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DEGREES OF SUSTAINABLE LOCATION OF RAILWAY STATIONS: Integrating Space Syntax and node place value model on railway stations in the province of North Holland's strategic plan for 2010-2040

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Abstract

Mobility on rails is acknowledged to be one of the most sustainable means of transportation between cities and towns. Therefore, a railway station's location in a built environment and its degree of accessibility is essential to reach as many travellers as possible. Even though there exist several writings on network cities and TOD principles concerning rail accessibility to urban centres and sub-sentres, the spatial configuration of the local street and road network in a railway station's vicinity is seldom taken into consideration in the discussion on railway transport. Therefore, two different analyses methods were used with purpose to identify the degree of regional and local inter-accessibility of all train stations in the province of North Holland in the Netherlands. The space syntax method provided measurements on a street net's inter-accessibility on different scale levels, while the Node Place model analyses provided the degree of a station's attractiveness in terms of place value and means of transportation value. As the results show, correlations were found between a station's degree of local and regional accessibility and frequency of the timetables. When implementing and improving sustainable means of public transportation, urban functions such as dwellings, shops, services, workshops and offices have to be in short walking distances from stations and the street network must be easily understandable for way-finding. The results from this inquiry were applied in the province's policy plan as a priority list for station improvements in terms of degree of local accessibility. Moreover, the priority list of the implementation of new housing areas was made on basis on the degree of local and regional accessibility to existing railway stations.

1. INTRODUCTION

Inter-accessibility is acknowledged in regional planning to be an important socio-economic indicator influencing several decisions concerning land use and infrastructural planning. It has been well documented that car dependence gives impacts on the environment, urban social life and economic investment and development. The more private car-dependent a city is, the more of the wealth of its inhabitants is spent on getting around (Newman & Kenworthy 1999). Conversely, the more a city spend on public transport, the more it saves space and the more space is available in the urbanised areas to generate diversification and intensification within short walking distances for the creative economy (Hall 1997 and Jenks 1996). Inter-accessibility can be approached from several scale levels in built environments, from neighbourhood level up to large regions. In this context, inter-accessibility means that a place or a node can easily be reached by a large variation of mobility means within a reasonable travel time.

In 2008 the province of North Holland in the Netherlands asked two researchers from Delft University of Technology, Faculty of Architecture to carry out space syntax analyses of the road and street network in the whole province. The purpose was to use these analyses in the new strategic plan for the next 30 years for the province.

The Netherlands has, in comparison with other European countries, a high density of the rail network. Trains are running frequently, and even several small villages are connected to the rail network. The Dutch capital city Amsterdam and Schiphol international airport are both located in province of North Holland. In total the province has an area of 2670 km2, and 2.613.992 people are at present living in the province (Structuurvisie 2008). The density is 979 inhabitants pr km2. Most of the urbanised areas are around Amsterdam and Haarlem, while the rural areas are in the province’s northern parts.

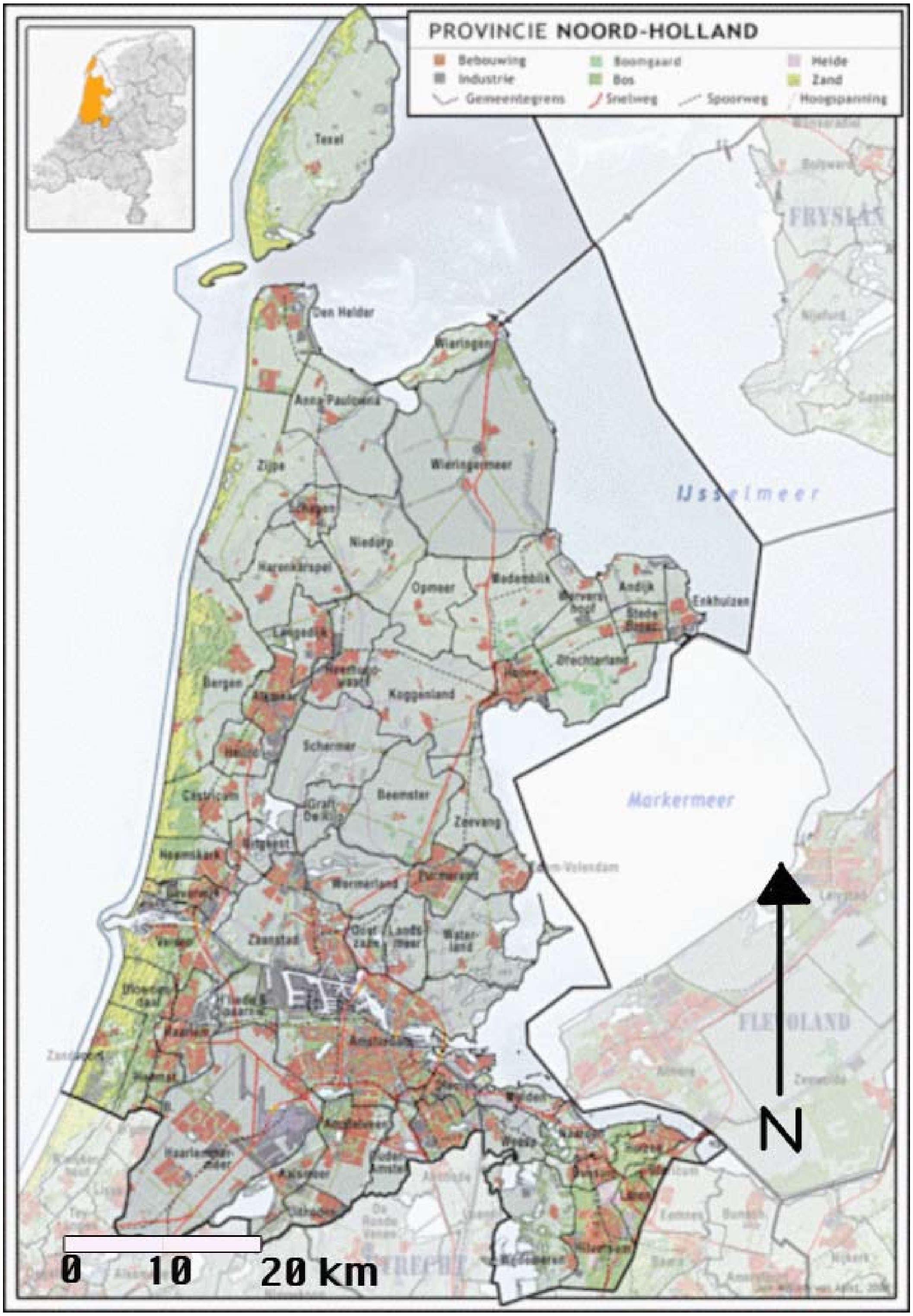

Figure 1: Map of province of North Holland.

In total there are 57 railway stations in the province. They vary from larger metropolitan railway stations, airport stations, intermodal hub stations, small local stations with one building along rail tracks, to just a track with a ticket machine along the rails. A strategic plan for the railway network is important for the province. It is acknowledged to be the best way for solving the traffic congestions problems in the urban areas inside and around Amsterdam (Structuurvisie 2008). Moreover, the rail network has to inter-connect the remote areas to the larger cities with frequently running trains. In particular the rail network also has to serve people who can or do not travel by car.

It is often believed that a railway station attracts economic activities such as shops, retail and offices. However, the spatial configuration of the local street and road network in a railway station's vicinity is seldom taken into consideration (Mulders-Kusumo 2005). Some stations are easily accessible by foot or by public transport, while others can only be reached by private car. Therefore the next question is to find out how sustainable the public transport network is in the province in terms of the degree of accessibility of railway stations to the built environment on various scale levels. First a review of writings on railway stations and built environments will be given. The literature about railway stations and urban development can be grouped in two groups. One is about the role of the railway station itself and its surroundings, and the other is about the role of the mobility network in a large metropolitan context. The discussion is brought in light with the compact city debate. Then the methods applied in the case studies will be described. Then the case studies are presented and finally the application of the results in strategic planning will be discussed.

2. THE RAILWAY STATION, ITS VICINITY AND SUSTAINABLE DEVELOPMENT

Railway stations are points of transport interchange where the departure and arrival activities take place. In essence, the station is a space between a particular place and the trains (Edwards 1997, p. 173). A railway station is a public place with a public facade to the city, open for everyone. At present, railway stations perform a variety of functions. First of all, they are places where people change from trains to the pavement, to subways, buses or cars, to a bicycle, a taxi, the light rail, to other trains, or to airplanes. Otherwise they simply arrive at their final destination, which is in the immediate vicinity of the railway station. Furthermore, train stations are also shopping malls, meeting places and urban landmarks. The passenger's station is the architectural manifestation of the railway system and its connection with the urban fabric. It is both a gateway to a rail network and it is a threshold for passengers entering a city. "What gives the railway station particular significance as architecture and essential elements in the life and cultures of cities is precisely this interface between these two worlds - the railway system and the urban back cloth" (Edwards 1997, p. xi).

After half a century of a globally high emphasis on road construction and an equally widespread neglect of railway infrastructures, the last two decades were marked by a renaissance of the railway. Due to increased pollution, congestion of private cars in streets, ecological movements and an increased public interest in sustainable development, public transport by rail has regained attention the last two decades. The railway system can be regarded as a solution for the transport problem of the cities. The ecological benefit of travelling by train, combined with technical breakthroughs concerning new types of trains, such as the fast French TGV trains running at 250 km/h, new types of suburban light rail systems, and new combined types of metro systems has led to an increased rail investment. Likewise, new high-speed rail links have been built between cities such that a throughout modernisation of the old railway stations or the construction of new ones became inevitable. One was thus heading for a functionally smooth transport system. Basically, it seems that modern railway stations mostly have the same spatial structure as old ones. The textures of the material, however, are slightly different (Edwards 1997, p. ix). Modern railway stations appear to be lighter, safer, and more commercial than older ones.

Interestingly enough, stations have become important economic catalysts for urban development. Their improvement has lead to massive urban development around several station areas, due to that the location of rails is fixed and last a long time. It gives a certainty for investment going beyond the period that investors need to get their investment back (Cervero 2003).

Airport stations and intermodal hub stations located in industrial areas are poorly connected to the local place where they are located. Larger railway stations are placed within or close to a city centre. They are localised in its dense network of central facilities. It is even more a part of city life, with a smooth transition from the city street to a seat on the train (Edwards 1997, p. 26). In smaller towns or villages, the railway station tend to be one building located along the tracks. Often the architecture of the building mirrors the local building style at the place. The smallest type of railways station consists of a track located along the rails with one shelter for the rain and a ticket machine. These stations tend to be located in the countryside or in post-war sub-urban areas.

3. THE RAILWAY STATION, THE REGIONAL SCALE AND SUSTAINABLE DEVELOPMENT

On a policy level, two major streams of thoughts are identified on how to design places and infrastructure networks for generating sustainable mobility means. The first one is the Transit Oriented Development (TOD) inspired by Peter Calthorpe's book *"The next American metropolis"*. The emphasis is on the role of the pedestrian and the mixed usage of urban space in neighbourhood areas. Calthorpe's concept of the pedestrian pocket accounts for the idea of an opportunity for walking distances for all kinds of people to all activities from home. Calthorpe explains TOD as follows: "moderate and high density housing, along with public uses, jobs, retail and services are concentrated in mixed-use developments at strategic points, along the regional transit system" (Calthorpe, 1993, p. 41). The TOD concept or policy idea is an alternative to car-dependent sprawled reality, mostly a problem in American built environments (Bertolini, 2006).

The other streams of thoughts are the idea of a mobile 'networked' urban society (Bertolini, 2006). This European-based thoughts conceive that a built environment is multi-nodal with a network that has to accommodate telecommunication technologies, car traffic and public transport. The focus here is more on what a generic god city is, rather than sustainable urban development as in TOD (Bertolini, 2006). The work of among others Dupuy (2008) and Klaasen (Klaasen, Rooij & Schaick 2007) belongs to this group.

According to these authors the network consists of nodes and links. The network concept is defined in three layers. Their concept of the so-called *topological criterion* refers to physical networks such as rail, road, and ICT infrastructures located in space. Their concept of *kinetic criterion* refers to the movement and communication between the nodes, basic a relationship between time and space: speed. Their concept of *adaptive criterion* concerns the capacity for the evolution of networks over time and space (Klaasen, Rooij & Schaick 2007). The rail and road network is considered to be the carriers of urban systems. The central aspect in the network city approach is that there is an interrelationship between the physical networks, the functional network, and the users of these networks. As Klaasen, Rooij and Schaick states: "Basically one could say that it is not longer about 'being some where' but about 'getting there': design and planning is not about 'places' but about 'places' in connecting with 'routes'" (Klaasen, Rooij & Schaick 2007, p. 8).

In her PhD thesis Knowledge-based design: Developing urban & regional design into a science Ina Klaasen discusses to what extend various urban models encourage collective or individual activities and which type of model encourage private car dependency. As she claims, the collective transport can be best supported by a star shaped or “the finger model” structured main route net. The orthogonal grid shaped main route network generates private car dependency and a demand for large parking spaces (Klaasen, 2004, p. 136).

The concepts used in the network city approach, as describe above, tend to be rather abstract. It is difficult to apply these concepts into concrete research projects as well as strategic planning and urban design projects. A finer morphological description is missing.

In this way it is difficult to make a detailed description of the spatial configuration of the various types of street and road networks of the nodes and the lines connecting these nodes. Likewise, a spatial description on a micro scale level is missing on how the various functions are linked to one another along a transit system. The challenge here is to link the understandings of the network city, location of activities or urban functions, and reveal them in light of how these aspects can generate sustainable mobility means.

During the last two decades, several authors such as Richard Rogers and Mike Jenks search for an understanding of the compact city model, which is recognised to encourage sustainable ways of living and energy use for transportation. Generally speaking, urban sustainability is thus accounted for in terms of compactness. As Rogers propose, a network with compact urban centres can support public transport with frequent services (Rogers 1999, p. 53)

Rogers’ approach to urban sustainability is reinterpreting and reinventing the “dense city model”. It is defined to consists of anti zoning, increase of energy efficiency, consuming fewer resources, produce less pollution and avoiding sprawling over the countryside (Rogers 1997, p. 33). Separation of functions contributes to the loss of street life, encourages car use and creates no man’s land. A “single-minded space use” is defined in terms of urban space fulfilling a single function. The design of residential areas segregated from working and leisure areas exemplifies this case. According to Rogers, rigid planning standards and controls on zoning, parking and density contribute to encourage a development towards car dependency (Rogers 1997, p. 9). The opposite label, i.e. “open minded space use” is defined in terms of multifunctional space use open for everyone. It is characteristic of the compact city. Another feature is “fine urban grain” which relates to qualities of mixture and variety (Rogers 1997, p. 10).

Likewise, the space syntax method has been used for describing the spatial properties of vital well-functioned cities. The concept urban sustainability has not been used explicitly. However, the identification of the spatial parameters for generating a lively well-functioning city can be found in several space syntax papers presented at symposiums and in journals. A lively urban area is defined to have high locally and globally integrated street network (Hillier et at 1993, 1998), high degree of connectivity of the street network within a short metrical distance (Hillier 1999), and to have active frontages (van Nes & Lopez 2010).

In 2003 the space syntax method was applied on various urban centres with purpose to identify the spatial parameters for generating sustainable mobility means. As this contribution concluded, urban compactness can best be approached from a configurable point of view due to that compactness is a topological term (Encyclopaedia 1955). Therefore urban compactness consists in a high density of the street network within a short metrical distance (van Nes 2007). As concluded in this research, it is not enough encouraging high density in urban areas by increasing the number of dwellings and locales for economic activities or in general high density of the built mass. It is also the density of the street grid and its local and global position in the whole system that are at issue. The degrees of connectivity of a street and its configurational position in a city influence the relationship between inhabitants and visitors. Seemingly, urban compactness is a necessary condition for a sustainable urban process in terms of high degree of inter-connectivity of the street grid and the way it is connected to the whole city on local and global scales (van Nes 2007).

In her PhD thesis, Camelia Mulders-Kusumo investigated to what extend railway stations attract investments and vital shopping areas in their vicinity. Planners and designers put a lot of effort into transforming railway stations into urban areas. However, the spatial structure of the local street the railway stations are connected to is often not taken into account at all. Therefore she analysed the local street pattern and correlated the degree of spatial integration with the location pattern of shops. As her case studies shows, stations in it self is not enough to attract shops and investment in the vicinity. A local area's degree of vitality has to be spatially supported by a local well-connected and integrated street and road network (Mulders-Kusumo, 2005).

She applied the traditional space syntax method, where only the number of direction changes from each street to all others is taken into account. However, during the last three years new methodological as well as software development has taken metric and geometric distance into account. These new spatial measurements and tools make it possible to analyse larger metropolitan areas with more diversity on the types of spatial analyses than in the past.

As indicated from the literature review, the spatial conditions of a sustainable urban development seems to be a compact city with an inter-accessible street and road network that have a spatial structure generating sustainable mobility means. A definition of inter-accessibility in this context implies that the railway station is embedded or well connected to its vicinity's street and road network and that the various services are easily accessible from the railway station. Moreover, the frequencies of public transport services and the mixture of urban functions (such as dwellings, offices, shops and leisure activities) has to be high.

4. THE NODE PLACE VALUE METHOD AND THE SPACE SYNTAX METHOD

Two methods were used to investigate the correlation between a street net's degree of spatial integration and the value of a railway station, the space syntax method and the Node Place value model.

The Node Place value model, developed by Luca Bertolini, aims at correlating the degree of functionality and degree of local place qualities for nodes (Bertolini 1999). According to this model, a station functions well when the *node value* and the *place value* correspond. The parameters for deciding the node value are the variation in the mobility types, the frequency of the public transport system of a hub, the accessibility of the network connected to the node, and the number of mobility means that can reach the hub. The higher variation of mobility means and the higher frequencies on the time tables during a day, the higher node value. The parameters for the place value are dependent on the number of functions accessible in the vicinity of the node, such as dwellings, offices, public buildings, leisure activities and shops and the way these functions are connected to each other. The higher number of functions and services within a short walking distance from a station, the higher place value. According to Bertolini, a mono-functional node with for example only offices has a low degree of place value than a node with dwellings and offices (Bertolini 1999).

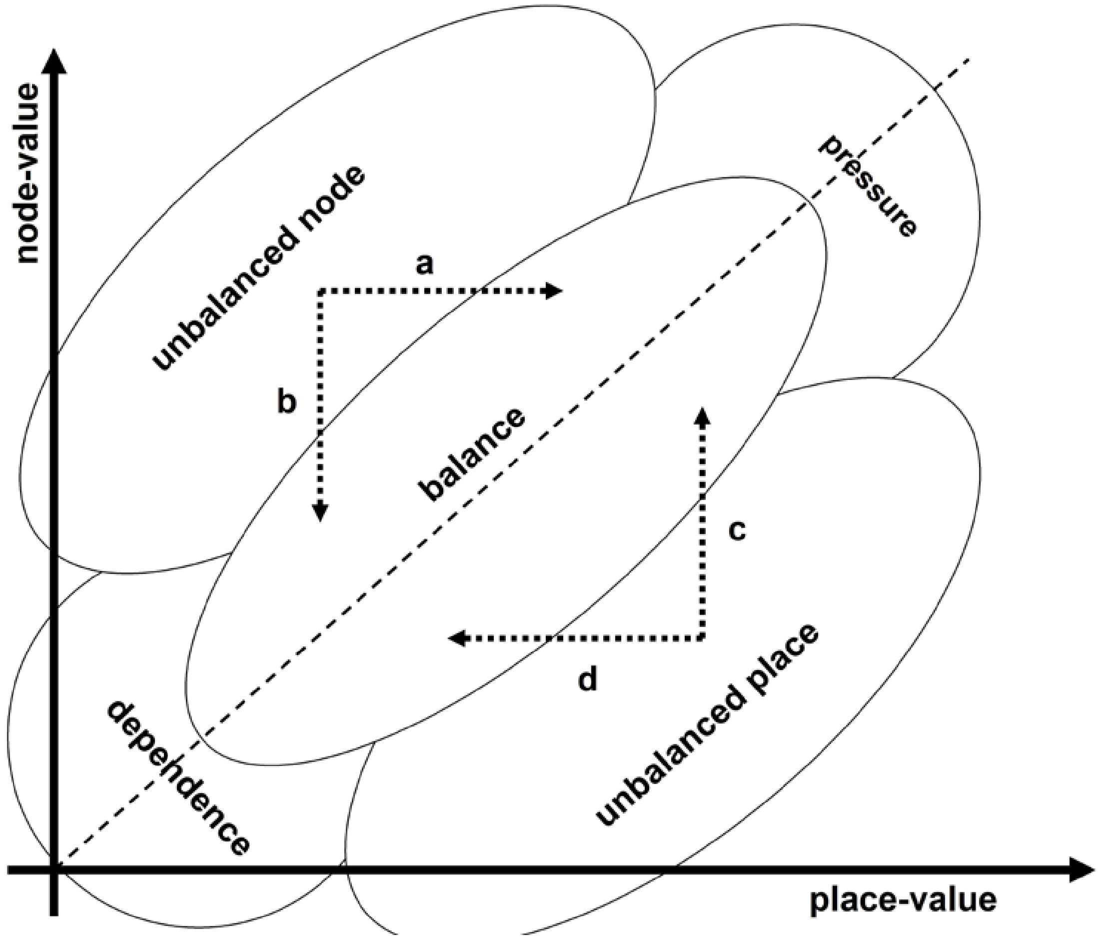

Figure 2: Degrees of balance between a node-value and a place-value (Bertolini 1999)

The Node Place value model illustrates therefore the optimal correlation between place value and node value. When there is a balance between this correlation it is defined to be a successful node and place (figure 2). Often railway stations located in these kinds of places tend to be successful. As soon as either the place value or the node value is dominating, these places are defined not to be successful for nodes. The model has been tested on station areas in the province of North Holland by Gerton Pieters (figure 3). He used the following four categories for the classification of the place and node value of a railway station: (1) large urban centre node, (2) transfer node, (3) regional node, and (4) local node. The next step is to compare these results with space syntax analyses of the road and street network of the whole province.

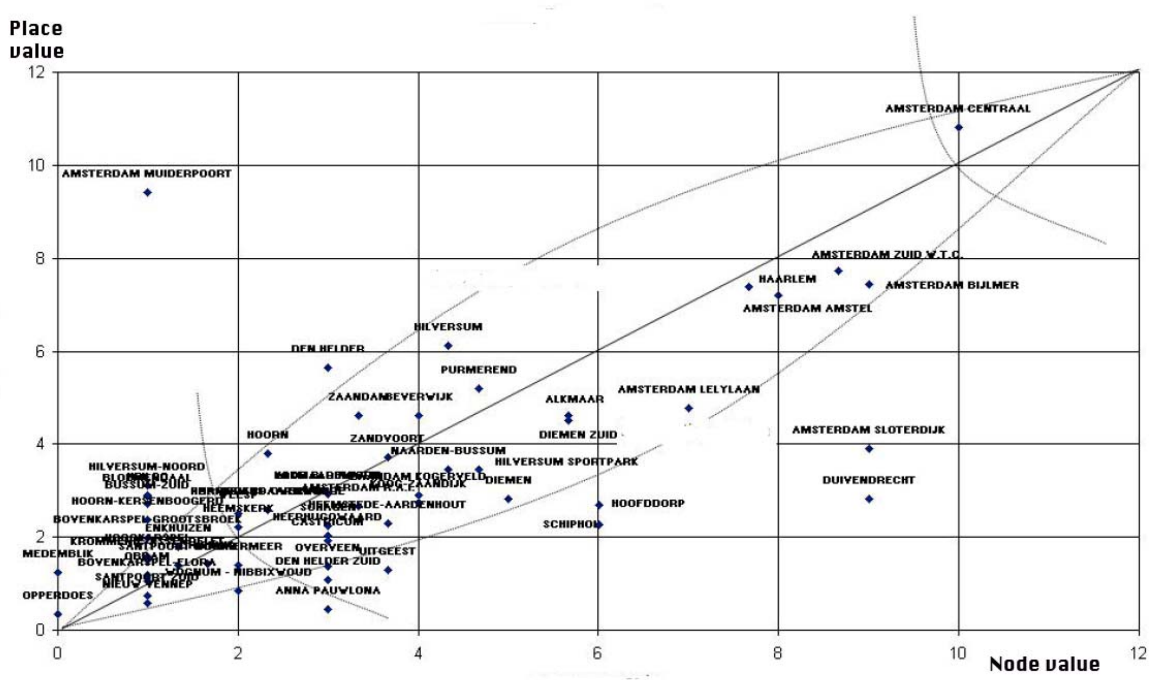

Figure 3: Gerton Pieters' analysis of stations in Province of North Holland (Source: North Holland 2009)

The aim with using the space syntax method is to get insights on how the spatial structure of the street and road network in a station's vicinity relates to the station's place and node value. The space syntax method is able to calculate how a street relates to all others in a town or city. The recent versions of the Depthmap software are able to calculate *topological distance* (how integrated a street is in relationship to all others in terms of the number of direction change), *geometrical distance* (how integrated a street is in relationship to all others in terms of the angular relationship between them), and *metrical distance* (Hillier et al 2007).

When analysing large settlements, recent software development have made it possible to analyse how each street relates to all others in settlements with more than hundred thousand street segments. As research has shown, there are correlations between a built environment's spatial layout of its street and road network and the location of economic activities, crime dispersal, land use along streets, and property values (Hillier et al 1998). Therefore the degree of spatial integration affects mobility flow rates. Moreover, it also affects the location of various economic activities such as firms and shops (Hillier et al 1993, 1998). If the structure of the street and road network changes, the mobility flow and the location pattern of economic activities are affected (van Nes 2002). In this respect, a station or a node's place value can be quantitative measured on the various degrees of spatial integration of the street and road net. The spatial parameters can be correlated with the social and technical parameters indicated in the Node Place value model.

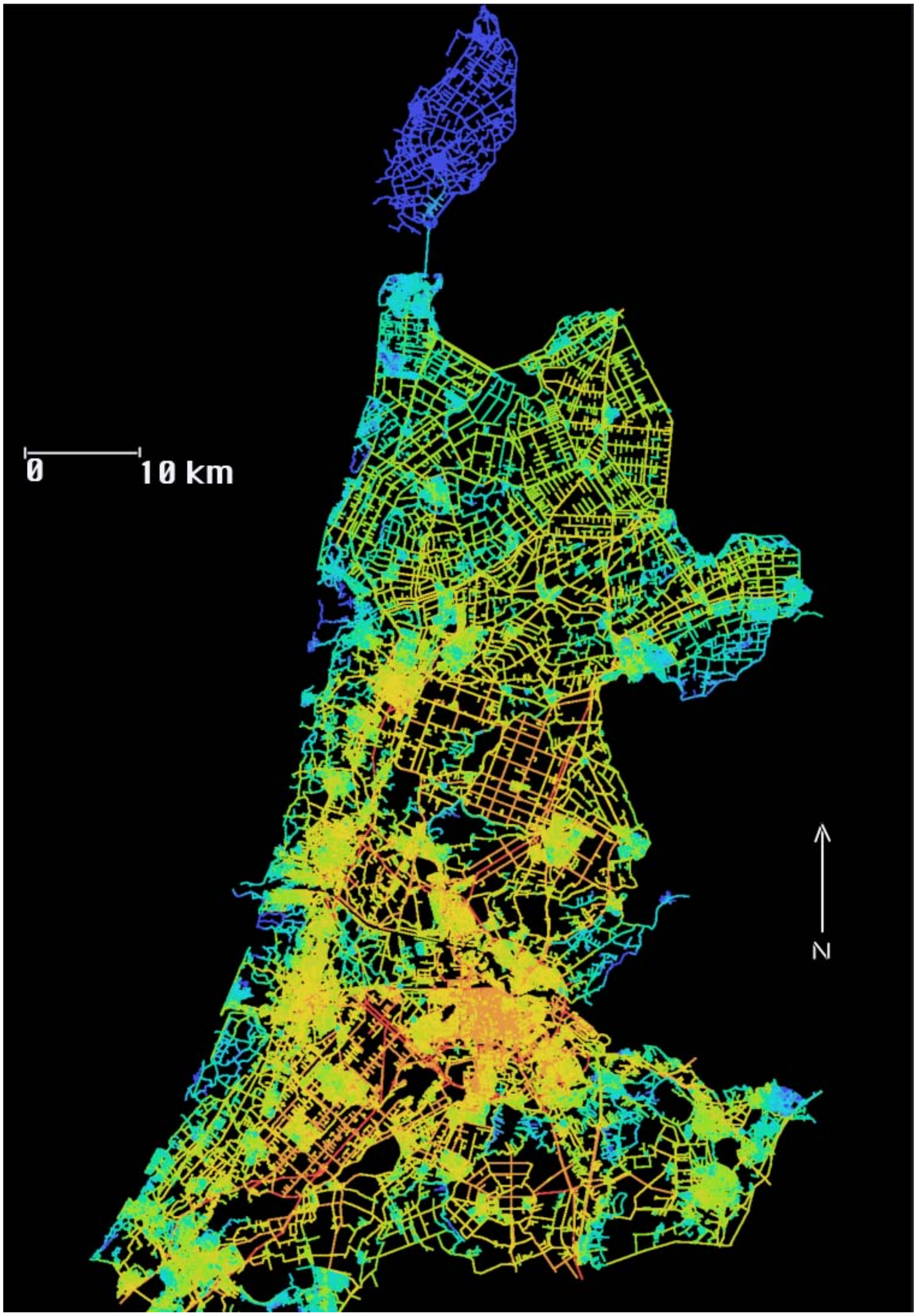

Figure 4: Global axial integration analysis of the street and road network in North Holland.

5. A NEW TYPOLOGY OF RAILWAY STATIONS IN THE PROVINCE OF NORTH HOLLAND

Figure 4 shows a global axial integration analysis of the road and street network in the whole province of North Holland. The red and orange lines represent the spatial most integrated areas in terms of the fewest number of turns. The more blue the lines get, the more spatial segregated the streets are. In order to reduce the edge effect of the global axial analyses, we added the Rijland region to the axial map. This region belongs to another province (Province South Holland). However, due to its strong connections to Schiphol Airport and Amsterdam, it is added.

As can be seen on the map, the areas around Amsterdam's ring road are the most integrated areas in the province. There most of the international companies and advanced producer services (APS) are located. The northern areas are the most segregated ones, coloured in blue. These areas are dominated by agricultural production, consist of some small villages and have a slight stagnation in the population growth. With other words, the global integration map shows the "to-movement" potentials on a provincial scale level. Hence, the spatial potentials for the location of large business centres, large-scale industrial activities, mega malls or car-based shopping centres are indicated.

On a local scale level, figure 5 shows a local angular integration analysis of the whole province. The angular analysis is segment based and the local radius is three times direction changes. The various local urban centres are highlighted in red and yellow, in particular the main streets and main routes through and between urban areas. Therefore the map shows the "through movement" potentials on a local scale. It shows the spatial potentialities for the local urban centres.

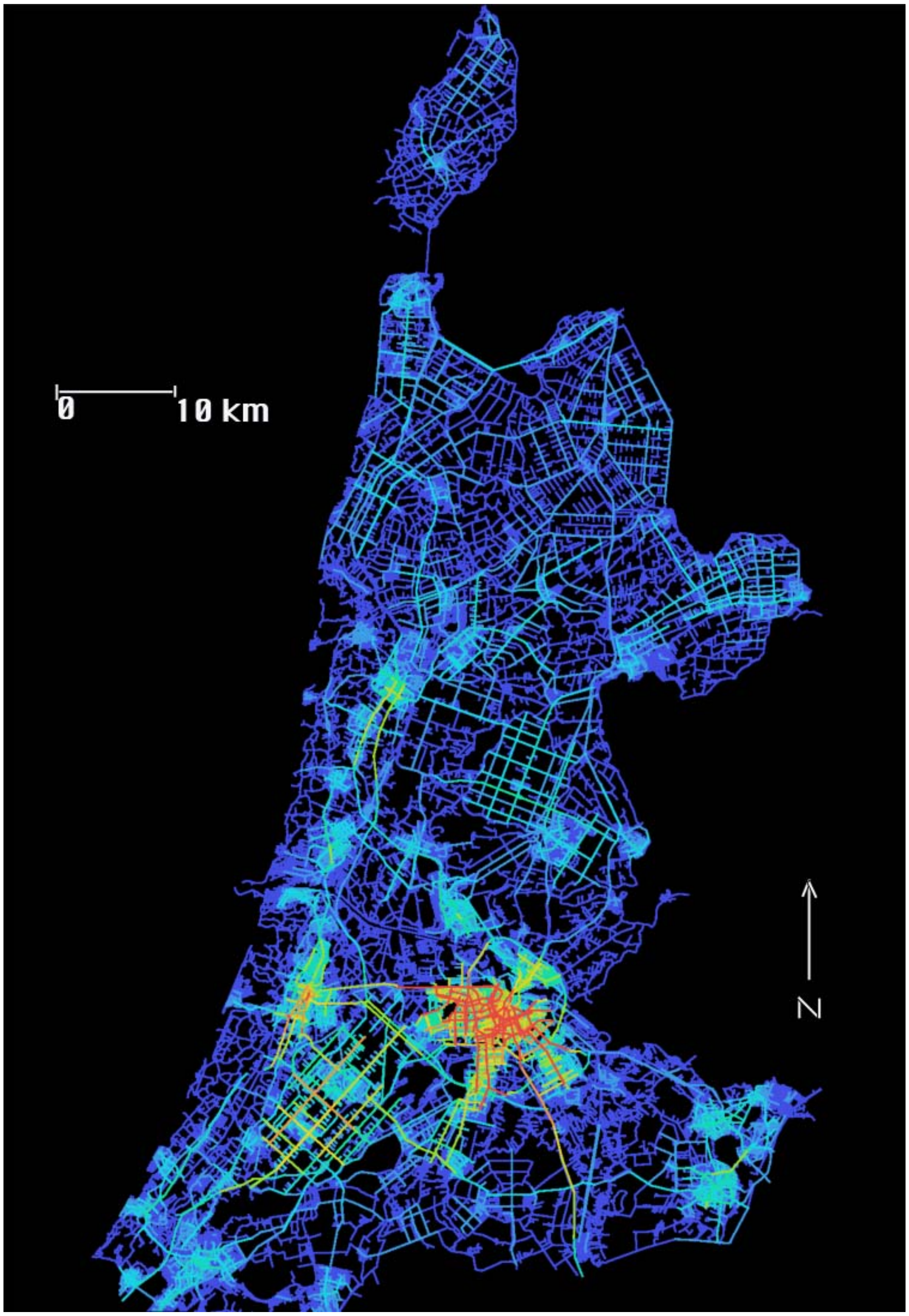

Figure 5: Local angular segment analysis with a topological radius 3 of the street and road network in the province of North Holland

When applying various metrical radiuses on the angular choice integration values, the degree of vitality of various nodes or centres is highlighted on various scale levels. An angular choice analysis with a low metrical radius highlights the old historic centres. In the past these centres were planned to be inter-accessible for pedestrian movement. A high metrical radius highlights the modern urban centres and the main routes network. Figure 6 shows an angular choice integration analysis with a metrical radius of 800 units. As can bee seen in the figure, the main streets in the historical core of Amsterdam, Haarlem and Alkmaar are highlighted in red colours. Likewise, all the small town and village centres are highlighted in light blue and yellow colours. These streets are frequented by pedestrians and have the liveliest shopping streets.

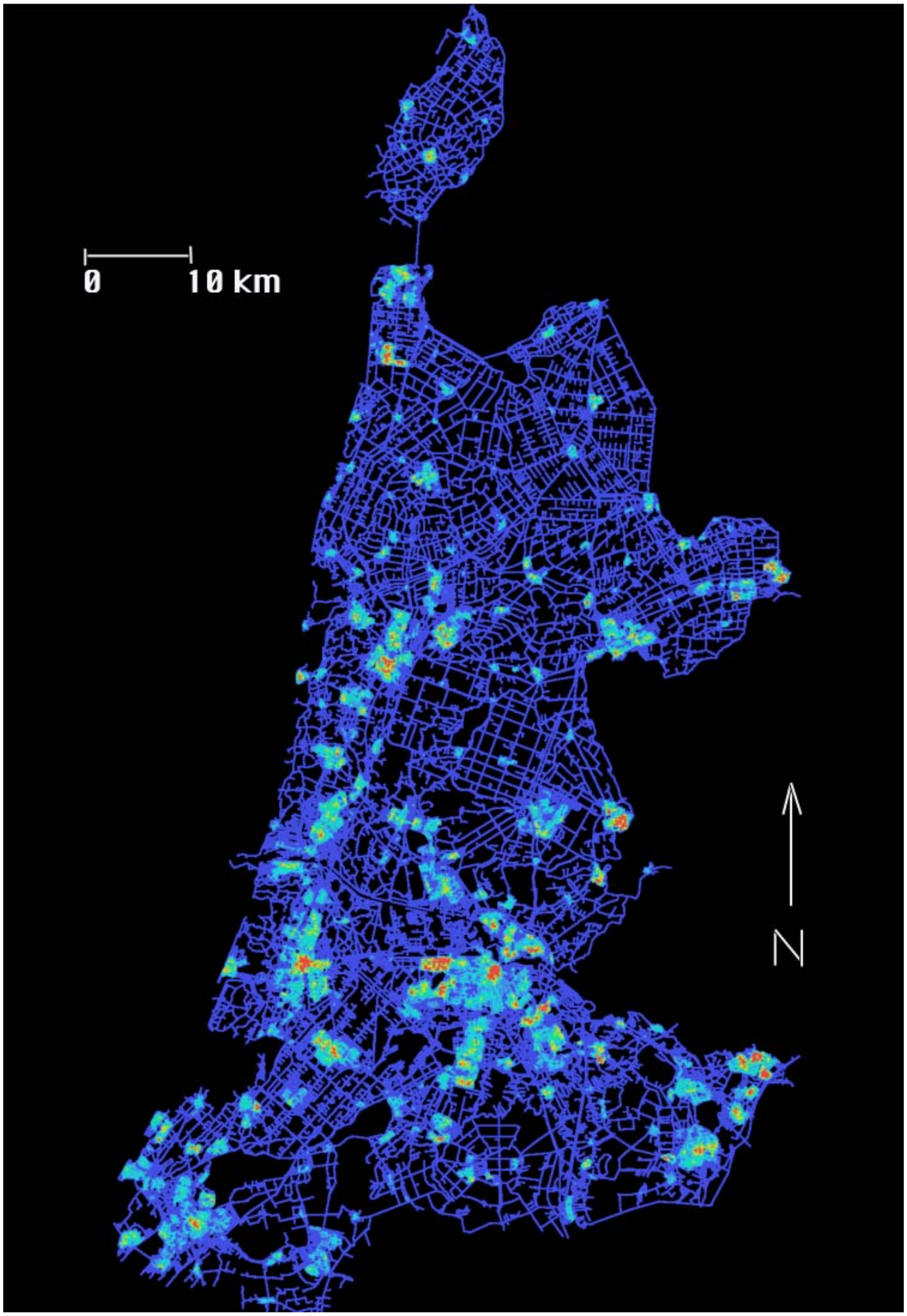

Figure 6: Angular choice analysis (segment) with a radius of 800 metrical units of the street and road network in North Holland

Figure 7 shows the angular choice integration analysis of the province with a metrical radius of 9000 units. The regional main centres are highlighted. In Amsterdam these streets are accessible by tram, busses as well as private cars. Often the main railway stations are in the vicinity of these centres. As can be seen on the map, the main centres are Amsterdam, followed by Haarlem and Alkmaar.

The location of all railway stations according to the typology presented by Gerton Pieters (North Holland 2009) can now be correlated with the results from the spatial analyses. The degree of potentialities and obstacles for development around station areas can be revealed. These results can be useful for making priorities of the development of station areas. In particular the combination of these two methods shows the degree of accessibility and vitality on various scale levels. But first the identification of the spatial parameters of what a sustainable train station is will be discussed for each type of railway station.

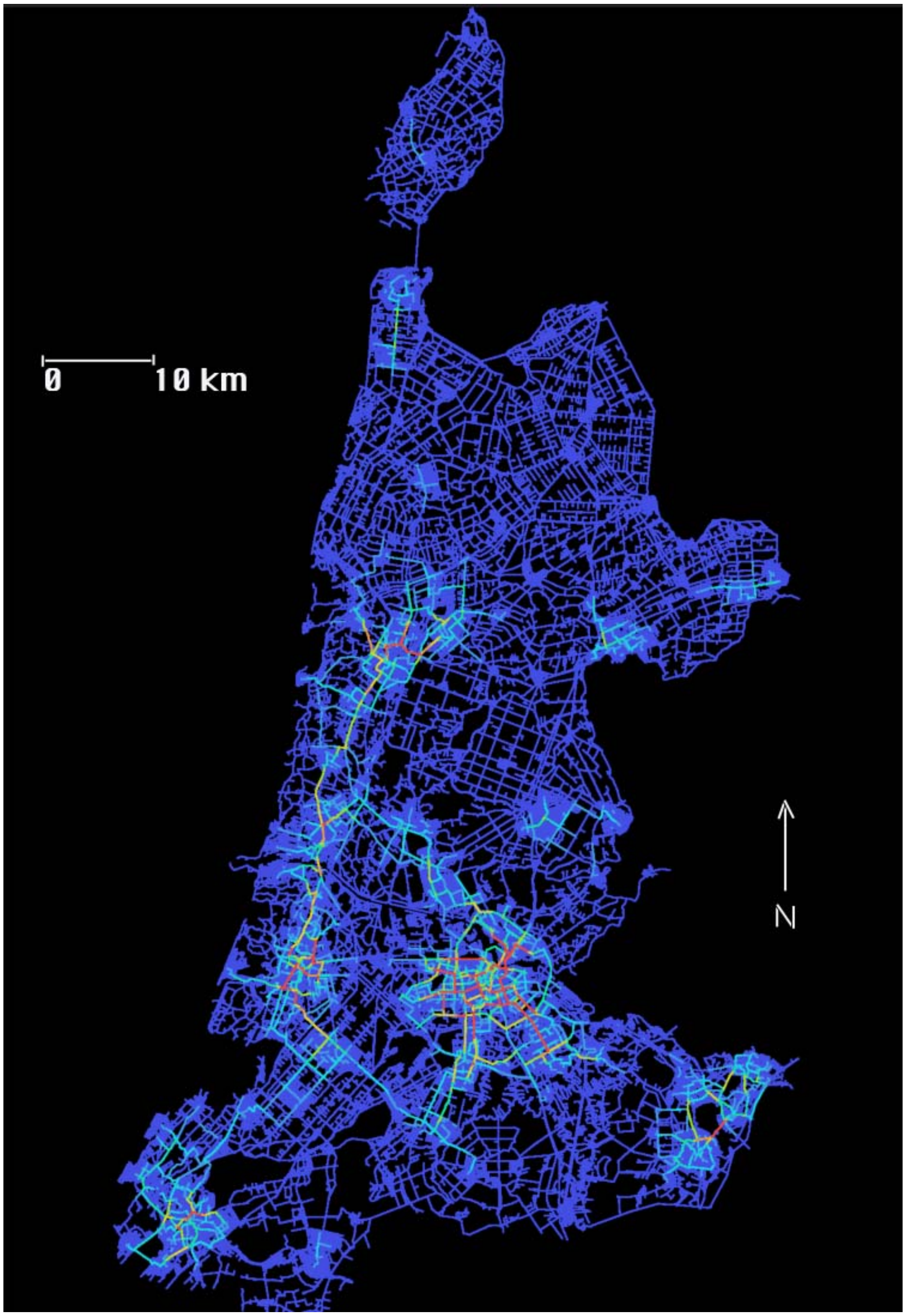

Figure 7: Angular choice analysis (segment) with a radius of 9000 metrical units of the street and road network in North Holland.

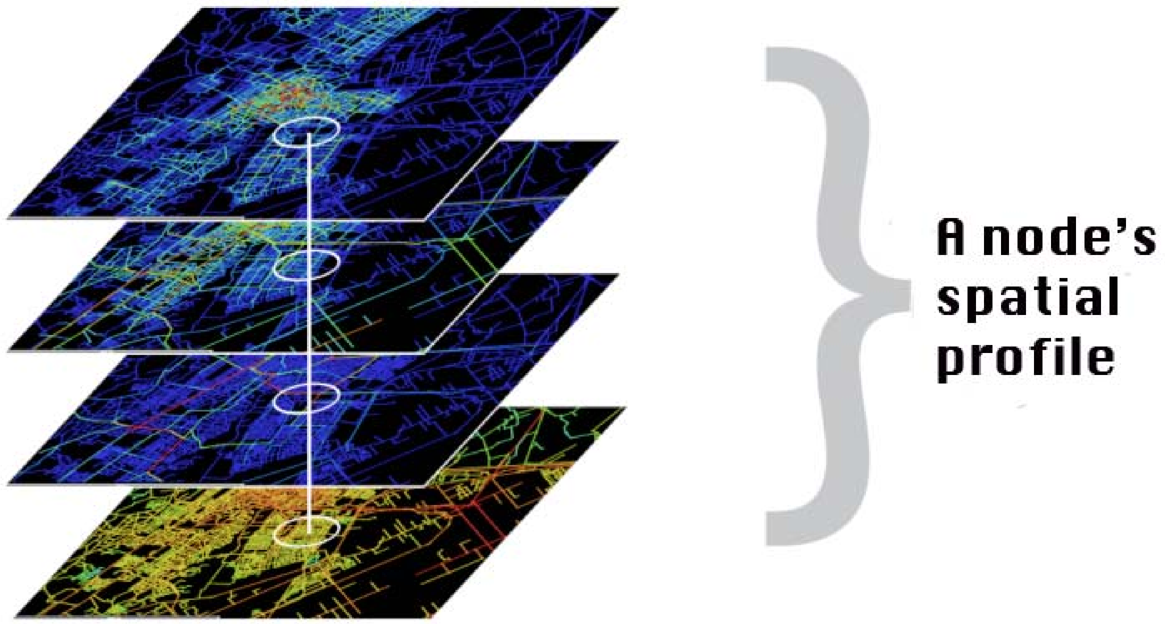

Figure 8: The degree of accessibility on various scale levels at one railway station.

In terms of the degree of accessibility of a node (a node's spatial profile), five types of railway stations are indicated based on the space syntax analyses and the node place value classification; (1) Well-connected on all scale levels, (2) Regional well-connected, locally isolated (3) Well-connected on town level, but poorly accessible for pedestrians, (4) Locally well-connected, poorly connected on regional level, (5) Poorly connected on all scale levels. The method for the classification is based on the space syntax analyses for each station, as shown in figure 8.

As it turns out, a station's degree of node and place value depends on the spatial configuration of the street and road net in its vicinity. The stations defined as being a large urban centre node with both high node and place values have a street and road network well-integrated on all scale levels. Stations with high place value, but low node value tend to have a street network that are highly locally integrated but poorly integrated on regional level. Conversely, stations with a high node value, but low place value tend to be located in mono-functional areas with a regional integrated street and road network. The local integration on the street and road network is low. Stations with both a low node and place value tend to have both a low integration on its surrounded street and road network on local as well as regional level.

Figure 9: The location of various types of railway stations.

Figure 9 shows the location of the typologies of all railway stations in province of North Holland. The well-connected railway stations on all scale levels (type 1) are the central stations of Amsterdam, Haarlem and Alkmaar. These stations are easily accessible on a provincial level as well as for pedestrians frequenting the stations' vicinity inside or adjacent to the city and town centres.

There is a balance between the place and the node value in the vicinity of a type 1 railway station. According to the Node Place value model, there tend to be high pressure on the land in the vicinity of these kinds of stations. Therefore, the location of a main railway station contributes to sustainable means of transportation in these kinds of areas. These stations areas' place value is very high due to a large mix of functions such as offices, shops, services, dwellings, café's and restaurants in the vicinity of these kinds of railway stations. Likewise, the density of the built mass is high in terms of a good balance between high floor space index (FSI) and ground space index (GSI) (Haupt and Berghauser Pont, 2010). These stations have a high node value due to a high frequency of all types of trains (intercity and local trains) and busses or trams departing from them. Since these stations are well connected to the regional as well as the local network and have a high variation of sustainable mobility means (train, trams, busses, bicycle etc), these stations have the most sustainable location. Often streets in their vicinity are difficult to access by the private car due to traffic regulations, in which force people to use the public transport or the bicycle.

The regional well-connected stations with poor pedestrian accessibility in the vicinity (type 2) are the Schiphol airport train station, and stations in industrial areas. Examples on these are Hoofddorp, Sloterdijk, Alkmaar Noord and Diemen. The vicinity of these stations is not pedestrian friendly and these stations are mostly transfer stations. Often offices with good parking facilities can be found in these stations' vicinity. These areas tend to have low GSI but sometimes a high FSI on their built mass. These stations tend to be on an unbalanced node. The place value is low because the node is mono-functional. In terms of node value, the frequency of trains departing from these stations tend to be relatively high. Some stations are well-connected to the local bus net.

The train stations accessible on a city or town scale level, but with low degree of pedestrian accessibility (type 3) are the train stations located on the edges of settlements. In particular railway stations in the vicinity of large throughout planned dwelling areas from the 60s, 70s and 80s with a high degree of private car dependency belong to this type. Examples on railway stations of this kind are Amsterdam Lelylaan, Beverwijk, Nieuw Vennep and Castricum. Often local centres can be found on only one side of these stations, or they do not have any centres at all. These areas tend to have a low GSI and medium to high FSI on their built mass. A large part of these stations areas' land surface is dominated by roads and parking lots. Due to that there is a mix of functions in the stations vicinity, the place value is high, but the node value is low due to that only local trains depart from these stations. Therefore the node place value is unbalanced. The challenge here is to encourage an urban development with a locally integrated street network generating a nature mix of functions.

The locally well-connected, but poorly connected on regional level railway stations (type 4) are often located in the town centres in the province's edges. Examples on this are the railway stations in Den Helder, Hilversum and Enkhuizen. These towns have a small historic centre where the railway station is easily accessible by foot. Local vital shopping streets and provision of services are in short walking distance from these stations. The density of the built mass is medium to high in terms of a good balance between high floor space index (FSI) and ground space index (GSI). Likewise, these station areas have a good balance on their place and node value in terms of a balanced mix of functions and that both local trains and some intercity trains departs from these stations. Some of them are interchange points to a local bus net.

Finally, the railway stations with poor connections to the street network on all scale levels (type 5) tend to have a remote location. These stations can only be reached by car and the street and road network in their direct vicinity do not generate pedestrian movement. Examples on these kinds of stations are Den Helder Zuid, Weesp and Naarden-Bussum. There are no services in the vicinity and these areas have low FSI and GSI. The node value is low due to that these areas are either dwelling areas or local industrial areas. Likewise, the place value is low in terms of low frequencies of local trains departing from these stations.

As the analyses shows, Amsterdam is the most vital centre in the province on all scale levels. However, the centre of Haarlem has a very high local integration combined with a relative high regional integration. It can be mirrored in the variation of shops in these centres. In Haarlem centre there is a much larger variation in types of shops within a short metrical distance than in Amsterdam centre. In Amsterdam the choices and variations of shops are larger than in Haarlem, but they are spread over a large metrical radius. Conversely, the province's areas in the north have low local and regional integration. These areas are poorly accessible by rail and public transport. Some of the local centres in the villages have high local integration on the street network and are known to be pedestrian friendly areas.

What are then the spatial conditions for a sustainable location of a railway station? First of all, a railway station located directly to a city centre or town centre that have a highly integrated road and street network on various scale levels has the most sustainable ones. As regards the theory of the natural movement economic process, street with high spatial integration on various scale levels tend to have high human movement flow rates as well as high concentration of services (Hillier et al 1993, 1998). Moreover, streets with both globally and locally high angular choice integration values within short metrical distances have high variation of functions and high density of the built mass (van Nes, Berghauser Pont, Mashhoodi 2011). Since these kinds of urban areas attract human movement towards them, a railway station easily accessible to them can stimulate transport on rail rather than private car use. When comparing the results from the space syntax analyses with the node-place value analysis, stations with a high local integration on the street grid in their vicinity tend to have a good balance between the place and node value. There is a balance between the timetables, frequencies, degree of multi-functionality in land use, and services and facilities provided. The higher global integration values, combined with high local integration values, the more pressure there is on the area. In these cases, the need of a railway station with high frequencies on the timetables can contribute to sustainable means of mobility to places with a high accessibility demand.

6. THE APPLICATION OF THE RESEARCH RESULTS IN THE STRATEGIC PLAN OF PROVINCE OF NORTH HOLLAND

The classification of the various railway stations based on their location in the province is useful when making a priority list of sustainable development of new housing areas. In the province's strategic plan for the next 30 years some areas are proposed for facilitating future urban expansion – mostly on the provision of new dwellings. The province has made a map of potential future location of new dwelling areas for facilitating living in the countryside or in the nature areas. According to the recent national spatial policy document (Ministeries van VROM 2006), there is a demand for this dwelling type. Therefore, in comparison with earlier national policy documents, the government and the provinces aim at choosing land facilitating a development of this kind. However, new housing areas of this kind tend to generate private car dependency and to contribute to urban sprawl into the countryside. It is therefore worth revealing the degree of sustainability of the province's proposed housing areas in terms of mobility means. The aim is to make a classification and a priority list of these proposed housing areas based on the railway station analyses with the space syntax method and the Place Node Value model.

These proposed new dwelling areas were correlated with the four space syntax maps and combined with the above presented various types of railway stations. The aim was to investigate what kind of local, regional and provincial accessibility these proposed new dwelling areas have. In particular the degree of spatial integration and hence the degree of vitality of the existing local centres' street network were taken into account. In this way, these dwelling areas were classified according to how they contribute to sustainable means of mobility, the type of eventual a railway station in the vicinity, and to what extend these proposed new areas generate urban sprawl into the countryside. The dwelling areas were classified in six different groups according to their location in terms of generating sustainable means of mobility and degree of vitality of the existing street and road network in the direct vicinity. Figure 10 shows the locations of the proposed new dwelling areas with their classification letters.

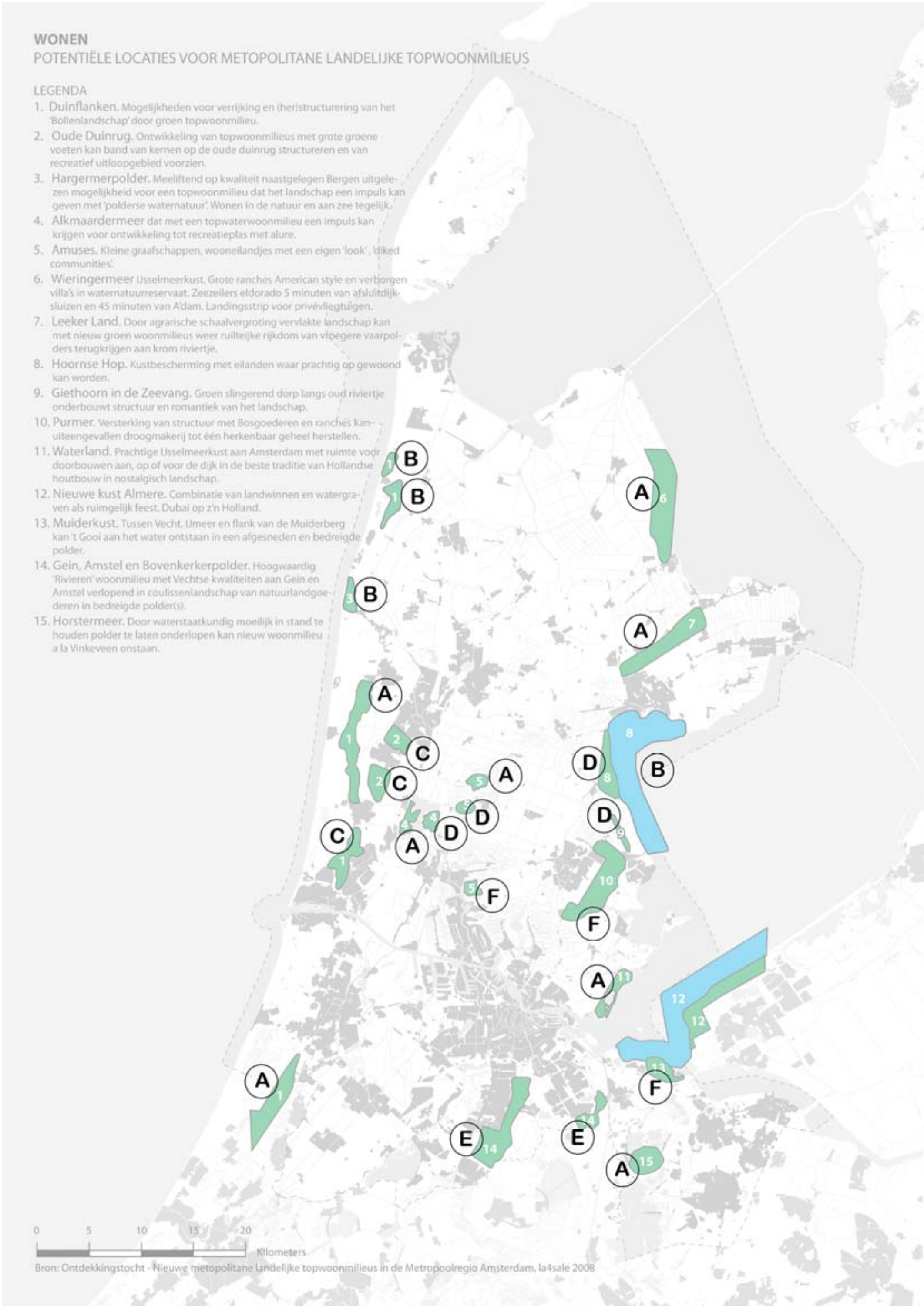

Figure 10: The location of the province's proposal of new dwelling areas.

Type A is poorly connected to the existing urban areas, has no railway station and is poorly accessible to the highway net. Implementing dwellings in these areas contribute to sprawl into the countryside and high degree of private car dependency, which conflicts with the Kyoto agreement. The areas belonging under type A are located at the edges of the province, with no connections to existing towns or villages.

Type B areas are closely located to the existing small villages. The local accessibility is high and can stimulate movement by foot or bike for the local movement. The regional accessibility is on the other hand low in terms of low degree of spatial integration of the street and road network and a lack of a railway station. Proposed dwelling areas of this kind can be supportive to the existing small village centres. It all depends how the degree of spatial integration of the local street network will be on a local scale in these new areas.

Type C areas are “fill-inn” areas between the existing urbanisation patterns. These areas have a high degree of regional as well as local accessibility of the existing street and road net. These areas are defined to be the most sustainable proposals for urban expansion, since the existing road, street and rail infrastructure is present in the direct vicinity. In addition these kinds of dwelling areas gives extra support for the survival of existing adjacent local urban centres and to get a high amount of people using the existing rail network.

The type D areas are located along the highly integrated regional road and rail network. They are not connected to any existing villages, towns or city centres. The challenge in the development of these areas is to provide them with a new well-connected local street network with high degree of spatial integration within a short metrical distance for generating a mix of functions. The best solution is to make a new town with a locally integrated street network in these proposed areas.

The type E areas are located adjacent to larger towns and cities and are well-connected to the regional rail and road network. In order to avoid spatially segregated sleeping suburbs, it is important that these areas’ local street network is well-connected to the main routes through and between urban areas. In addition, the new local centres with the necessary facilities needs to be on these main routes. In this way these areas can benefit from the potential extension of the existing tram and rail network.

The type F areas are the specific cases not belonging to any of these other abovementioned types. These areas have to be treated individually, depending on their specific local context of the street and road network and the degree of adjacency of a railway station.

As can be concluded, the proposed locations for new housing areas belonging under type C generate the most sustainable means of mobility. Therefore urban expansion should take place first in these areas. These areas have the potentials for becoming vital local communities and to generate an optimal use of the existing mobility infrastructure and local urban pedestrian friendly shopping areas. These areas has high local as well as regional spatial integration, they are adjacent to existing centres, and generates pedestrian activities and usages of public transport. Type D expansions is on the second place, type E is on the third place, and type B is on the forth place. Type A expansions should be avoided, since it generates urban sprawl and private car dependency.

7. THE SPATIAL PARAMETERS FOR GENERATING SUSTAINABLE MOBILITY MEANS

At the results from this inquiry show, the spatial configuration of the local street and road network matters for the degree of sustainable mobility means around stations areas. High angular choice integration values with both a high and low metrical radii generate multi-functional urban areas with high variation of mobility means (walking, bicycling, tram, bus, light rail, train etc) and high frequencies on timetables.

It is well known that successful railway stations with high frequencies of services and timetables have high number of people (inhabitants, commuters and visitors) using it. It is dependent on high number of services, functions (such as jobs, shops, amenities, dwellings, and offices) in its vicinity, high density of the built mass (FSI and GSI), and high variation of step over possibilities to other mobility means (bicycle, tram, metro, light-rail, bus, walking, taxi and car) within a short metrical distance. However, diversity and frequencies seems to depend on the spatial configuration of the street and road network in a station's vicinity.

Main railway stations in large towns and cities have high local and as well as regional inter-accessibility on the spatial configuration of the street and road network, while railway stations in smaller towns and villages have mostly high degree of local accessibility. These two station types have in common to have lively and vital streets in their vicinity. There is a balance between to node and the place value. Seemingly, the degree of balance between place and node value is dependent on the spatial configuration of the street network in terms of high local angular choice integration within a short as well as large metrical distance.

Stations with high regional accessibility and low local accessibility are transfer stations such as airport stations or industrial areas where two or more major railway lines are intersection. In these stations' vicinity, the street networks' spatial structure is only suitable for vehicle transport and these areas are not pedestrian friendly. They are unbalanced nodes. Train stations with both a low regional and local integration values on the street and road network in their vicinity are located in remote areas with high degree of private car-dependency. These stations have a low frequency of train departures, little variation in mobility means, and their surroundings are mono-functional. They are unbalanced places.

Correlations were also found between the frequency of the timetables and a station's degree of accessibility to its vicinity. The more regional as well as local a station is spatially connected to its local street and road network, the higher frequencies of the timetables. Accessibility to potential train travellers is therefore essential for getting the critical number of population for using the rail network.

The various types of station areas and dwelling areas require different strategies for generating sustainable means of mobility in the planning and urban design practice. For example a station and a proposed housing area with a strong regional accessibility can be sustainable on a local scale level through implementing a well-connected and integrated local street net. However, not every type of station area and proposed housing area can be improved upon. At least, from a sustainability perspective, the two methods applied in this inquiry contribute to make a priority list of urban tasks in the provincial plans. Likewise, this approach sheds some light on realistic and effective investment strategies. It shows the spatial potentials as well as constraints in the various stations' vicinities.

Railway stations seem to be a direct product of the transportation modes of the society. New technology relating to new kinds of trains or to public transportation in general might come about in due course. Developments of this sort will probably set new claims on railway stations. But until now, a sustainable well functioning station generating sustainable means of mobility, depends on being well-connected to the street network in its direct vicinity. It encourages a large amount of people to use rail transport instead of private car use. Such basic qualities do not only depend on the number of shops, tracks, railway companies, the density of the built mass, and on the size of the piece of architecture in which they figure. The spatial structure of the street and road network on various scale levels in the vicinity plays also a significant role in generating sustainable means of mobility.

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