station managers do not have a direct influence on most of these factors, which (apart from topography and climate) depend mainly on infrastructure and general cycling policies set by local governments. Nonetheless, cycling presents a cost-effective access mode for railway stations (Semler and Hale, 2010) that contributes to social equity by offering a transport alternative for those that cannot (afford to) drive (Martens, 2004). Therefore, it is important that station managers evaluate cycling accessibility to and from the node and collaborate with local authorities and relevant stakeholders in order to improve it (Galiza and Charles, 2013; Green and Hall, 2009).

The indicators listed below are related to factors affecting cycling accessibility outside the station area and, therefore, elements such as parking facilities, ease of access within the station, etc., are not included here since they are examined under "Indicators and Criteria at Node" (3.3.3).

Cycling Infrastructure

The presence of continuous and safe cycling infrastructure is an important factor affecting the use of this mode of transport for the trip to and from the node.

Example of Cycling Infrastructure Indicators:

- Presence of a safe, easy-to-access and continuous bicycle network (Semler and Hale, 2010; Galiza and Charles, 2013; Kittelson and Associates, 2012)
- Integration of bicycle routes within the overall street network (Galiza and Charles, 2013)
- Characteristics of the cycling network (Monteiro and Campos, 2012):
    - effective lane width of bicycle lanes
    - regularity of lane pavement
    - presence of trees
    - street lighting
- Safety (Monteiro and Campos, 2012):
    - safe crossings
    - distance from vehicle flow
    - flow vehicle density
- Gradient of bicycle lanes (Monteiro and Campos, 2012)

Distance

Distance is an important factor that influences accessibility to and from railway station by bike due to the physical effort required by this mode. According to Rietveld (2000) cycling as an access mode is dominant for distances between 1.2 and 3.7 km, which is in line with Givoni and Rietveld (2007) that suggest that access by bike is highest within 3 km. Green and Hall (2009) on the other hand suggest that the average distance covered by bike for reaching a railway station is around 5km (3 miles).

Information Availability

Information on cycling network in relation to railway stations can also have a positive impact to the share of cycling in accessibility to and from the node.

> **Example of Information Availability Indicators:**
>
> - Are bicycle route and network maps provided and easily accessible? (Galiza and Charles, 2013)

4.5 Sharing mobility: bike sharing and car sharing

Accessibility to and from the node should also consider sharing mobility (i.e. bike sharing and car sharing) as it provides alternative modes of transport for access to and from railway stations beyond walking distance, and consequently increase their accessibility.

As it was mentioned earlier (section 4.4) cycling at the activity end of a trip is limited due to the fact that bikes, as a private mode of transport, are mainly available at home and usually there are restrictions for their transport on trains. Thus, bike sharing provides a solution for those who cycle at the origin station or those who only want to cycle for one leg of the journey (Galiza and Charles, 2013), and can increase cycling while reducing car use. In fact, a study of Dutch initiatives to promote bicycle use in access trips determined that flexible rental bicycles at train stations resulted in "*a small reduction in car use, growth in train trips, and growth in bicycle use for non-recurrent trips*" (Martens, 2007).

Similarly, car sharing offers an alternative for addressing the first or last mile of railway trips.

Many of the factors influencing cycling accessibility to and from railway stations are also relevant for bike sharing, i.e. cycling infrastructure. Since these elements are already considered in section 4.4, this section will concentrate on the availability of bike sharing at the station and near origins/destinations. This is also true for car sharing as the present work assumes that railway stations can be easily accessed by car.

It is clear that both for bike sharing and car sharing the station managers do not have a direct control on the service, therefore, they should seek a close collaboration with the relevant operators in order to ensure their most appropriate positioning and achieve the highest benefit possible. As noted in the previous chapter (3.5.1), a range of stakeholders are generally involved in station management and their conflicting interests should be coordinated.

> **Example of Sharing Mobility Indicators:**
>
> - Are cycle hire facilities provided near origins/destinations and stations? (Galiza and Charles, 2013)
>
> This indicator, revised accordingly, can also be applied to car sharing.

4.6 Additional elements influencing accessibility to and from node

Accessibility to and from node is also influenced by the accessibility of information on the available modes of transport and the ease of combining them. In other words, the integration of information and fares among different transport operators and modes has a positive impact in the ease of access to railway stations as it allows easier and more reliable transfers. Nowadays information and communication technology has greatly enabled such integrative policies, i.e. urban journey planners combining different modes of transport, smart cards combining all modes on a single ticket, common sales channels.

Example of Information and Ticketing Indicators:

- Availability of public transport journey planner for pre-trip planning (Christiansen and Andersen, 2013)

This indicator could be generalised in order to consider all modes of transport.

- Existence of interoperable systems enabling integrated fares (Malicet et al. 2013)
- Existence of integrated fares (Malicet et al. 2013; Kuhnimhof et al 2007)
- Existence of common media / ticket between transport operators/networks (Malicet et al. 2013; Grafl et al. 2008; Kuhnimhof et al 2007)
- Smart ticketing (Christiansen and Andersen, 2013)
- Existence of pricing framework and multi-trip tickets (Malicet et al. 2013)

5. Summary and next steps

This literature review has presented existing criteria and indicators for assessing the urban node accessibility. Within the framework of Activity 1 of the RAISE-IT project ‘urban node’ is defined as an urban area where the railway station is located, while the term ‘node’ itself means a railway station. Existing indicators have been reviewed with reference to three levels of spatial contexts 1) accessibility at/within a node (i.e. railway station); 2) access relationship between a node and its surrounding areas within a radius of 800 m from a station; and 3) accessibility to and from a node at urban scale, within the town and city boundaries.

Chapter 3 has focused on indicators concerning the performance of railway station and its connection with surrounding areas. Five main criteria have been identified to present existing indicators which were used for rail node studies by previous research. These are: Integrated planning and mix-land use at / around a node; Design of node; Pedestrian access and information provision; Management and business provision; and Environment and climate change. These indicators are concerned with diverse subject areas ranging from spatial planning, architectural and urban design, user perception, management and business planning to environmental issues. On the other hand, the focus of Chapter 4 has been placed on transport related indicators since the chapter aims to explore the transport connectivity between node and urban area within the town/city boundaries. After providing context information affecting all modes of transport, indicators for examining public transport, cycling and sharing mobility have been presented, and then additional elements influencing accessibility to and from node have been discussed.

This literature review has provided an overview of relevant criteria and indicators to RAISE-IT and will be used as a basis for developing tailor made benchmark indicators for examining the six urban nodes (Arnhem, Nijmegen, Düsseldorf, Frankfurt am Main, Karlsruhe and Genova). In the next stage, Task 2 will start with creating a list of indicators which will be used for data collection in the six urban nodes. Subsequently, a methodology for data collection and analysis will be identified in collaboration with local partners from the six urban nodes.

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7. List of Abbreviations

AFCS	Automatic Fare Collection Systems
AV	Alta Velocità (Italian HS)
AVE	Alta Velocidad Española (Spanish HS)
B+R	Bike and Ride
CIVITAS	Cleaner and better transport in cities, 2002- on going
CLOSER	Connecting Long and Short-distance networks for Efficient transport
CODE24	Corridor Development 24 Rotterdam – Genoa
DB	Deutsche Bahn
GUIDE	Group for urban interchanges development and evaluation
HSR	Used in some graphics and for statistical units: Belgium (BE), Germany (DE), ES (Spain), FR (France), IT (Italy), NL (the Netherlands), SE (Sweden).
KITE	A knowledge base for intermodal passenger travel in Europe
LINK	The European forum on intermodal passenger travel
K+R	Kiss & Ride
Madrid TIP	Madrid transport Interchange Plan
MEDIATE	Methodology for Describing the Accessibility of Transport in Europe
MIMIC	Mobility, intermodality and interchanges
NFC	Near Field Communication
ORIGAMI	Optimal Regulation and Infrastructure for Ground, Air and Maritime Interfaces
PIRATE	Promoting Interchange Rationale, Accessibility and Transfer Efficiency
PPP	Public Private Partnership
P+R	Park and Ride
PRM	Passenger with Reduced Mobility
PT	Public Transport
SEM	Station Experience Monitor
SUMP	Sustainable Urban Mobility Plan
SWITCH	Sustainable workable intermodal transport choices
TDA	Transport Development Areas
TJD	Transit Joint Development
TOD	Transit Oriented Development