# Assessing accessibility for the Randstad metropolitan area in the Netherlands: learning lessons for Asian megacities

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March, 2011

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| **Course Title:** | Geo-Information Science and Earth Observation<br>for Environmental Modelling and Management |
| **Level:** | Master of Science (MSc) |
| **Course Duration:** | September 2009 – March 2011 |
| **Consortium partners:** | University of Southampton (UK)<br>Lund University (Sweden)<br>University of Warsaw (Poland)<br>University of Twente, Faculty ITC (The Netherlands) |

Assessing accessibility in the Randstad metropolitan area in the Netherlands:
Learning lessons for Asian megacities

by

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Thesis submitted to the University of Twente, faculty ITC, in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation for Environmental Modelling and Management.

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**Abstract**

Accessibility is a comprehensive performance measure for the integration between land use and transport systems. In this research, two accessibility measures are described and applied to two urban areas: Hanoi – Vietnam and Randstad - the Netherlands. Job accessibility by private and public transport are calculated using the traditional potential accessibility measure corrected for competition of jobs. The further goal is to compare accessibility of private versus public transport. The results illustrate the complex relationships between city centres and their neighbourhoods and help to understand the influence of major transport infrastructure, which are motorcycles and buses in Hanoi, and cars and public transport network in Randstad.

More investigations are done on the interaction and impacts of two basic urban form configurations (i.e. monocentric form in Hanoi and polycentric form in Randstad) on differences of accessibility of private and public transport modes. Five scenarios with changing job distribution, labour distribution, infrastructure conditions or combination of these are tested for this purpose. The results show the potential enhancement of Hanoi accessibility by changing to polycentric urban form. Improvements of bus network in Hanoi are also valuable options. Scenarios on the Randstad show some small improvements by enhancing the transport conditions and certain advantage of monocentric urban form. More study should be done to identify and utilize the advantages of both monocentric and polycentric urban forms.

This study provides planners and decision makers with valuable information on accessibility in Hanoi and Randstad by different transport modes. In addition, it is a valuable access for public who want to stick to the sustainable development by using more public transport mode.

**Acknowledgements**

I would like to thank my supervisors, Dr. Ir. Mark Zuidgeest and Ing. Frans van den Bosch, for their support and guidance throughout the duration of this research. From problem solving to moral support, their help is really invaluable. I would also like to thank them for their great efforts to obtain the data, which made this research possible. I am also grateful to Mr. Nguyen Ngoc Quang for providing me with partly network of Hanoi. He also gave me a lot of advice during the first stage of this research. I would like to give special thanks to Dang Duong for his extremely helpful lessons on programming. Thanks to him for always standing by my side in this phase. Finally, I extend my thanks to my family and friends, who always support me and without them, this thesis will not be possible.

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# CHAPTER 1
# INTRODUCTION

## 1.1. Background

Transport plans are often based on increasing mobility, which is easy to use and to interpret for planners and the general public (Geurs and Ritsema van Eck 2001). However, the realization that transport is a derived demand and the increasing attention for sustainable transport have raised the concept of accessibility. Accessibility and mobility are typically defined in contrast. Mobility often refers to actual movements along a network, the ease to travel from one place to another place (Handy and Niemeier 1997; Gutiérrez, Rob et al. 2009). Oppositely, accessibility is generally defined as the ease to reach goods, services, activities and destinations, which are altogether called opportunities (Geurs 2006; Litman 2010). Thus, mobility represents the infrastructure, while accessibility is a sharp reflection of the relation between land use and transport. As a result, accessibility has been used recently as a key criterion to assess transport policies, as well as density and spatial distribution of people and activities in cities or countries.

Accessibility as a concept first appeared in the 1950s (Gutiérrez, Rob et al. 2009) and has been developed since then. A number of studies were done to review, classify and evaluate accessibility and its measures (Geurs and Ritsema van Eck 2001; Geurs and Wee 2004; El-Geneidy and Levinson 2006; Geurs 2006; Gutiérrez, Rob et al. 2009). There are several approaches as well as contexts to evaluating accessibility. The simplest one is through calculating available opportunities from a point within a travel time or distance. More complex approaches are based on the utility theory and through the individual demands.

The concept of accessibility also makes it the performance indicator for sustainable development, which is the combination of economic development, environmental protection and social equity (UITP 2003). Good accessibility supplies good exchanges of goods and people, which play an important role in economic development. On the perspective of environmental protection, good accessibility is thought to bring up less energy use, less pollution, and less other environmental issues. These better environmental related results are not only within the comparison of one transport mode but also related to different pollution levels of public transport and private transport. In case of social equity, better accessibility can help people to join in more social activities, which are necessary parts of our daily lives. Benefits and equal access of members in the society are often the most important factors. As a result, modes of transport are also important in evaluating social equity. By using comparisons among accessibility of different transport modes, the level of sustainable development is partly evaluated. In this thesis, accessibility by different modes of transport as well as different urban configurations is the main themes.

The use of public transport obviously brings more benefits than private transport, such as cars, in term of environmental perspective. In addition to less carbon dioxide released, more use in public transport requires less use in energy; less money spend on maintenance or space for parking. From the perspective of economy, public transport also requires less payment. It can also provide equal supply and access to every members of the society. However, in several studies on accessibility of public transport and private accessibility (Dong, Ben-Akiva et al. 2006; Geurs 2006), private transport has always surpassed over public transport in almost every region. The explanation first involves in some reasons of flexibility, cost and time. People are ready to change from private transport to public transport in case they can easily have information and go out whenever they want; or they can save more using public transport regarding time and cost (Carr 2008; Ovstedal, Oderud et al. 2008). In addition to the public service conditions, these reasons are also derived from the urban structure which has a close relationship with land use patterns. Although governments from most countries have not only invested in improving quality of public transport system but also supported and encouraged people to use public transport, public transport is still less than private transport in general. What may cause this fact? The answer can be given from analyses on the accessibility level provided by both modes in relation to the urban structure of cities.

As for mode shifting from private transport to public transport, there is a need to compare public and private transport; as well as to identify the impacts of urban form in general. More specifically, catering for accessibility helps to see how more sustainable transport options such as railway or buses can provide a competitive degree of accessibility that matches less sustainable options such as cars or motorcycles. The comparison can provide insight and understanding into the causing facts or the underlying problems. From that understanding, solutions can be suggested.

### 1.2. Research Problem

Although there are studies on comparisons between public and private transport, there are still not many studies on the effects of different urban forms in combination with the different modal options. Two of the most popular urban forms at present are polycentric and monocentric. While the effects of these urban forms on transport and the land use system have been the key elements for many planning systems to reduce private transport, the best form is still a controversial issue of scientists, researchers as well as planners (Boarnet and Crane 2001; Bertolini, le Clercq et al. 2005). Dealing with this issue, this study will add the effects of different urban forms: monocentric and polycentric to the comparisons between accessibility level of different travel modes - public and private transport.

Even though many studies use more complex indicators for accessibility measures, the use of mode-based travel time to evaluate accessibility is obviously effective. Thus, in this study, the travel time threshold is used in the potential accessibility measures and then corrected with the competition based on destination locations (Geurs and Ritsema van Eck 2001; van Wee, Hagoort et al. 2001).

### 1.3. Research Objectives

The general objective of this study is to calculate, evaluate and compare effects of different urban forms on job accessibility of different travel modes (public transport and private transport). This general objective is further sub-divided into the following sub-objectives:

- To evaluate job accessibility of different travel modes using location based measures using a travel time indicator and corrected for competition at the destinations;
- To evaluate and compare the effects of different urban forms on accessibility;
- To draw lessons for urban and transport planning.

## 1.4. Research Questions:

For each sub-objective, the following research questions have been formulated.

*To evaluate job accessibility of different travel modes using location based measures using a travel time indicator and corrected for competition at the destinations:*

- What measures exist in the literature?
- How are local contexts driving the choice for measure?
- Which data is needed for implementing the chosen accessibility measures?
- What are the differences of accessibility in different travel modes?
- What are the differences of accessibility in different urban forms?
- Does the competition factor alter the results?

*To evaluate and compare the effects of different urban forms on accessibility:*

- How do the urban forms affect transport?
- How do the urban forms affect the accessibility level?

*To draw lessons for urban and transport planning.*

- What are the existing problems of private and public transport in these areas?
- How do the scenarios affect the present accessibility measures?
- What policies can be formulated to improve urban and transport planning?

## 1.5. Conceptual framework

A conceptual framework is drawn to obtain the objectives of this research. Accessibility of private and public transport, as well as the two basic urban forms, i.e.: monocentric and polycentric are the core parts of this research. Comparisons of the effects of different urban forms in combination with different transport modes are evaluated also in different scenarios. To obtain these goals of the research, data on land use and transport conditions are required. These data together with assumptions and calculations will be processed using potential accessibility measures corrected with competition factors. The ultimate goal is learning lessons for transport and land use planning. More details are provided in Figure 1 below.

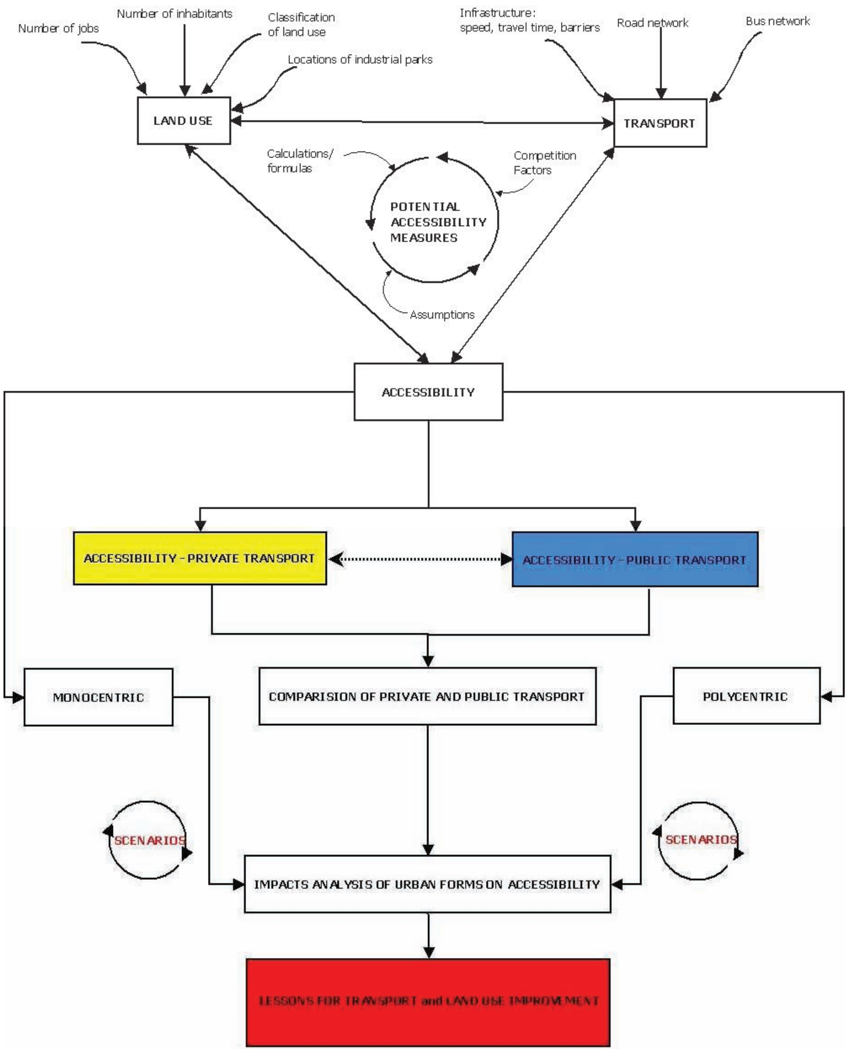



**Figure 1: Conceptual Framework**

## 1.6. Thesis structure

This thesis is mainly composed of two parts: accessibility comparison of private and public transport modes in study areas, and impacts evaluation of urban forms on accessibility. Five chapters follow. Next chapter will describe two study areas and their main characteristics. Literature review is provided in Chapter 3 for different accessibility measures and relationship of urban forms, land use and accessibility. Chapter 4 will concentrate on using different measures to evaluate different accessibility levels of private and public transport in two study areas. Chapter 5 illustrates more on effects of urban forms by using different scenarios. Some additional discussions follow by conclusion in Chapter 6.

# CHAPTER 2
# STUDY AREAS

This chapter describes briefly the two study areas for this research, i.e.: Randstad – The Netherlands and Hanoi – Vietnam. These two areas are supposed to provide two characteristic urban forms for this study, i.e.: a polycentric and monocentric configuration.

The Randstad region is a large area in the West of the Netherlands, comprising of large cities such as Amsterdam, Rotterdam, Utrecht, The Hague, Amersfoort, Leiden, Dordrecht, Haarlem, Hilversum and Gouda. With a population around 7.1 million over more than 8200 square kilometres, Randstad covers only 20% area of The Netherlands, while more than 40% of the population is living there, and about half of the income of Netherlands is earned within this area (OECD 2007).

In comparison to the Randstad, Hanoi region is a large urban area in the North of Vietnam with a population of 6.5 million over 3.4 square kilometres. Surrounded by five satellite towns and 13 townships, Hanoi city is considered not only the political and cultural centre, but also economic and demographic center for this region.

The following sections will discuss two main elements: urban form characteristics and transport characteristics of these study areas.

## 2.1 Urban form characteristics

Firstly, the urban structure of Randstad and Hanoi will be discussed. The Randstad comprises of 779 districts, modelled in Hanoi's transport studies as Transport Analysis Zones (TAZ). These TAZs form 147 cities within this region. In Hanoi, there are 574 communes as TAZs which divide into 29 districts. The demographic data of these two areas are firstly used to identify their urban form characteristics. For this research, two study areas with two urban forms will be analyzed: Is Randstad polycentric and is Hanoi monocentric?

From literature, an urban centre has a close relationship with employment, employment density, population, population density. However, employment is the key in forming urban centres. A centre is best identified by the clearly higher employment density than the surrounding areas (McDonald 1987; Giuliano and Small 1991). More complex ways to identify a centre may be based on both land use mix and commuter flows (Giuliano and Small 1991). Different approaches for centres identification have also been proposed. Giuliano and Small identified centres by cutoff values of employment data and the notion of proximity (Giuliano and Small 1991). McDonald and his colleagues used the regression analysis to determine the centre areas (McDonald 1987). McMillen used locally weighted regression to illustrate the locally employment density function (McMillen 2001).

In this thesis, to simplify the identity of urban structures, a simple method to identify urban centres is applied based on the work of Giuliano and Small (1991). From this study, a center is defined as a continuous set of zones which have a density (in terms of employment) above pre-set cutoff values $\overline{D}$, and altogether have at least $\overline{E}$ total employment. In addition, all the immediately adjacent zones must have a job density smaller than $\overline{D}$. This definition helps identify all high-density zones to be part of urban centre unless they are too small to form a total employment above $\overline{E}$. Cutoff values for each study areas depend on the minimum total employment and maximum area.

For The Randstad, the cutoff values with different number of centres are presented in Table 1.

**Table 1: Cutoff values and equivalent number of centres for Randstad**

| ***Total employment cutoff*** | ***Number of centres*** | ***Area (km$^2$)*** | ***Cumulative area (%)*** | ***Employment density cutoff*** | ***Number of centres*** | ***Area (km$^2$)*** | ***Cumulative area (%)*** |
|---|---|---|---|---|---|---|---|
| 400,000 | 1 | 196.4 | 3.15 | 2,500 | 1 | 84.2 | 1.35 |
| 300,000 | 2 | 467.0 | 7.48 | 2,000 | 5 | 417.5 | 6.69 |
| 200,000 | 4 | 650.2 | 10.4 | 1,500 | 10 | 520.2 | 8.33 |
| 100,000 | 10 | 1136.5 | 18.21 | 1,000 | 18 | 979.0 | 15.69 |

With these cutoff values, four large centres emerge in the Randstad with a total employment of more than 200,000 and an employment density higher than 1,000 jobs per kilometres square are. These centres (obviously) are the known large cities in the area, i.e.: Amsterdam, Rotterdam, Utrecht and Den Haag.

These four cities are spread over the Randstad region, which justifies naming this a polycentric urban form. More illustration can be found in Figure 2 and 3.

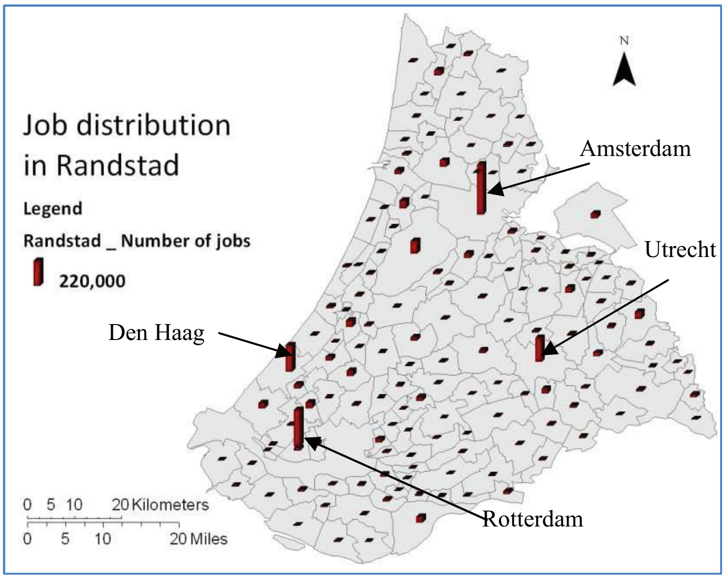



**Figure 2: Job distribution in Randstad cities**

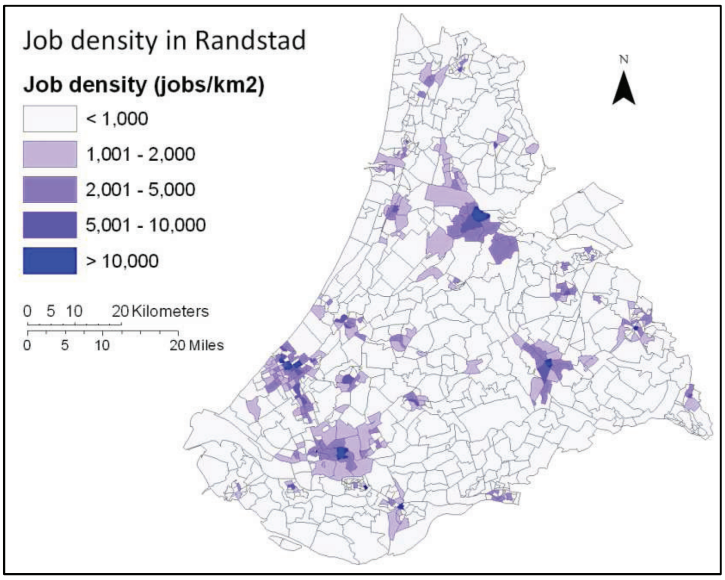



**Figure 3: Job density in the Randstad area**

Similar to the Randstad area, the process to identify cutoff values for Hanoi has been done and is presented in Table 2. However, because Hanoi districts have quite different size, ranging from 5 kilometres square (for Hai Ba Trung District) to more than 400 kilometres square (for Ba Vi District), urban centres identification for

Hanoi will mainly depend on employment density figure, rather than employment figure. An illustration of the Hanoi job distribution is presented in Figure 4. Centres in Hanoi have employment density higher than 400 jobs per kilometres square, and total employment will be larger than 15,000 jobs.

**Table 2: Cutoff values and equivalent number of centres for Hanoi**

| Employment density cutoff | Number of centres | Area (km$^2$) | Cumulative area (%) |
|---|---|---|---|
| 5,000 | 1 | 5.2 | 0.15 |
| 3,000 | 2 | 15.0 | 0.45 |
| 2,000 | 4 | 34.4 | 1.02 |
| 1,000 | 6 | 56.0 | 1.67 |
| 400 | 10 | 214.1 | 6.4 |

Centres identified in Hanoi lie next to core area. Employment density decreases from Hanoi centres to suburban areas. Hanoi city appears clearly as a monocentric area.

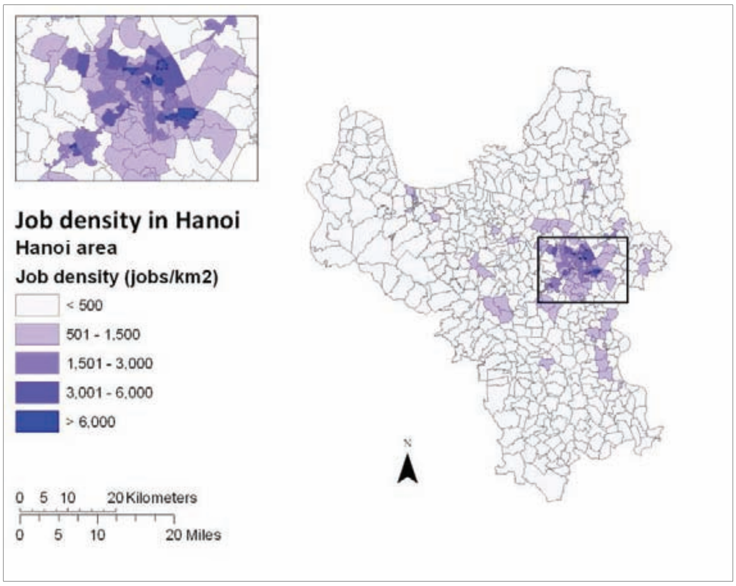



**Figure 4: Job density in Hanoi districts**

In addition to job distribution, the population distribution in Randstad and Hanoi are also investigated and shown in Figure 5 for reference.

In general, with their existing urban forms, Randstad and Hanoi are ideal cases representing for polycentric and monocentric structures. Each urban form will have its own advantages as well as disadvantages. For example, polycentric urban form may have better mobility and space due to its bigger area and higher utility of space. However, polycentric urban form requires planners to be more careful in designing and implementing a public transport network. In addition, due to its larger space and area, people normally travel longer distance/time and with more car dependency. Monocentric urban form, in adverse, can provide planners with easier function of public transport by designing radial network. Nonetheless, monocentric urban form can result in high congestion levels which may then lead to negative environmental consequences.

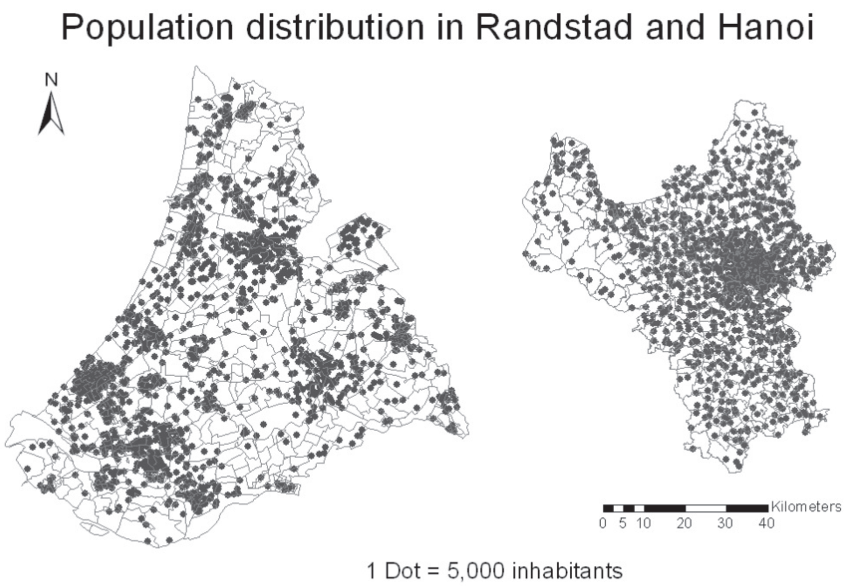



**Figure 5: Population distribution in Randstad and Hanoi**

## 2.2 Transport characteristics

Randstad, with its high rate of population and jobs, has made many activities move outside of the city centres. New settlements are about 10-15 km from the cities (Hilbers and Wilmink 2002). Daily commuting for work, home and entertainment is thus in different directions and often take place over a longer distance. In the Randstad area, transport is facilitated by generally good infrastructure network of motorways and various kinds of public transport such as railways, subways, tramways and bus in several cities. However, over the past decades, travel in Netherlands or particularly in Randstad has increased significantly (Hilbers and

Wilmink 2002; Van der Werff, Lambregts et al. 2005). Explanations for this are increasing working population and the longer travel distance to work. Therefore, the existing network with not many alternative routes may encounter problems of inadequacy.

Starting from the Renovation Period in the 90s, Hanoi region, together with the rest of Vietnam, is under a rapid change in urbanization (van Horen 2005). However, rapid urbanization in Hanoi is exceeding the development of industries and infrastructure, strengthened by the fact that there is a lack of planned integration of transport and land use. Informal settlements have been established near the core city. Traffic congestion becomes one of the most urgent problems, especially in the city centre (Nguyen 2007). Although there are several Master Plans for Hanoi on transport such as building new railway, highways or subways within the city (Vietnamese Ministry of Transport 2010), bus is still the main public transport mode at present in this big city; and the most common private transport is motorcycles.

Even though Randstad and Hanoi basically have two different economic and infrastructure conditions, the balance between public and private transport should suggest some impacts of urban forms. Thus, this thesis will investigate and assess the impacts of urban forms through the comparisons of transport modes. In Randstad, the quality of private transport is examined by the accessibility of available highways and regional roads, which together contribute to the accessibility by cars; while the quality of public transport is assesses through the supply of rail and bus networks, which affects the accessibility by public transport in general. Since more than 80 percent of transport in this area is by cars or public transport (Statistics Netherlands (CBS) 2010), these modes will be representative for the quality of private and public transport orderly. Regarding Hanoi area, according to HAIDEP (ALMEC Corporation, Nippon Koei Co. et al. 2007), buses and motorcycles account for more than 70% of transport in Hanoi. Thus, the quality of private and public transport will be assessed through motorcycle and bus networks.

# CHAPTER 3

# LITERATURE REVIEW

The definition of accessibility is often linked to the listing of accessibility measures and indicators (van Wee et al 2001). There is a wide variety of accessibility measures which have been developed since 1950s. For example, Vickerman (1974) built his measures by using indices of different land use types and transport conditions. In a different way, Bertolini (2005) used suitable places for residential areas as the accessibility indicator. From the literature, there are mainly three types of measures together with indicators indicated clearly in the overview of Geurs and Ritsema van Eck (Geurs and Ritsema van Eck 2001, Geurs and van Wee 2004):

- Infrastructure based measures: analyse the performance of the system based on infrastructure characteristics using indicators such as "level of congestion", "average travel speed" or "travel time". This measure is often used in transport planning.
- Activities based measures: comprised of location – based and person-based measures. Location-based measures analyse the accessibility at locations and evaluate the spatial distribution of services or activities. This measure uses such indicators as "the number of jobs that can be reached within 30 minutes". This measure is used typically in urban planning. Person-based measures analyse the activities at individual level. It use indicators such as "number of people traveling to one destination at a specific time" or "number of activities that people can participate in a specific time".
- Utility based indicators: analyse the travel cost between destinations and origins based on the utility theory which assumes people will choose the highest utility alternatives. This measure uses indicators such as "travel cost between destinations and origins".

For these three measures, infrastructure based is the simplest because it only depends on the transport infrastructure characteristics. However, it does not provide insight and understanding to how accessibility levels vary with different groups and land use patterns. Person-based and utility-based measures can provide results at micro level. However, they require an intensive data supply which is very difficult to obtain in reality. Among the above measures, location-based measures are preferable. This kind of measures has a balance between required data and quality of results. This is the reason why location-based measures are methods to be applied in this research. The traditional potential accessibility measure and accessibility measure with competition are chosen. These two methods will be described with more details in the following part of this chapter. Moreover, summary of main activities based accessibility measures are shown in table 2 below.

**Table 3: Summary of activities based accessibility measures**

| *Measures* | *Reference* | *Principles* | *Formulas for accessibility* |
|---|---|---|---|
| Contour measures (different name: cumulative opportunity , isochronic measure, proximity count, daily accessibilit) | (Wachs and Kumagai ; Geurs and Wee 2004; El-Geneidy and Levinson 2006; Cerda and El-Geneidy 2010) | - Count the number of opportunities that one can reach within a given time/distance/cost from a location; or<br>- Measure the required amount of time/distance/cost to reach a fixed number of opportunities | $A_i = \sum_{j=1}^{j} B_j O_j$<br>$A_i$: Accessibility at point $i$ to potential activities in zone $j$;<br>$O_j$: opportunities in zone $j$;<br>$B_j = 1$ if zone $j$ is within the predetermined threshold;<br>$B_j$=0 if zone $j$ is outside the threshold. |
| Potential accessibility measure (or gravity measure) | (Vickerman 1974; Geurs and Wee 2004) | - Similar to the contour measures, but account for the cost to reach the opportunities;<br>- More distant opportunities will be diminished in attractiveness. | $A_i = \sum_{j=1}^{n} O_j \exp(-\beta C_{ij})$<br>$A_i$: accessibility in zone $i$ to all opportunities in zone $j$;<br>$C_{ij}$: cost to travel from $i$ to $j$;<br>$\beta$: cost sensitivity parameter, need to be chosen carefully. |
| Adapted potential measures | (Shen 1998; van Wee, Hagoort et al. 2001; Cerda and El-Geneidy 2010) | - Competition at origins and/or at destinations is included;<br>- The effect of competition is expressed by dividing the available number of opportunities of zone i to the demands of zone i. | $A_i = \sum_{j=1}^{n} \frac{O_j f(C_{ij})}{D_j}$<br>$D_j = \sum_{j=1}^{n} P_j f(C_{ij})$<br>$A_i$: accessibility of location $i$;<br>$O_j$: opportunities at point $j$;<br>$f(C_{ij})$: impedance of cost function from $i$ to $j$;<br>$D_j$: demand for opportunities;<br>$P_j$: number of people in $j$ seeking for opportunities |

| | | | |
|---|---|---|---|
| Balancing factors (competition factors) | (Geurs and Ritsema van Eck 2001) | - The flow to and from a zone equals to the number of activities in that zone;<br>- Account for both competition at destinations and origins. | $$A_i = \frac{1}{\sum_{j=1}^{n} B_j D_j f(C_{ij})}$$ $$B_j = \frac{1}{\sum_{i=1}^{m} A_i O_i f(C_{ij})}$$ $A_i$ $B_j$: balancing factors that transform the activity units to flow units;<br>$O_i$ $D_j$: number of activities in zone *i* and *j*;<br>$f(C_{ij})$: negative function *f*, reflecting the impedance to travel from *i* to *j*. |
| Place rank | (El-Geneidy and Levinson 2006) | - Each locations will be ranks based on the number of people going to it to reach the opportunities;<br>- Based on the flows between origins and destinations;<br>- Account for the number of opportunities that individuals pass over in a zone to reach an opportunity in another zone. | $$R_{j,t} = \sum_{i=1}^{I} E_{ij} * P_{it-1}$$ $$P_{it-1} = E_j * (\frac{R_{j,t-1}}{E_i})$$ $R_{j,t}$: place rank of *j* in iteration *t*;<br>*I*: total number of *i* zones that link to zone *j*;<br>$E_{ij}$: number of people leaving *i* to reach an opportunity in *j*;<br>$P_{it-1}$: the power of each person leaving *i* in the previous iteration;<br>$E_j$: the original number of people destined for *j*;<br>$R_{j,t-1}$: the place ranking of *j* from the previous iteration;<br>$E_i$: the original number of people residing in zone *i* |

### 3.1 Potential accessibility measures

The traditional potential accessibility measure is a location-based measure which has been used most in literature. The accessibility level is assessed within a travel time or travel cost threshold (or a combination) and using a single travel mode. Attractiveness of opportunities will decrease with longer distance or higher travel cost. In this measure, there are assumptions on the decreasing level (impedance function) of opportunity attractiveness. This function will vary according to economy, travel habit and perception of the opportunity value in each region. The common function used is the negative exponential function. The following equation is used to calculate the accessibility level of zone *i* ($A_i$):

$$A_i = \sum_{j=1}^{n} O_j f(C_{ij}) \ or \ A_i = \sum_{j=1}^{n} \frac{O_j}{T^{\alpha}} \quad \text{(Equation 1)}$$

Where $A_i$: accessibility level of zone *i;*

$O_j$: the opportunities at zone *j*;

*f*($C_{ij}$)*:* impedance or cost function to travel from *i* to *j*;

*T*: travel time from *i* to *j* (minutes);

$\alpha$: coefficient depending on the real travel.

This equation can be applied several times with different travel modes. For example, accessibility to jobs can be calculated using car, train, bus or motorcycle. Thus, the results then can be compared and evaluation for the effective of different modes is withdrawn.

Limited by available secondary data, time and resources in this research, the traditional potential measure with travel time as the cost factor is applied in this thesis.

Although the potential accessibility measure can reflect the supply of opportunities over spatial distribution, it does not account for competition of available opportunities. In this case, it assumes that the competition will not affect the level of attractiveness or accessibility level. This disadvantage can be tolerated in some opportunities, but not with jobs. That is why the next paragraph discusses the same measure with inclusion of competition.

### 3.2 Accessibility with competition

For job accessibility, which has the competition at the destinations and/or at the origins, many studies include competition factors to alter the results (Vickerman 1974, Shen 1998, Van Wee et al 2001). An impedance function (or competition factor) is added to the equation to limit the opportunities that one can reach. This factor depends on the education background, characteristics of jobs or spatial distribution of people and opportunities. One reasonable measure including competition factor is the adapted potential measures (Shen 1998). In this method, the effect of competition at destinations is expressed by dividing the available number of opportunities in a zone to the demands reaching that zone. Van Wee (van Wee, Hagoort et al. 2001) enhanced this measure by integrating volume component with the competition component in his equation:

$$A_i = Volume\ component\ \times competition\ factor$$

$$Volume\ component = \sum_{j=1}^{n} \frac{Jobs_j}{T_{ij}^{\alpha}}$$

$$Competition\ factor = \frac{\sum \frac{Division\ \times Volume}{Time}}{\sum \frac{Volume}{Time}}$$

$$A_i(T < T_{max}) = \sum_{j=1}^{n}\left(\frac{Jobs_j}{T_{ij}^{\alpha}} \times \frac{\sum_{k=1}^{k=n}\left(\frac{\frac{Jobs_k}{Lf_k} \times Lf_k}{T_{jk}^{\alpha}}\right)}{\sum_{k=1}^{k=n}\left(\frac{Lf_k}{T_{jk}^{\alpha}}\right)}\right) \quad \text{(Equation 2)}$$

Where : $A_i$: accessibility of job *s* within a certain time $T_{max}$ from zone *i* ;

$j = 1 \ldots n$: all zones within certain time $T_{max}$ from zone *i*;

$k = 1 \ldots n$: all zones within certain time $T_{max}$ from zone *j*;

$Jobs_j$: number of jobs in zones *j*;

$Lf_k$: the size of employment market in zone *k* (active population);

$T_{ij}$: travel time from zone *i* to zone *j* (minutes);

$\alpha$: parameter for the distance function;

With their method, Van Wee et al (2001) enhanced the existing adapted potential measure by taking into account the impacts of other jobs on other zones related to the original zone *i*. Visualization of this method is presented in the following figure:

Source: (van Wee, Hagoort et al. 2001)

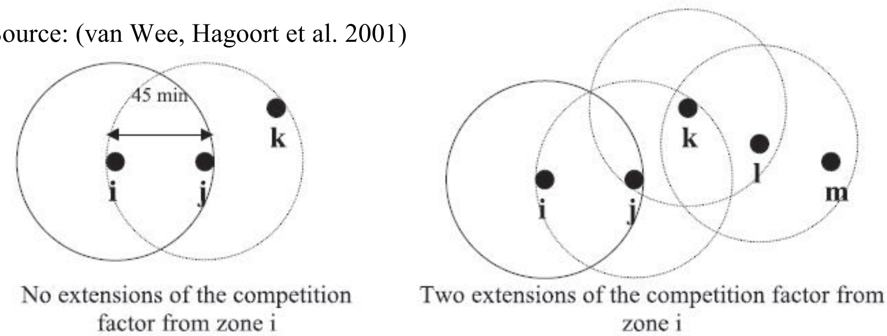



**Figure 6: Visualization of accessibility with competition of zone *i***

The accessibility of zone *i* is not only affected by number of jobs and population in zone *j* (which is next to *i*) but also affected by number of jobs and population in zones *k, l, m* and etcetera. As long as zones *k*, *l, m* and other zones lie within the maximum travel cost from zone *i* (in this case is travel time, or $T_{max}$), they will have impacts on the accessibility of zone *i*. The more jobs these zones have, the more job accessibility that zone *i* has. In adverse, the more working people these zones have, the less job accessibility that zone *i* has. Travel cost from each of these zones to *i* will also be important factor which decides the influence of these zones on zone *i*. The competition factor of a zone measures the ration between weighted total jobs and the weighted total labours of the whole urban area. Both totals are weighted by travel time to that particular zone. In other words, it measures, as its name suggests, how competitive it is to get a job at a particular point. In theory, the number of zones that can affect zone *i* is unlimited if maximum travel cost is infinite. In the equation of Van Wee, these impacts are included in the competition factor. In each zone within the travel cost, number of jobs per working person, labour market, and travel cost from zone *i* are determinants of competition factor of zone *i*.

Other measures including competition are balancing factors and place rank measure. The balancing factors measure assumes that the flow to and from a zone equals to the number of activities in that zone (Geurs and Ritsema van Eck 2001). El Geneidy and Levinson (2006) developed the place rank measure. Each location will be ranked based on the number of people going to it to reach the opportunities. Details and equations of these methods are described as in Table 2 above.

To enhance the result from the traditional potential accessibility measure, the accessibility measure with competition invented by Van Wee, Hagoort et al. (2001) is applied in this research. Besides the need to include competition in accessibility levels to jobs, there are also several reasons for choosing this measure. Firstly, this measure has included the potential measure in its equation. Therefore, it is easier to compare the difference of these two methods. Secondly, this method is less time consuming comparing to other methods such as balancing factors or place rank measure. Last but not least, the data requirements of this method are suitable for the scope of this research. Available data is always important for most of researches.

### 3.3 Impacts of urban form on transport and accessibility

Different urban forms, whether polycentric or monocentric, have different characteristics in density, geometric shape, land use, and infrastructure. The indicators to assess the function of urban forms can be listed as density, fragmentation and accessibility (Grazi, Fabio et al. 2008).

Impacts of urban forms on transport or travel behaviour are based on the notion that travel is a derived demand (Schepel and Zuidgeest 2009). These impacts have been studied through indicators from individual to city or region levels. However, they have still been under controversy (Schwanen, Dieleman et al. 2001; Alberti 2008; Grazi, Fabio et al. 2008). Majority of studies find a relation between urban forms and travel behaviour. Some studies pointed out that the impacts are small. Some other studies mixed between statistical correlation and causality of urban form on travel. (Grazi, Fabio et al. 2008). Generally, urban form is concluded to have impacts on travel behaviour through its spatial distribution of important activities such as residences, jobs and shops. One caution should be noted is that the changes in urban forms is gradually over time, while other changes in economy or transport happen with a more rapid rate. Thus, in a mean time, impacts of urban forms on transport are difficult to identify.

Several studies have been done on influences of urban form on travel behaviour and had concluded with variable factors (Handy and Niemeier 1997; Kitamura, Mokhtarian et al. 1997; Boarnet and Crane 2001; Cera 2003). In general, three main factors are including density of development, mix of land use and local accessibility to public transport (Cervero 1996; Schepel and Zuidgeest 2009).

The density of development factor is dealing with travel distance. Higher density of development, which often appears in more compact urban form, can reduce the transport distance and the number of trips made by individuals to home, work, and service areas. In detail, in more compact urban forms or monocentric form, people are likely to live near their downtown jobs (Williams 2003; OECD and ECMT; 2007; Grazi, Fabio et al. 2008). More compact cities also provide the population density high enough to build the public transport system. Consequently, more people will use public transport, walking or cycling. It is also expected that people in more compact urban form will use less private car in order to get rid of congestion which can result in low speed, high time loss and high cost. In addition, people can have more variety of possible destinations that can be reached within a same distance. This can obviously increase the opportunities accessibility.

Mix of land use characteristics in urban form relates to its spatial distribution of activities, travel distance and travel modes as a result. In the research of Cervero in 1996, non-motorized travel modes appear as being influenced the most by mix of land use. For example, having grocery and consumer service within 300 feet of distance will encourage people to commute by mass transit, cycling, and walking. However, with the distance from 300 feet to 1 mile, people often use auto-commuting for the possible reason to link work and shop trips by car (Cervero 1996). In the other words, presence and absence of neighbourhood shops and commercial land uses can predict partially the use of transport modes and physical separation of activities such as going to work/home, shopping and entertainment.

Another factor to affect transport mode is the proximity to public transport (Kitamura, Mokhtarian et al. 1997). Increasing distance to nearest railway station, for example, can reduce the choice of using train as transport mode. Increasing distance to bus stop can increase number of car journeys. The geographical locations of workplace also have impacts on the choice of transport modes (Susilo and Maat 2007; Manaugh, Miranda-Moreno et al. 2010). If the workplace of a company is nearer to public transport terminal, its employees tend to use more public transport as commuting mode to work.

In summary, there is a link between urban form characteristics and travel patterns. More compact cities seems to bring less travel distances, more use of public transport, and hence, more sustainable transport option. However, some researchers claim that these findings are the results of over-simplification of complex travel behaviours, especially for the working purpose. Moreover, there are still findings that commuting distance per person may not increase because of the development of polycentric urban structures. Otherwise, it can be relatively small in some urban areas (Schwanen, Dieleman et al. 2001). Another difficulty is to identify the compact level within that the city transport is sustainable. One option for this is to develop city corridors and multi-centred cities which can balance the density and the sustainability.

To understand more about the impacts of urban forms on sustainable transport or accessibility, this research will evaluate the results of accessibility in present conditions and in assumed scenarios.

# CHAPTER 4

# ACCESSIBILITY EVALUATION FOR PRIVATE AND PUBLIC TRANSPORT IN RANDSTAD AND HANOI

## 4.1 Methodology, data source and assumptions

### 4.1.1 Methodology

In this chapter, two accessibility measures are applied to Hanoi and Randstad in their current situation. First the potential accessibility measure and then the accessibility measure corrected with competition (as explained in the previous section, with the method of Van Wee et al, 2001) are implemented. These two methods are mainly chosen because the balance of available data and the quality of results aimed for. The objective is twofold. Firstly, potential accessibility measures will be tested for two transport modes: car and public transport for Randstad, and motorcycle and bus for Hanoi, enabling comparison between these couples of two modes. Secondly, accessibility measure corrected with competition is applied to alter the result. Comparison of new results to the traditional potential accessibility measure will also be investigated.

For traditional accessibility measure, the following equation is applied:

$$A_i = \sum_{j=1}^{n} O_j f(C_{ij}) \ or \ A_i = \sum_{j=1}^{n} \frac{O_j}{T^\alpha} \qquad \text{(Equation 1)}$$

For accessibility with competition, the following equation of Van Wee (2001) is used:

$$A_i(T < T_{\max}) = \sum_{j=1}^{n} \left( \frac{Jobs_j}{T_{ij}^\alpha} \times \frac{\sum_{k=1}^{k=n} \left( \frac{\frac{Jobs_k}{Lf_k} \times Lf_k}{T_{jk}^\alpha} \right)}{\sum_{k=1}^{k=n} \left( \frac{Lf_k}{T_{jk}^\alpha} \right)} \right) \qquad \text{(Equation 2)}$$

(For more detailed explanation, please refer to the previous chapter).

The impedance function $f(C_{ij})$ represents the degree to which zone $i$ is attracted by other zones basing on the travel time or cost. In the equation, impedance function of travel time depends on the actual trip modes, trip purposes, and household characteristics such as gender, age, income and educational level (Geurs 2001). Because of its complex nature, the choice and identification of travel time impedance in these equations are still under research. The form of impedance function is varied from simple inversely linear regression to more complicated negative exponential function or logistic function (van Wee, Hagoort et al. 2001; Geurs and Wee 2004; El-Geneidy and Levinson 2006). Some researchers also tested accessibility level using different impedance functions for their study areas (El-Geneidy and Levinson 2006; Geurs 2006).

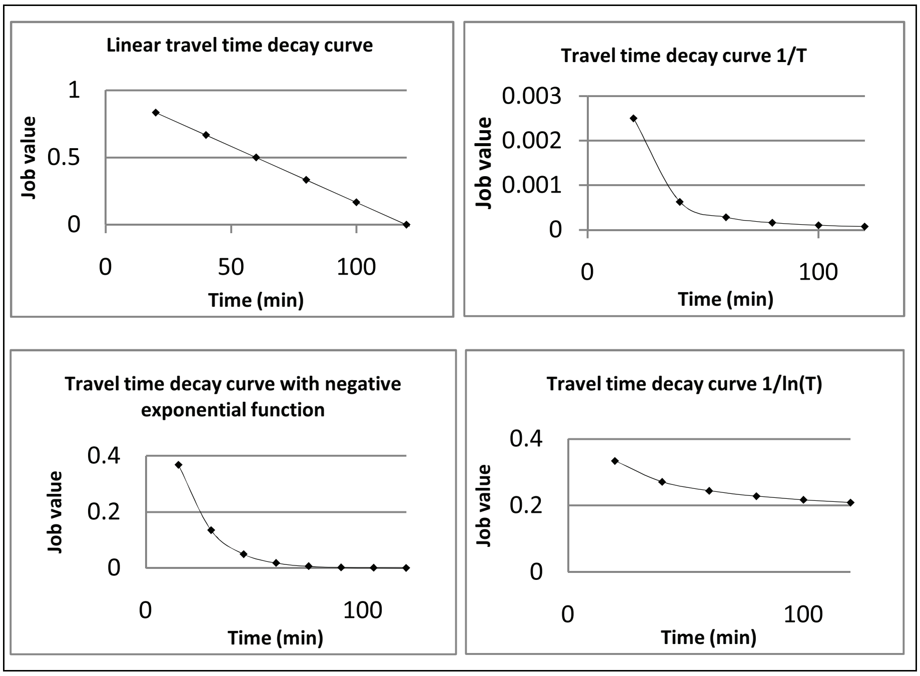



**Figure 7: Impedance functions (all modes and all trip purposes taken together)**

It should be noted that comparison of accessibility, which is the main goal of this research, should be done in a relative manner and not to compare the numbers directly. Thus, in this research, to easily identify how the competition factor alters the results, the impedance function of time is the same for the two methods: the values of jobs/labours will decrease with $\alpha$ power of time. This kind of reciprocal of $\alpha$ power of travel time impedance function were used in some researches such as (Geurs 2001) and (El-Geneidy and Levinson 2006). The choice of this function here is due to its simplicity and lacking of actual travel behaviour data to estimate the real impedance functions. Although this function is crude and simplified, it can include the impacts of travel time or cost on the employment market and it is suitable for the goal of this research: to compare accessibility levels by different transport modes and affected by different urban forms.

For the chosen exponential impedance function, estimating the $\alpha$ is rather complicated and requires several trials. The $\alpha$ value represents the degree to which people in one zone prefer to work near their home. Two extreme cases of $\alpha$ values are zero and infinity. If $\alpha$ equals zero, people can work everywhere. In adverse, if $\alpha$ reaches infinity, people in zone $i$ will only accept to work in their zone. Because people in Randstad have 39 minutes as mean travel time to work (Statistics Netherlands (CBS) 2010) and people in Hanoi travel to work with 19 minutes as average (ALMEC Corporation, Nippon Koei Co. et al. 2007), the travel time decay curve is faster for Hanoi. Assumptions on $\alpha$ values are 0.5 for Hanoi and 0.4 for Randstad to represent the average travel time. The chosen $\alpha$ values are thus only based on average travel time. Therefore, care must be taken when interpreting the results. Following are the graphs of assumed $\alpha$ values for the above equations.

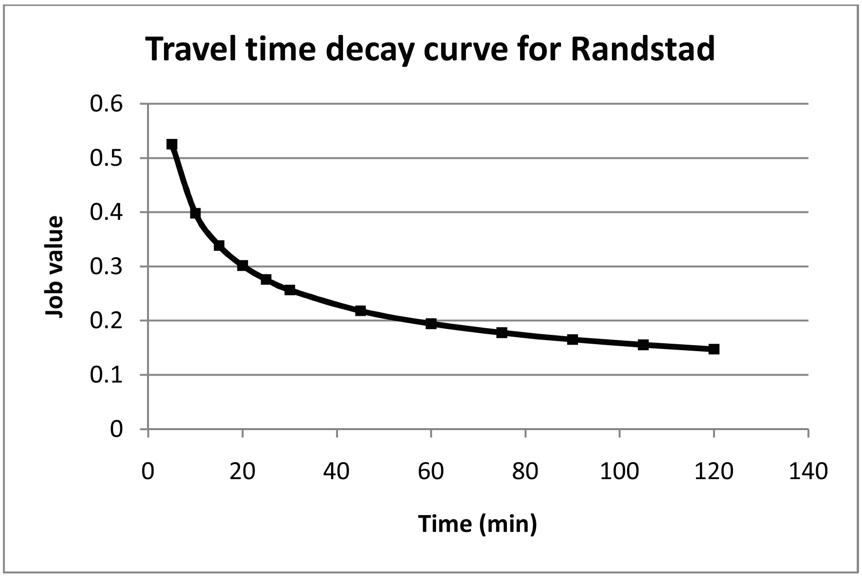



**Figure 8: Travel time decay curve for Randstad**

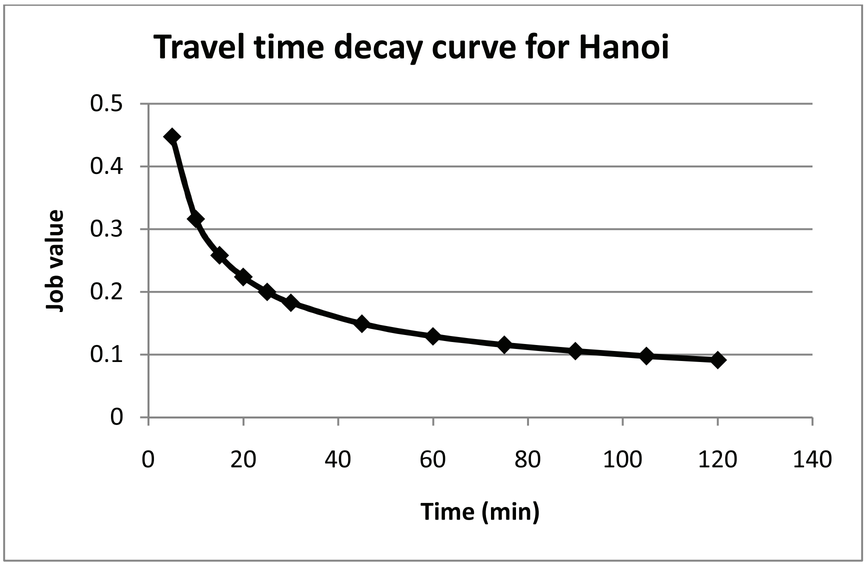



**Figure 9: Travel time decay curve for Hanoi**

### 4.1.2 Data and assumptions

Data for this thesis is listed in Table 4 as below. As discussed in the study areas chapter, car and public transport accounts for more than 80 percent of transport in Randstad; while buses and motorcycles account for more than 70 percent of vehicles in Hanoi. Therefore, the research use these transport modes as representatives for public and private transport in these two study areas. Job accessibility levels are calculated for each transport mode in each study area using the data given.

**Table 4: Data source**

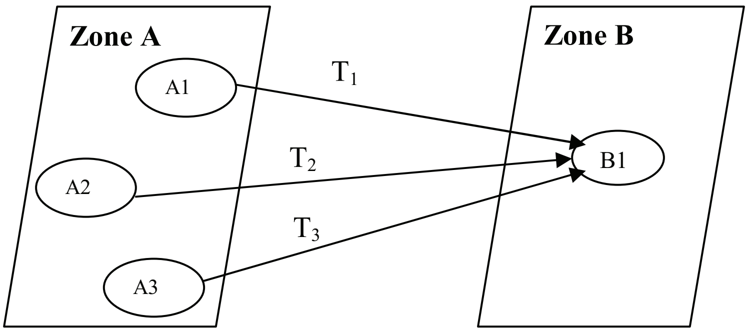
| *Region* | *Data* | *Source* | *Type* |
|---|---|---|---|
| Randstad | Administrative boundary | (Statistics Netherlands (CBS) 2010) | Secondary |
| | Travel matrices | (Goudappel Coffeng and Transumo 2010) | Secondary |
| | Population | (Statistics Netherlands (CBS) 2010) | Secondary |
| | Employment | Unknown | Secondary |
| Hanoi | Administrative boundary | (DIVA GIS 2010) | Secondary |
| | Road network:<br>- Old Hanoi area<br>- New Hanoi | <br>(Nguyen, Zuidgeest et al. 2008)<br>Digitized | <br>Secondary<br>Primary |
| | Bus network | Digitized | Primary |
| | Population | (Vietnamese Ministry of Natural Resources and Environment 2004) | Secondary |
| | Employment | (Hanoi Statistical Office 2004, 2009) | Secondary |

In addition to data provided, accessibility levels of TAZs in Randstad and Hanoi is calculated with several assumptions.

### *Randstad*

Accessibility to jobs in Randstad is also calculated using two measures described previously. These measures are generated at district level (wijk in Dutch), which is then considered transport analysis zones (TAZ). There are 799 TAZs within Randstad metropolitan region. The administrative boundary and the population data of 799 TAZs are downloaded from the website of Statistics Netherlands (Statistics Netherlands (CBS) 2010).

The travel time matrices of public transport or car from zones to zones are obtained directly from (Goudappel Coffeng and Transumo 2010). These matrices were generated using travel demand OmniTRANS software. There are two matrices that can be used: one is the travel time by public transport, another one is travel time by car which accounts for congestion in non-peak hours. The matrices generously obtained from Goudappel Coffeng, however, have travel time data from several locations within some TAZs (for example: Central, North or South of a district or from a port within that district). Thus, when calculating the accessibility level for that district, the author assumed that people will choose the shortest way to get from TAZ A to TAZ B. Therefore, caution should be used when interpreting the results for Randstad. Illustration of this process is shown in Figure 10 below.




If $T_1 < T_2 < T_3 \rightarrow$ Travel time from A to B = $T_1$

**Figure 10: Method for travel time calculation of Randstad**

### *Hanoi*

Accessibility level in Hanoi was calculated using two measures at commune level. The total number of zones (communes) is 574, downloaded from DIVA_GIS, a website which was supported by several CGIAR institutes: Biodiversity International, the International Potato Center, the International Rice Research Institute, and by the University of California, Berkeley, Museum of Vertebrate Zoology and others.

Employment at county level and demographic information was obtained from Hanoi Statistical Office and Vietnamese Ministry of Natural Resources and Environment.

However, these data source only contain the most important sectors of the economy, i.e. industry, commerce and services. Therefore, the accessibility will be only applied to those sectors.

Road network in Hanoi is partly digitized by the author from Hanoi map 2010 (Viet Nam Publishing House of Natural Resources - Environment and Cartography (NARENCA) 2010), and partly obtained from the previous work of Nguyen (2007). Bus network is digitized based on the official website of Hanoi bus (Transerco 2010)

Travel time is calculated in ArcGIS software based on the length and speed on each street. Speed of motorcycle is classified into 4 categories which obtained from (Nguyen 1999) and (Chu Cong, Kazushi et al. 2005). Details of categories are showed in table 5. Bus average speed is obtained from (Nobuyuki, Tetsuro et al. 2005) which is assumed 22.27 km per hour. Speeds of motorcycles or buses are assumed to be average speed during a day. Bus speed is assumed to be the same in every street. Travel time in the network is assumed for a single travel mode. Transit travel time is generated using a GIS network. These travel times include the walking time to the transit stop, in-vehicle time, transfer time, and walking time to the destinations. An O/D matrix of transit time from zones to zones will be produced and used to calculate the accessibility measures. Travel times, however, don't include the average waiting time at bus stops for bus travels based on scheduled frequencies. So the results should also be interpreted with caution.

**Table 5: Motorcycle speed categories**

| Category Number | Street Type | Average speed (km/h) |
|---|---|---|
| 0 | Highway | 40 |
| 1 | Big streets in city | 20 |
| 2 | Small streets | 15 |
| 3 | Lanes | 8 |

Source: (Nguyen 1999; Chu Cong, Kazushi et al. 2005)

There are also other assumptions to build bus network for Hanoi:

- On average the walking speed is 3 km/h on streets that don't have bus services.
- The transit time for the bus from one station to another station is given in the field Traveltime which is calculated by Length divided by speed.
- The bus stays for a certain time at the stations. This time depends on the bus stop type as indicated in Table 6. Bus stop type is classified based on the number of buses which pass each bus stop. If more buses stop at a bus stop, that bus stop will be classied in a lower category and have a longer dwell time.

**Table 6: Bus stop time**

| Number of buses | Bus stop type | Dwell time (Seconds) |
|---|---|---|
| 1-6 | 3 | 20 |
| 7-10 | 2 | 30 |
| >10 | 1 | 40 |

The number of jobs that can be reached from each commune is calculated within a travel time threshold. The number of jobs in each commune was calculated from the number of jobs in each district within the urban regions. Land use data for 14 counties was used and overlaid with administrative boundary. Percent of land use area of each commune is assumed to proportional to the percent of relative kind of jobs. For 15 counties which do not have available land use data, layer of industrial parks was used. Industrial jobs in industrial communes were assumed to be five times higher than non-industrial communes. Trade and service jobs in these counties were assumed to be proportional to the population (for clearer explanation, refer to Appendix 1).

## 4.2 Measure 1: Traditional potential accessibility measure

### 4.2.1 Job accessibility of private transport in Randstad and Hanoi

As mentioned before, cars and motorcycles are two representative means of private transport for Randstad and Hanoi respectively. Potential accessibility to jobs in Randstad and Hanoi are calculated using the travel time decay curves as in Figure 8 and 9 with ArcGIS 10 and Network Analyst extension.

The potential accessibility measure is only applied to the number of jobs. Since this measure can reflect the availability of opportunities and how users will perceive the transport system, closer opportunities will have more weight than those that are further. The value of opportunities or jobs in this case, is expressed in the charts of impedance function.

In Figure 11, the potential numbers of jobs that can be reached from each zone by cars in Randstad and by motorcycles in Hanoi are presented.

On one hand, the potential accessibility level of Randstad has the polycentric result which takes 4 big cities as centres for Randstad: Amsterdam, Rotterdam, The Hague and Utrecht. The result of job accessibility using cars in Randstad is comparative to some previous result such as Geurs (2001). The green heart which lies among these four cities also has higher accessibility than border areas in general. Only in one area on the right of Rotterdam, from Nederlek to Zederik, the accessibility is low even though these areas are near some big cities. This may be due to these areas are mainly rural and are forests. Thus, the transport conditions of these areas are not as good as other areas and lead to lower job accessibility.

On the other hand, applying the measure on Hanoi shows a typical monocentric result. Higher levels of accessibility to jobs quickly extend from city centre to lower levels of accessibility in suburban areas, regardless of transport modes. This is the result from the fact that city centre is well located regarding accessibility to job opportunities.

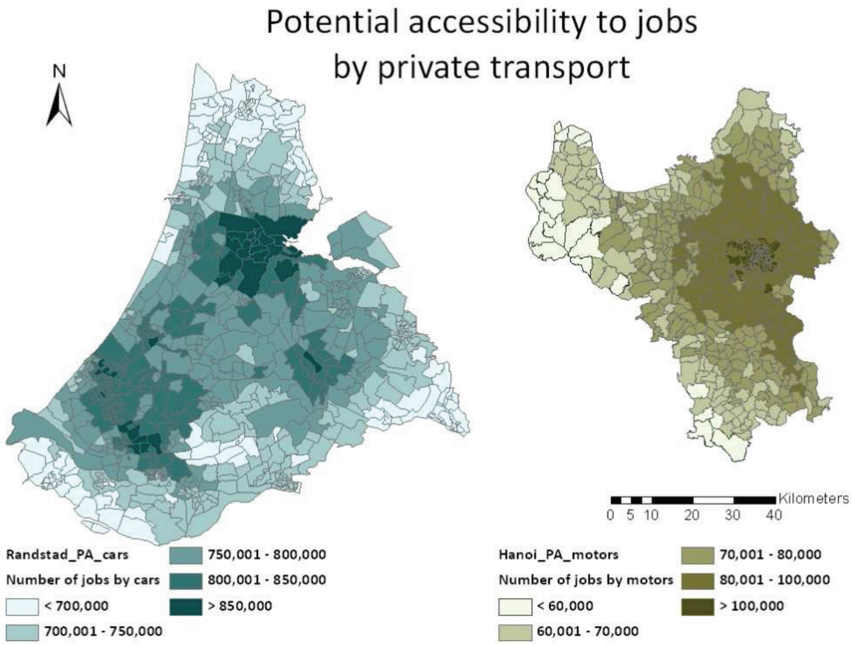



**Figure 11: Potential accessibility to jobs by private transport in Randstad and Hanoi**

In Hanoi area, some TAZ are outside the city centre but have a high accessibility on the North and North West directions and some TAZ in Thuong Tin on the south of the city. This is either the result of the locations of big industrial parks or locations of highways/bus route, which increase the job accessibility level to these TAZ.

By using motorcycle as transport mode, most of the internal counties of Hanoi have access to almost all the number of jobs. The southern part along the highway such as Thuong Tin, Van Dien also has a high accessibility. However, the accessibility levels are much different in some areas. The corridor in the West of the city still has limited accessibility to job opportunities. Inside the medium accessibility areas, there are still some zones that have lower accessibility comparing to other zones in the same counties. This result indicated that the road network in Hanoi is not uniformly developed. Other shortcoming can be that the road network in the low accessibility in the west is poorly connected to the highways or better quality roads.

According to the formula of World Bank, the road density is equal to ratio of the length of roads to the area. In Hanoi region, the road density is about 147 kilometres over 100 square kilometres. This number is much higher than the medium road density of Vietnam (about 48 kilometres over 100 square kilometres (World Bank 2007)). In addition, by using buffer zones, it is illustrated that more than 73% of

Hanoi is within 500 metres from all kinds of roads. This suggests that the road network in Hanoi is more condense but not evenly spatial distributed. There are big differences in infrastructure investments in different areas within the city. More details are illustrated in Figure 12 below.

Source: HAIDEP 2007

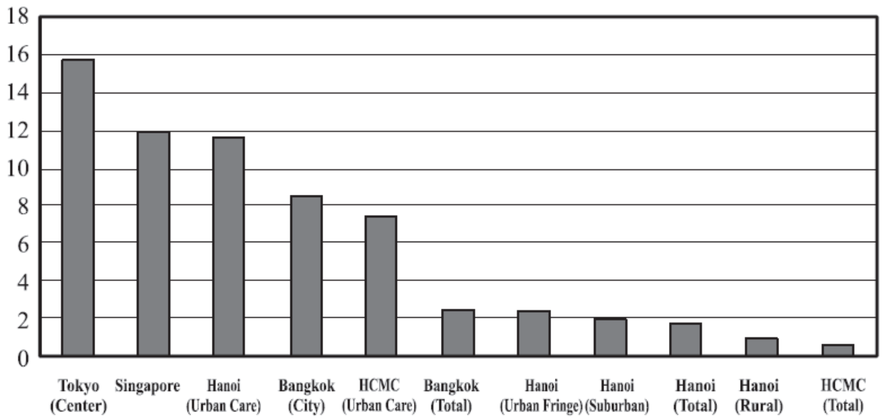



**Figure 12: Road density in Hanoi comparing to other megacities in Asia**

### 4.2.2 Job accessibility of public transport in Randstad and Hanoi

The same method is then applied to public transport in Randstad and Hanoi. Result is shown in Figure 13.

Large and some medium-sized towns in Randstad have the highest accessibility by public transport. Four biggest centres also emerge to have highest accessibility by public transport. Some zones in the middle of Randstad and between Utrecht and Rotterdam have lower accessibility comparing to surrounding areas. This may be explained by the rural, lakes/ponds conditions which lead to less supply of public transport.

By using buses in Hanoi, the potential opportunities are much lower than motorcycles, especially in the suburban areas. Bus network in Hanoi is only available at the city centre. In addition, there are several bus routes connecting city centre with some suburbs on the South and West of the city. However, these connecting bus routes are quite short, limited, and cannot cover the demand of the very large rural and suburban outside. This can easily explain for the fact that there is a huge difference between potential accessibility level of Hanoi centre and Hanoi rural or suburban.

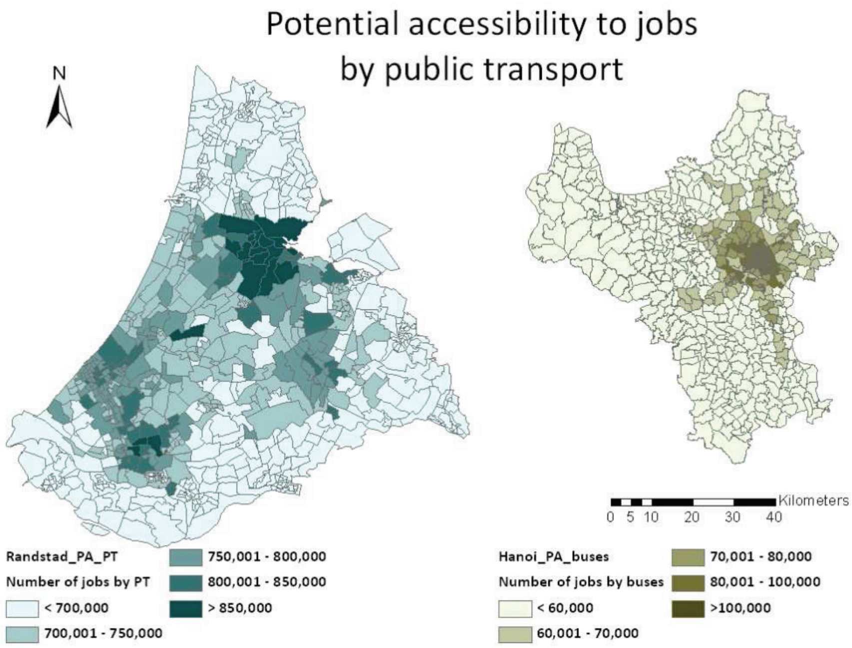



**Figure 13: Potential accessibility to jobs by public transport in Randstad and Hanoi**

### 4.2.3 Comparisons of private and public transport in Randstad and Hanoi

***Randstad***

In Randstad, job accessibility by cars is generally higher than by public transport. Interestingly, Stadsdeel Amsterdam Oud – Zuid has the highest job accessibility by public transport, which is also higher than Stadsdeel Osdorp (Amsterdam) which has the highest job accessibility by cars. Some more cities have higher job accessibility by public transport than by cars such as: Zanvoort, Mijdrecht (De Ronde Venen), and some TAZ in Amsterdam, Den Haag and Rotterdam. More details are shown in Figure 14 which describes the difference between potential accessibility of car and public transport.

Using the potential accessibility measure to calculate job accessibility, number of jobs that can be reached by car is from 0.86 to 1.4 times number of jobs that can be reached by public transport. The differences between car and public transport are quite evenly distributed. Four big centres, together with some surrounding cities such as: Delft, Pijnacker, Capelle, Lopik, Wijdemeren, Amstelveen or Bloemendaal, form an area with less difference between cars and public transport. In these areas, public transport may even have higher accessibility than cars. The border areas of Randstad generally have more differences between private and public transport. Cars seem to be more prominent than public transport. The result suggests that the conditions of using car or public transport are more or less equal among areas within Randstad and public transport is a sufficient means to approach jobs as well as cars.

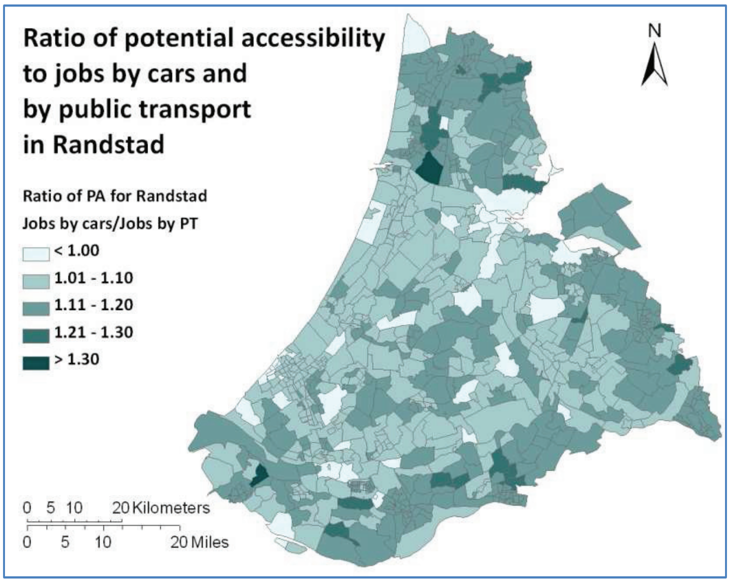
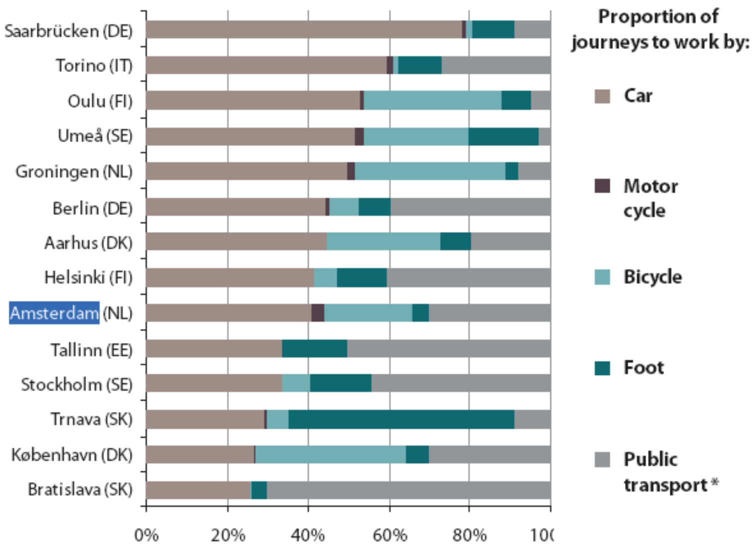



**Figure 14: Ratio of potential accessibility to jobs by private and public transport in Randstad**

The sufficiency of public transport comparing to private transport, such as cars, in the large cities of Randstad metropolitan area are partly proved by the study of Eurostat office. From Figure 15, public transport (including rail, metro, bus, and train) is quite competitive transport mode to work comparing to cars in Amsterdam.




Source: (European commission 2009)

**Figure 15: Distribution of journeys to work in selected cities in Europe**

***Hanoi***

To compare the difference between using motorcycles and buses, the ratio of potential accessibility of these two modes is calculated and shown on Figure 16. Ratio of motorcycles to buses is range from 1.12 to 2.4, which means that motorcycles have better access to jobs than buses in the whole city. However, in the city centre or along the bus routes, this ratio is small and ranges from 1.124 to 1.4. In other regions, especially the North West and south west region, the number of jobs that can be reached by motorcycles are more than 2 times by buses. This happens due to not available bus service in these areas.

The ratio of accessibility by motorcycles to buses in Hanoi somewhat shows the sufficiency of private and public transport in Hanoi. Due to lacking of bus network in Hanoi rural and suburban areas, the accessibility to jobs by public transport in these areas are not suitable to compare with the accessibility by private transport. This comparison should be done for only Hanoi city centre. Although job accessibility by public transport in Hanoi centre is less than by private transport in the whole, the differences may be acceptable. Thus, if the economic, social and convenient factors are included in the choice of travel modes, public transport may still surpass private transport in Hanoi city centre. However, this research does not deal with these factors. Thus, the unfavourable result of public transport mode over private transport mode is only partially evaluated here.

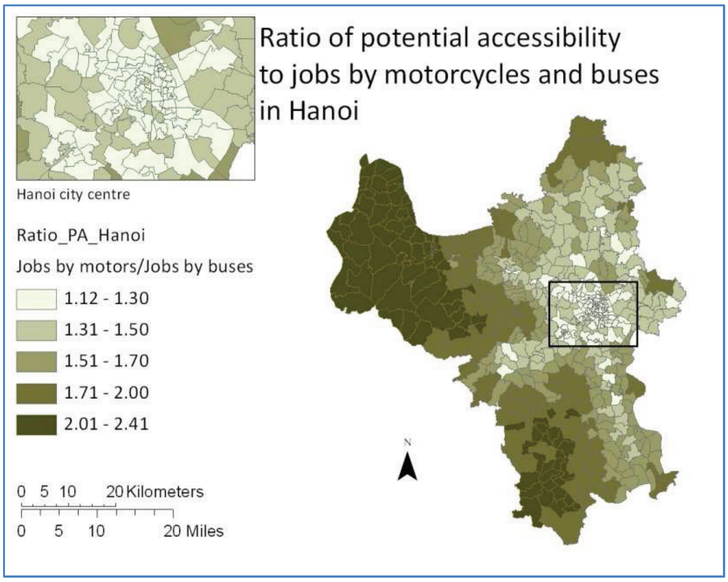



**Figure 16: Ratio of potential accessibility to jobs by private and public transport in Hanoi**

## 4.3 Measure 2: Accessibility measure with competition

### 4.3.1 Job accessibility of private transport

Accessibility with competition is tested on both Randstad and Hanoi for private and public transport modes using Equation 2 as described above. This measure will take into account for jobs and labours competition at locations.

In the accessibility formula, the travel time limit is one important parameter. Due to lacking of actual travel time thresholds for both study areas, these values in this thesis are only estimated values. Basing on the study of (Egeter, E. Verroen et al. 2000) (which was cited in (Geurs 2001)), the average public transport trip in the Randstad area is 70 minutes in 1995. The used data for this research is in the year 2004. As travel time limit will be set the same for both private and public transport for the goal of comparison between these two transport modes, the author assumed that maximum travel time to work (or travel time threshold) may take 90 minutes in Randstad. Thus, 90 minutes travel time threshold is set for Randstad. In the case of Hanoi, the travel time threshold is set based on the study of (ALMEC Coorporation 2004). Average travel time by buses was found about 50 minutes in 2001. The value 90 minutes travel time threshold, thus, is set also for both Hanoi motorcycles and buses.

The travel time threshold is set as 90 minutes for every zone in both study areas. Within this threshold, the values of jobs and labour that can reach one zone are valid. Otherwise, they will not be included in calculating the accessibility level for that zone. The more jobs can be reached from a zone, the higher accessibility level that zone has. Results are shown in Figure 17.

Within 90 minutes, most of Randstad can access more than 400,000 jobs by car. Only some TAZs in the North, East , South borders, and from Nederlek to Zederik (on the right of Rotterdam) can access less than 400,000 jobs within 90 minutes. An explanation for this result should be based on the locations of these areas as well as their natural conditions of rural and forests as discussed in the previous measure. Therefore, they have limited road network and limited access to jobs within a travel time threshold.

Big cities such as Amsterdam, Rotterdam, Den Haag and Utrecht also form areas with high accessibility. These results show the high available number of jobs within these areas despite the big labour market. The results reflect that number of jobs exceeds the labour force in these cities. This fits to the expectations and the results from (van Wee, Hagoort et al. 2001). Even though this thesis uses a simpler different impedance function than the function used by Van Wee and Hagoort, the correlation of accessibility levels of different zones is quite similar to their research.

For Hanoi area, the accessibility with competition remains highest in the central part of the city, and lowering in the suburbs areas as expected. Although the city centre has a high population and workers, it also has a better transport system. That can explain how it always has the highest accessibility to jobs.

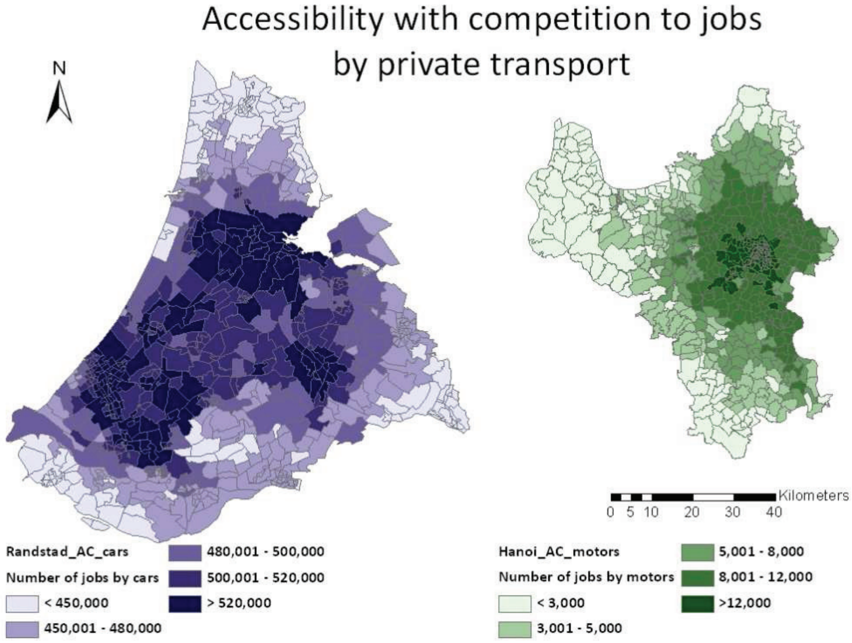



**Figure 17: Accessibility with competition to jobs by private transport in Randstad and Hanoi**

### 4.3.2 Job accessibility of public transport

The same method with competition is applied to public transport in Randstad and buses in Hanoi. Results are shown in Figure 18. High accessibility levels are also found in four big cities in Randstad and Hanoi city centre. In Hanoi, there are also some zones scattering around the city centre which have higher accessibility to jobs. This result happens mainly because of the existing industrial parks in these zones. Other zones which have bus connections will have the higher accessibility level comparing to the surrounding areas. In the Randstad case, high accessibility is found also in four big cities and in the green heart area which lies among them. Especially some surrounding cities such as Wassenaar, Kaag en Braassem, Maarssen have quite high accessibility to jobs comparing to other cities. This result can be explained because these smaller cities are in the suitable positions to approach jobs in big cities. Within the travel time threshold, these smaller cities can reach jobs in not only one but also in four big cities. This feature results in high job accessibility in these cities. Special cases with lower accessibility are in the middle of Randstad and area from Nederlek to Zederik on the East of Rotterdam. All of these areas are rural, forest or lakes which are not suitable for building public transport system here. Therefore, these natural conditions can explain for our results.

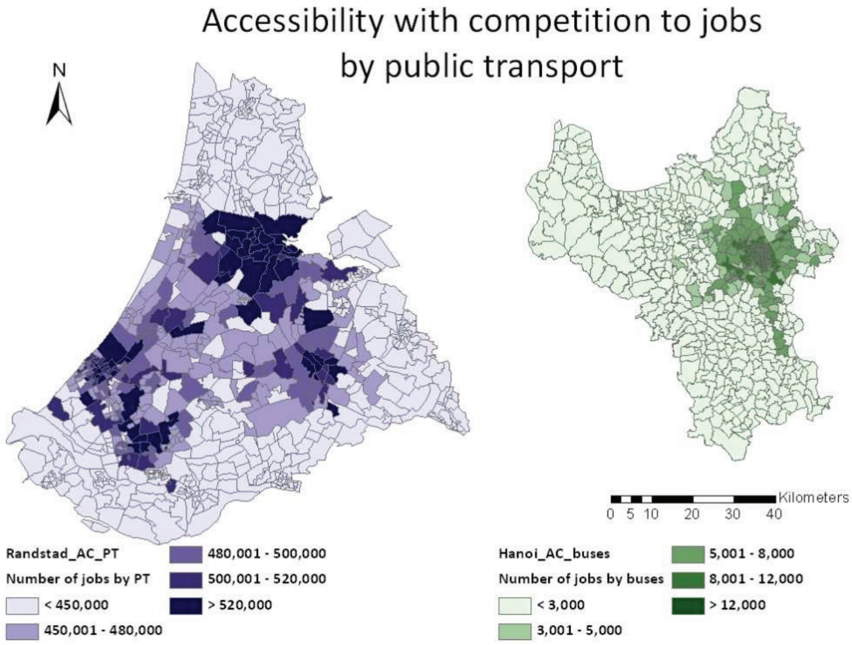



**Figure 18: Accessibility with competition to jobs by private transport in Randstad and Hanoi**

### 4.3.3 Comparison of private and public transport in Randstad and Hanoi

Ratios of accessibility with competition to jobs by private and public transport in two regions are also investigated and shown in Figure 19 and 20.

***Randstad***

Although the number of jobs that can be reached is 1.5 times lower than the number of jobs calculated in potential accessibility measure, car still has higher accessibility than public transport generally in Randstad.

As with the potential accessibility measure, the difference is more evenly distributed comparing to Hanoi result in Figure 20. The border of Randstad seems to have more difference than the centre region. An explanation for this result is that public transport among four big cities is better than public transport to or within the border regions. Although most of the inner region have lowest ratio of number of jobs that can be reached by cars and jobs reached by public transport, there are still some small TAZ inside which have high ratio. The explanation again relates to low job accessibility by public transport, which is the result of their natural conditions and conservation needs.

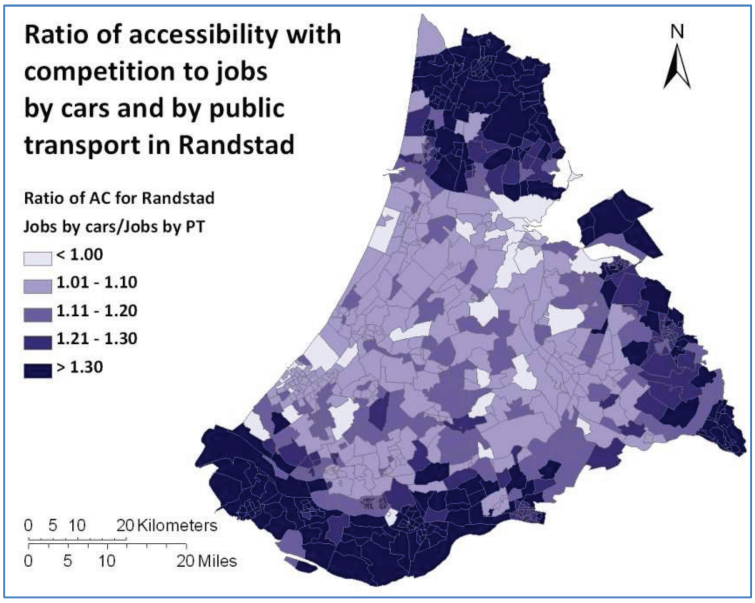



**Figure 19: Ratio of accessibility with competition to jobs by cars and public transport in Randstad**

***Hanoi***

Figure 20 shows the ratio of jobs in accessibility with competition by using motorcycles and buses. The difference in number of jobs that can be reached by motorcycles and buses is much larger than in the potential accessibility measure. In the city centre, the number of jobs by motorcycles is 1.45 times the number of jobs by buses. However, in the suburban areas, the number of jobs by motorcycles can reach 800 times the number of jobs by buses. This can be explained by the fact that there is no bus service at these communes, but the road network here is still good. Thus, the accessibility by motorcycles is much higher than accessibility by buses.

The lowest difference in job accessibility between motorcycles and buses are found at three zones in the West border. However, these small differences are due to the low job accessibility of both motorcycles and buses. In these areas, both road network and bus network are poor. Positive aspect of the problem is that these zones lie in the Ba Vi national park and natural Huong Tich cave.

The results show a clear deficiency of public transport service in Hanoi, especially in the rural and suburban areas.

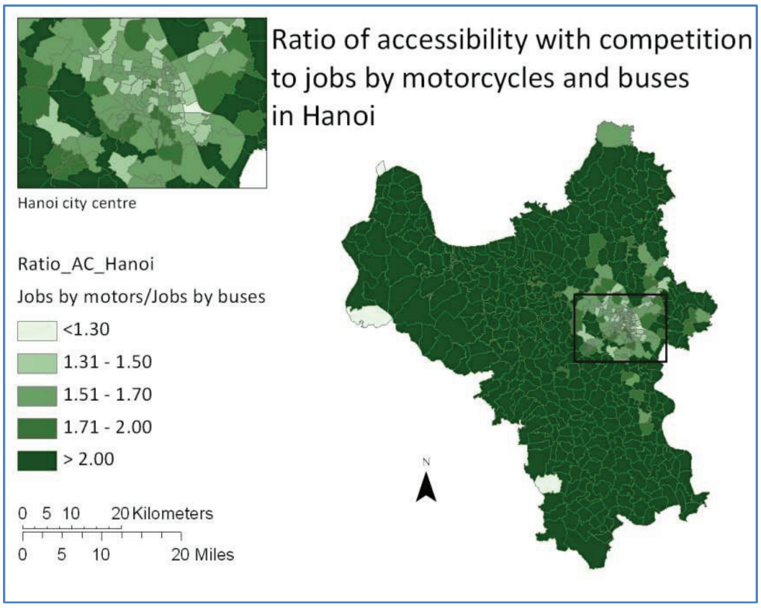



**Figure 20: Ratio of accessibility with competition to jobs by motorcycles and buses in Hanoi**

### 4.4 Correlations of potential accessibility measure and accessibility measure with competition

To identify the differences between the above two measures, the correlation charts are drawn for both Hanoi and Randstad as in Figure 21 to Figure 24.

There is clearly alteration in both areas when applying accessibility with competition, especially for Hanoi. For Hanoi motorcycles, the number of jobs by potential accessibility measure can be from 7 to 1,500 times more than the number of jobs by accessibility with competition. While for Hanoi buses, the difference of these two measures can reach 17,000 times. Randstad has much lower differences, which are only 1.5 to 1.6 times for cars and from 1.5 to 3.6 times for public transport. This result can prove clearly that the competition does make a huge change in job accessibility of Hanoi, while it has only limited impacts on Randstad region. This can happen due to the small employment market size in Hanoi.

As all of the paired results have a correlation coefficients of more than 94%, it is obviously proven that these two measures are highly related. Although accessibility measure with competition is preferred to the traditional potential measure because of its more theoretical soundness, the traditional potential accessibility measure does have some benefits over such as being more transparent, less time consuming, easy to understand and explain, and less data requirements. Therefore, it is possible to use the traditional accessibility measure instead of the accessibility measure with competition in cases dealing with comparisons within a region or dealing with politicians and general public.

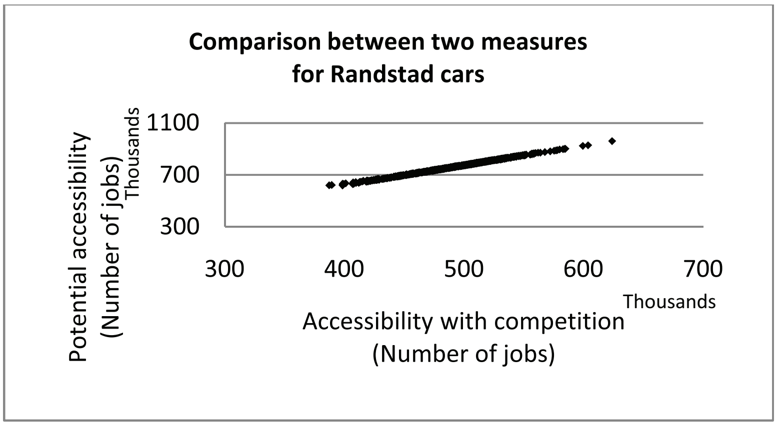



**Figure 21: Correlation of two methods for Randstad cars**

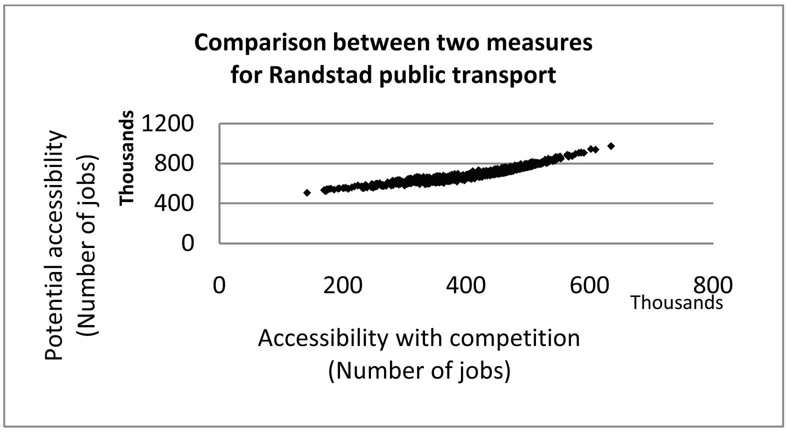



**Figure 22: Correlation of two methods for Randstad public transport**

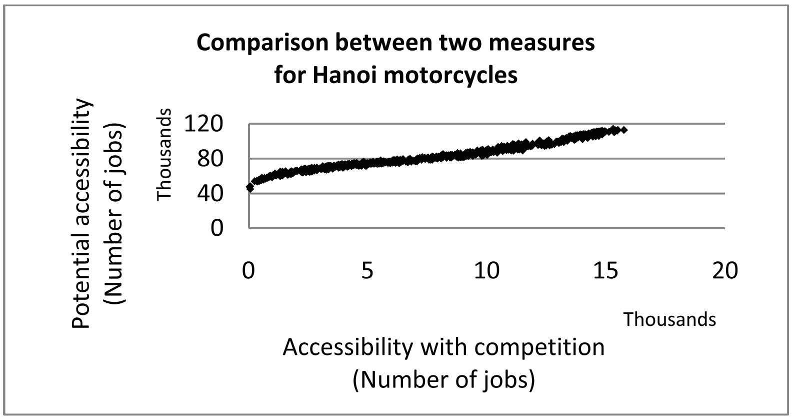



**Figure 23: Correlation of two methods for Hanoi motorcycles**

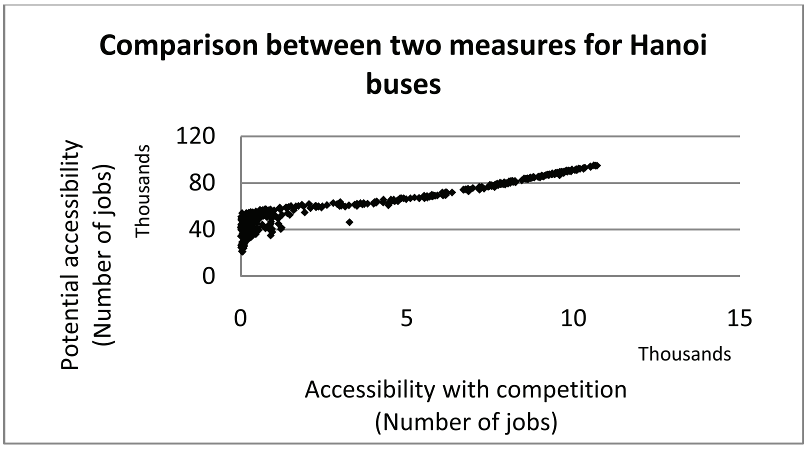



**Figure 24: Correlation of two methods for Hanoi buses**

### 4.5 Discussion

In general, Randstad and Hanoi have job accessibility levels for the different transport options varying relatively with their urban form structure: polycentric in Randstad and monocentric in Hanoi. Four big cities (Amsterdam, Rotterdam, Den Haag and Utrecht) in Randstad and the city centre in Hanoi always get the highest level of job accessibility. The border areas often have the lowest accessibility to jobs. However, the job accessibility of border areas should be carefully interpreted because impacts of employment market from outside of Randstad and Hanoi are not included. These impacts are normally strongest on these border areas.

Using the potential accessibility corrected with competition, private transport surpassed public transport in almost every zone. The situation leads to the demands of finding solution to improve public transport, which can supply the more sustainable transport. In addition, although the job accessibility is shaped by urban structure, the effects urban characteristics on accessibility and transport are still questionable and need more illustration.

The following part of this thesis, therefore, tests on different scenarios of both Randstad and Hanoi to fulfil the described demands. These scenarios will help to study the effects of urban characteristics on accessibility as well as the configuration of different urban forms. Learning lessons will also be withdrawn for the goal of improve public transport or sustainable transport mode.

# CHAPTER 5
# SCENARIOS

To test the effects of urban form on job accessibility, both case areas, Hanoi and Randstad will be given the opposite urban form, ceteris paribus, i.e. Hanoi will have a polycentric urban form and Randstad will have a monocentric urban form. In subsequent scenarios other variables will be altered as well.

For Randstad region, one large centre is proposed as Amsterdam with an area of more than 200 square kilometres.

For Hanoi region, three new urban centres are proposed: Son Tay in the North West, Soc Son in the North East and Van Dinh in the South. These three new centres are chosen based on the Project Hanoi master plan to 2030 and vision to 2050 (PPJ (Perkins Eastman – US 2010). In this project, Son Tay and Soc Son are proposed to be satellite municipalities and Van Dinh is an ecological township based on their existing conditions. In this research, these three new centres are also chosen because of their spatial distribution comparing to Hanoi old centre.

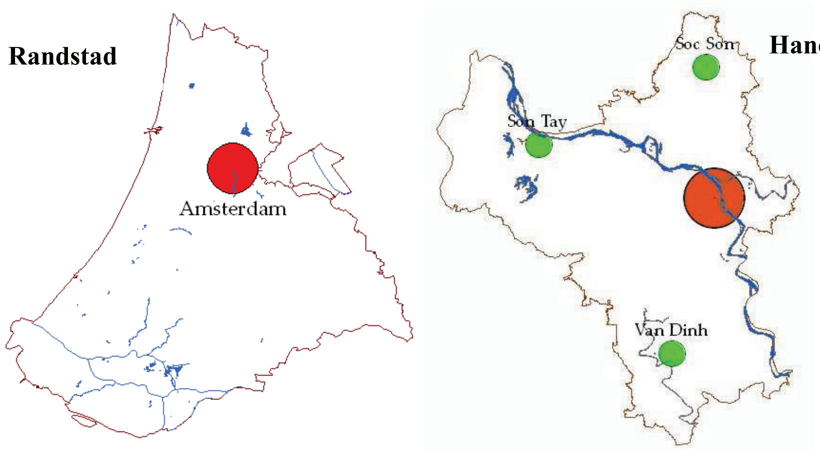



**Figure 25: Hanoi and Randstad new urban structures**

Because the accessibility measure with competition has a better theoretical basis, all of the scenarios here will concentrate on this measure. Thus, for general potential accessibility of some scenarios, please refer to Appendix sections

Five scenarios are tested in this research for Hanoi and Randstad:

- Scenario 1: Changed job distribution: Hanoi and Randstad jobs will be redistributed according to their new urban forms.
- Scenario 2: Improved infrastructure: There will be three new bus routes for each new centre in Hanoi. For Randstad, new high speed train routes are included by reducing travel time data.

- Scenario 3: Combined job distribution and improved infrastructure: This is the combination of Scenario 1 and 2. In addition, the impacts of travel habit and competition are also included through different travel time thresholds.
- Scenario 4: Changed labour distribution: In this scenario, the labour market will be redistributed according to new urban forms.
- Scenario 5: Changed job distribution and labour distribution: this scenario is the combination of scenarios 1 and 4.

Summary about urban characteristics and changes in scenarios are shown in Table below:

**Table 7: Summary of urban characteristics and changes used in Scenarios**

| Scenario | | Urban form structure | Changes |
|---|---|---|---|
| 1 | Randstad | Monocentric | Move jobs to Amsterdam |
| | Hanoi | Polycentric | Move jobs to three new centres |
| 2 | Randstad | Polycentric | Improve the travel time between big cities |
| | Hanoi | Monocentric | Improve bus connection in suburban areas |
| 3 (Scenario 1 + Scenario 2) | Randstad | Monocentric | Move jobs to Amsterdam and improve the travel time between big cities |
| | Hanoi | Polycentric | Move jobs to three new centres and improve bus connection in three new centres |
| 4 | Randstad | Polycentric employment | Move labour to Amsterdam centre |
| | Hanoi | Monocentric employment | Move labour to three new centres |
| 5 (Scenario 1 + Scenario 4) | Randstad | Monocentric | Move jobs and labour to Amsterdam |
| | Hanoi | Polycentric | Move jobs and labour to three new centres |

## 5.1 Scenario 1: Changed job distribution

In scenario 1, 70 percent of jobs from Hanoi old centre will be redistributed to other three new centres. Old Hanoi centre is generally including old districts of Hanoi: Ba Dinh, Cau Giay, Dong Da, Hai Ba Trung, Hoan Kiem, Tu Liem, Hoang Mai, Ha Dong, Long Bien, Tay Ho and Thanh Xuan; while three new centres will take three existing townships as centre points, and 10 surrounding communes as other parts of new municipalities. Jobs are distributed equally to communes in three new centres.

For Randstad region, 70 percent of jobs from three big cities: Den Haag, Rotterdam and Utrecht are moved to Amsterdam. New job distribution is presented in Figure 26 for both study areas.

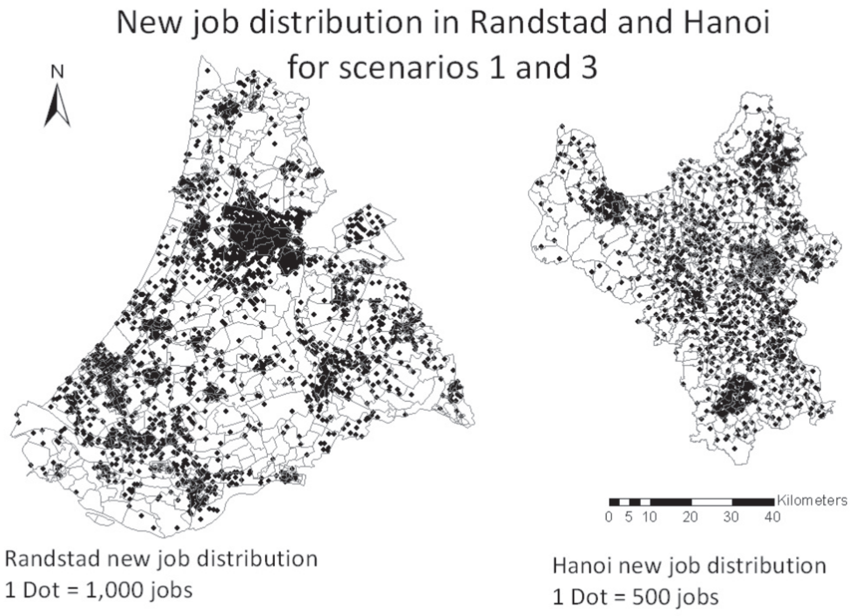



**Figure 26: New job distribution for Randstad and Hanoi in scenarios 1 and 3**

Accessibility levels are calculated for both areas with the same parameters as in the previous chapter, which means $\alpha$ values are 0.4 for Randstad and 0.5 for Hanoi, travel time threshold is 90 minutes for both areas.

The redistribution of jobs leads to an opposite result for motorcycles in Hanoi versus cars in Randstad, and buses in Hanoi versus public transport in Randstad.

Using the accessibility measure with competition in this scenario, the number of jobs that can be reached by motorcycles in Hanoi generally decreases on the East side, while it increases on the West side of the city. With the existing road network, the accessibility is more evenly distributed as compared to the result in Figure 17. The largest accessibility level is found to be 14 thousands as compared to 16 thousand found in the non-scenario calculation. In the opposite, the largest number of jobs accessed by car in Randstad increases from more than 600 thousands to 800 thousands. Randstad has the monocentric result as predicted. An increase in job accessibility happens in almost region, except for two big cities, Den Haag and Rotterdam, and the southern region of these two cities.

Scenario 1 and, to a lesser extent, scenario 3 which will be presented later, on Hanoi obviously show how the competition factor, which measures the ratio between weighted total jobs and the weighted total labours of the whole urban area, affects accessibility. In those scenarios, 70% of jobs in Hanoi's center are distributed to its three satellites cities, making the four cities at a same level of number of jobs. As a result, number of potential accessibility jobs is approximately the same for the four cities (as in Fig. 27). The accessibility with competition, however, is much smaller in Hanoi center than in three new centres due to its high competition (Fig. 29 and Fig. 30). In other words, at a same level of potential accessibility, the inhabitants in Hanoi center have to compete much harder with each other to get a job, hence having a smaller 'real' accessibility to jobs than their neighbours in the satellite cities. As we can see, the accessibility with competition reflects more accurately the reality then potential accessibility (without competition).

Similarly to the result of motorcycles in Hanoi versus car in Randstad, the highest accessibility of buses in Hanoi decreases while the highest accessibility of public transport in Randstad increases. For Hanoi buses, the accessibility of the whole city is generally low. There are only some communes in the new centres has higher accessibility, which can be explained by more jobs are distributed here than labour. Randstad has exactly similar structure as "real" Hanoi: Amsterdam and nearby cities have much higher accessibility than the border regions. Competition factor here again proves its efficiency when dealing with Hanoi case. With more jobs but remaining small labour force, three new centres emerge as the most attractive place for job accessibility.

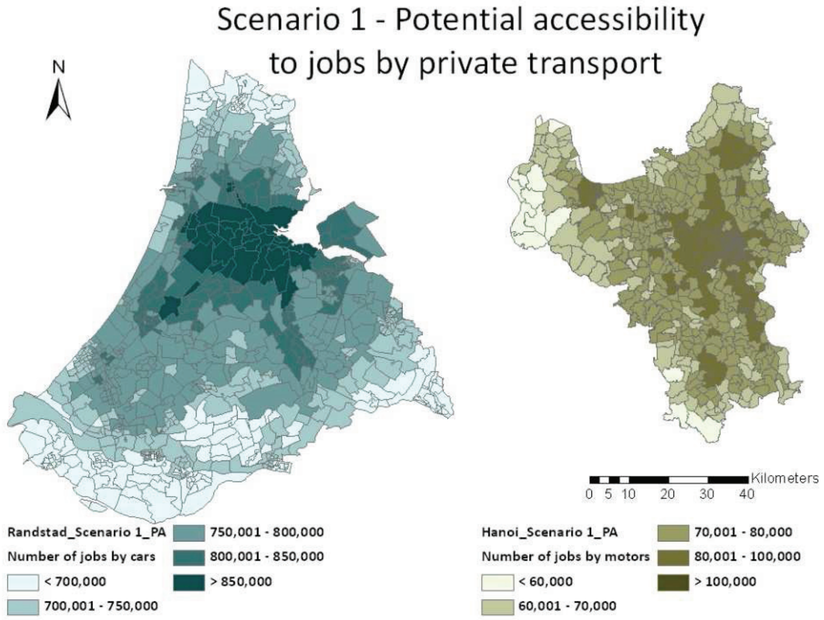



**Figure 27: Scenario 1 – Potential accessibility to jobs by private transport**

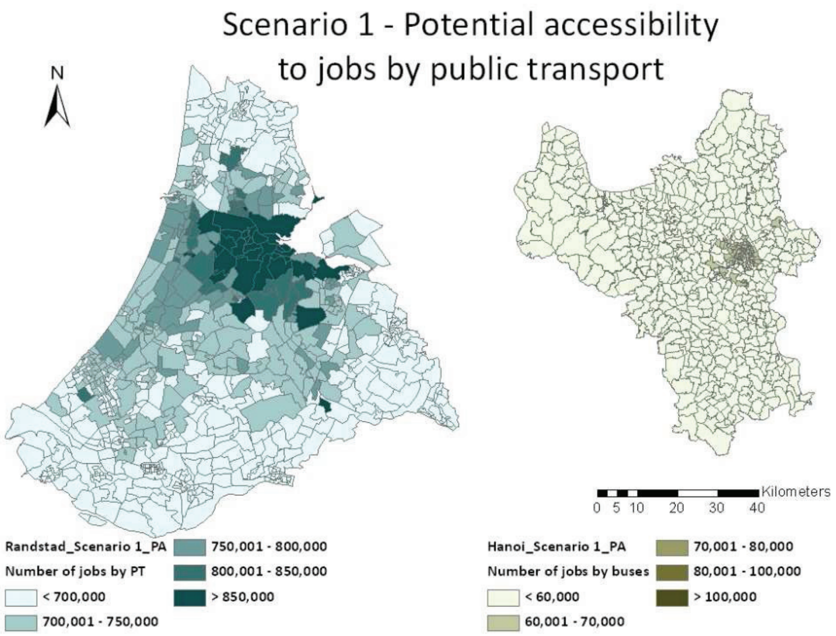



**Figure 28: Scenario 1 – Potential accessibility to jobs by public transport**

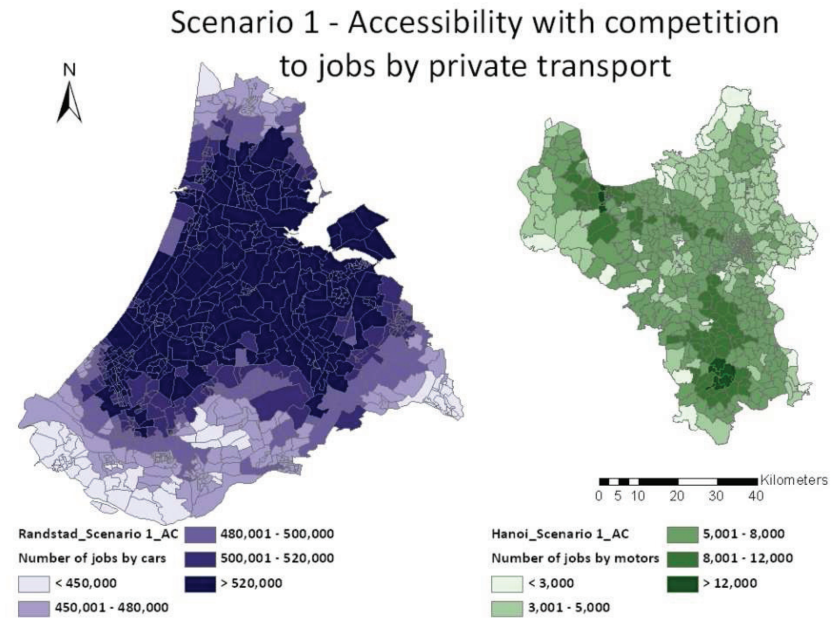



**Figure 29: Scenario 1 - Accessibility with competition to jobs by private transport**

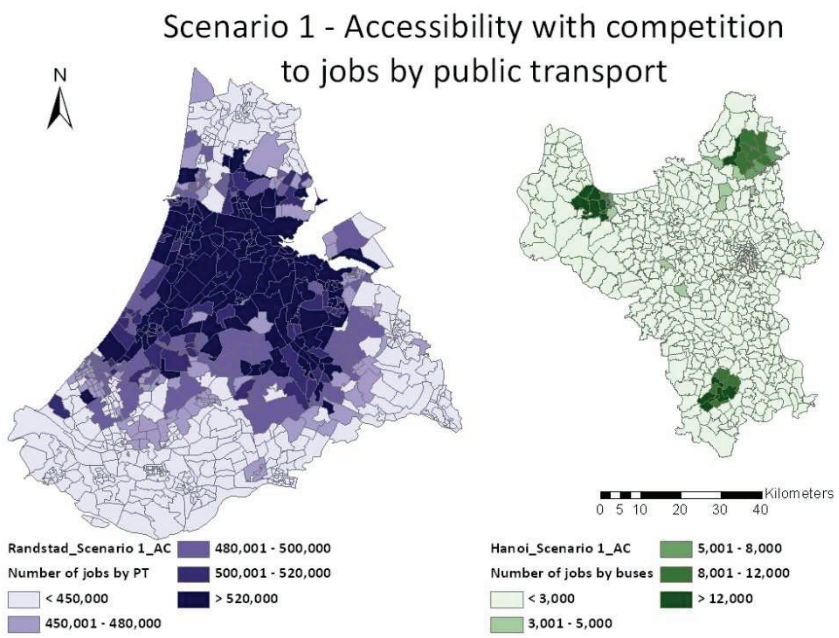



**Figure 30: Scenario 1 – Accessibility with competition to jobs by public transport**

## 5.2 Scenario 2: Infrastructure improvement

In this scenario, public transport in Hanoi is improved. Nine new bus routes are digitized crossing the three new centres and connecting these centres with nearby areas as well as the old centre. The routing is based on the researcher's own best interpretation of most suitable locations. Therefore, accessibility levels will be calculated only for buses in Hanoi and are shown in Figure 31.

The results show an increase accessibility of communes along the bus network for both measures. However, using the accessibility with competition, there are still communes along the bus network with low accessibility. This result can be explained by the unequal distribution of jobs and labours, or because of the set travel time threshold which can limit the access to job centres.

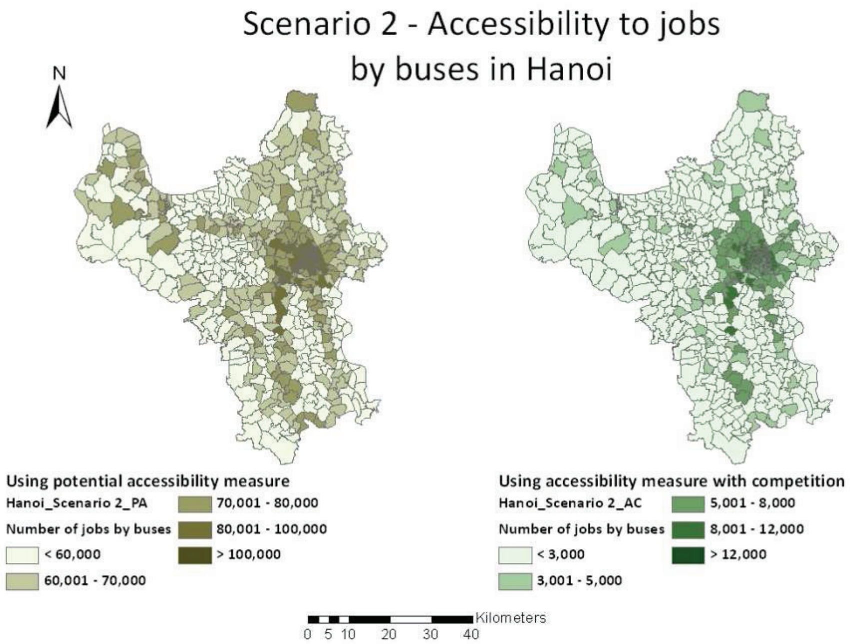



**Figure 31: Scenario 2 - Accessibility to jobs by buses in Hanoi**

In the case of the Randstad region, accessibility is improved by means of introduction of a number of hypothetical hi-speed rail connections between the four big cities. Six hi-speed lines are assumed: Amsterdam-Rotterdam, Amsterdam-Utrecht, Amsterdam-Den Haag, Rotterdam-Den Haag, Rotterdam-Utrecht, and Den Haag-Utrecht. Each city will have one hi-speed station which is the same with central station. Travel times on these links, for example from Den Haag centre to Amsterdam centre, are reduced by a factor two to cause an immediate effect. For other links, travel time might also be reduced as people can now use hi-speed train in a part of their journey. Due to locations of the chosen hi-speed stations, (centres of Amsterdam, Utrecht, Rotterdam and Den Haag), it can be assumed that an optimal journey between two arbitrary points can be made by at most one hi-speed connection.

New travel times between two zones A and B for all hi-speed links can be written as:

$$T_{new\_A\text{-}B} = \min_{hsX,hsY}(T_{old_{A-B}}, T_{A-hsX} + T_{hsX-hsY} + T_{hsY-B} + T_{transfer}, \dots)$$

Where:

$T_{old\_A\text{-}B}$ / $T_{new\_A\text{-}B}$: old/new travel time from *A* to *B*,

$T_{A\text{-}hsX}$: travel time from zone *A* to start point of hi-speed in zone *X*,

$T_{hsX\text{-}hsY}$ : travel time from zone *X* to zone *Y* by hi-speed train,

$T_{hsY\text{-}B}$: travel time from zone *Y* to destination *B*,

$T_{transfer}$: transfer time in the whole journey.

In our scenario, *X* and *Y* refer to four city centres of Amsterdam, Rotterdam, Den Haag and Utrecht. *A* and *X* or *Y* and *B* can be the same, in which cases $T_{A\text{-}hsX}$ and $T_{hsY\text{-}B}$ will be zero. Transfer time is estimated and is assumed 10 minutes per correspondence.

The results are shown in Figure 32 and 33 for two measures and compared with Figure 13 and 18 respectively. The results show increased accessibility to jobs not only at the centre of four big cities, but also surrounding areas and nearby cities as expected. This scenario adds a positive result to four big cities and nearby areas. However, the situation of low accessibility areas, which have limited public transport network or lie far from four big centres, remains the same.

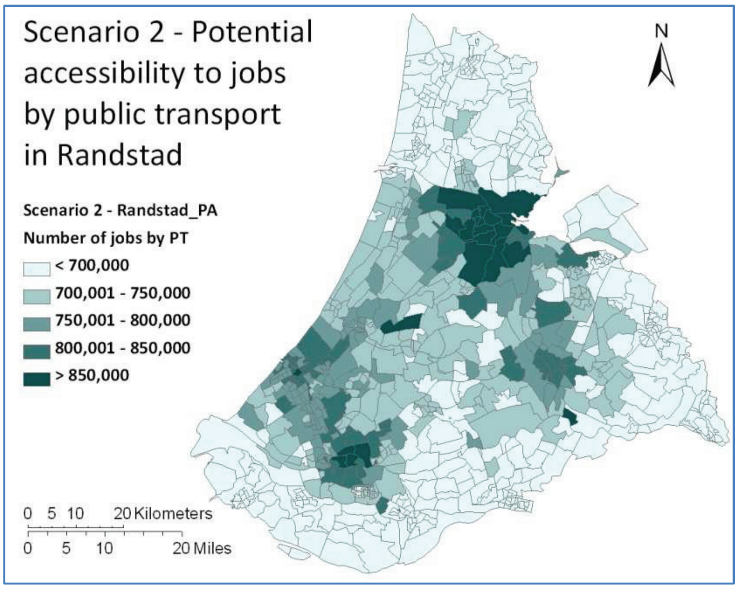



**Figure 32: Scenario 2 - Potential accessibility to jobs by public transport in Randstad**

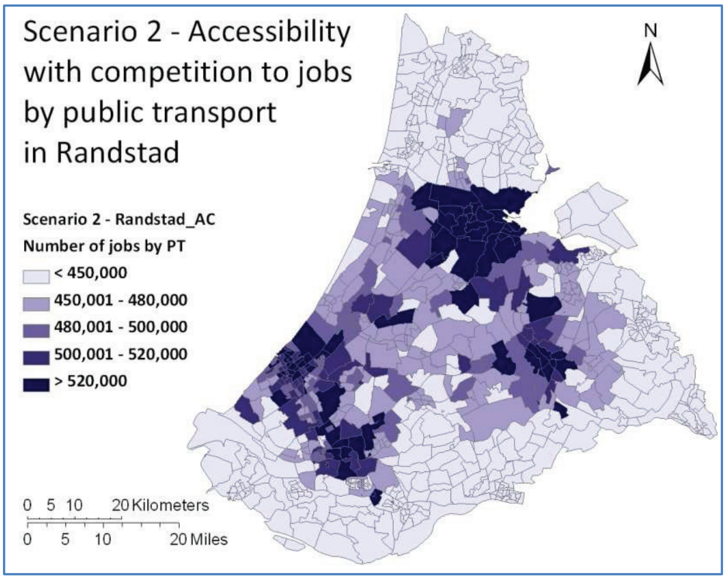



**Figure 33: Scenario 2 – Accessibility with competition to jobs by public transport in Randstad**

### 5.3 Scenario 3: Combined job distribution and improved infrastructure

This scenario is the combination of scenarios one and two. In addition, changing travel behaviour will be tested by using different travel time thresholds. Three travel time limits are used for both areas: 60 minutes, 90 minutes and 120 minutes. The results are shown in Figure 34-35 for Hanoi and Figure 36-37 for Randstad and for only accessibility measure with competition. For potential accessibility measure, please refer to appendix section.

Within 60 minutes, job accessibility by motorcycles in Hanoi in this scenario gives three new centres the highest levels while old Hanoi city centre has lower level. This can reflect the unequal distribution of jobs and labour. When travel time limit increases to 120 minutes, the result seems to be in an adverse direction. The whole region has more evenly job accessibility, while old Hanoi city centre increases quickly its job accessibility level. This is due to the fact that workers in Hanoi old city centre have enough time to compete for jobs of other regions and then make the job accessibility of these regions lower.

In Hanoi, high accessibility levels by buses are found along the network outside the city centre. Only with travel time threshold of 120 minutes, old Hanoi city centre has a competitive accessibility to three new centres. This result can illustrate that people in Hanoi centre may have to travel more time by buses to reach the same number of jobs. Thus, old Hanoi city centre is not an ideal place for job accessibility in this scenario.

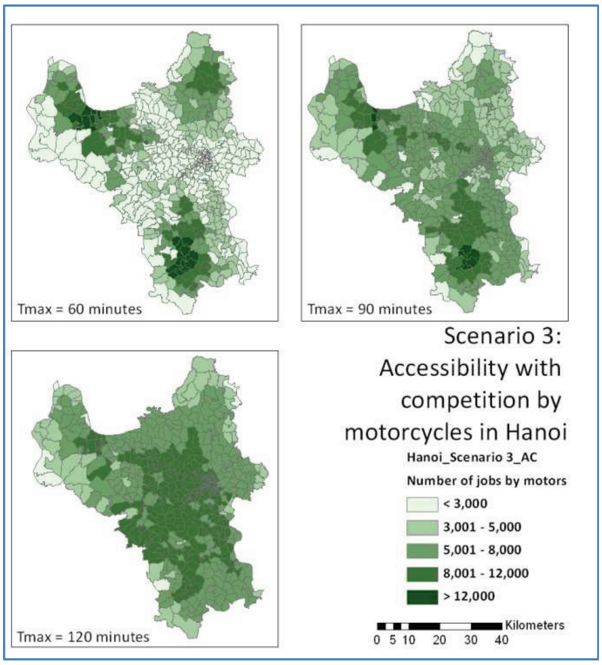



**Figure 34: Scenario 3_Accessibility with competition by motorcycles in Hanoi**

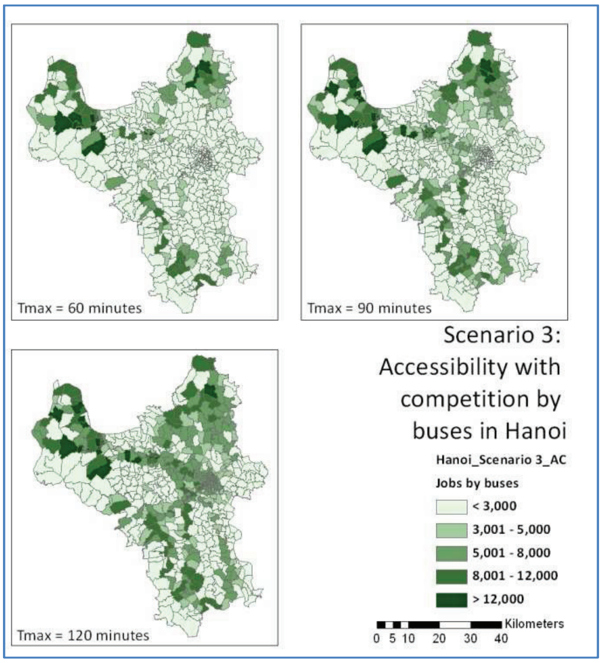



**Figure 35: Scenario 3_Accessibility with competition by buses in Hanoi**

In Randstad case, Amsterdam is still the big centre and has the highest job accessibility. Cars have better accessibility than public transport as usual. Border areas have worse accessibility than areas near Amsterdam. Values of accessibility by cars with travel time thresholds of 90 minutes and 120 minutes are not much different. The reason is that 90 minutes of travel time is very near to the "top" travel time in Randstad. As from the data given, the longest travel time by car within Randstad is 1.7 hours. Thus, 120 minutes travel is actually unlimited travel time for competition among areas within Randstad and 90 minutes is nearly unlimited number in this case.

With job accessibility by public transport mode, travel time thresholds highly affect the green heart region and old centres such as Den Haag, Rotterdam and Utrecht. These areas have good accessibility with travel time bigger than 90 minutes. The area in the North of Amsterdam has remarkably increases in job accessibility as compared to their situation in scenario 2. Oppositely, the areas on the south of Rotterdam and Den Haag decreased in their job accessibility. It is hardly to say which scenario brings better option in this case. To utilize the results, the context should be included. Depending on the context on which zones are needed to develop, one can choose the better scenario.

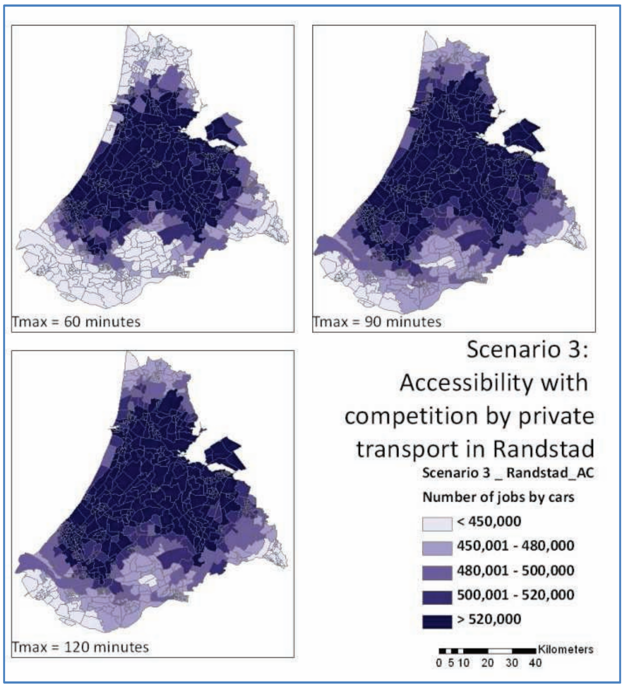



**Figure 36: Scenario 3_Accessibility with competition by cars in Randstad**

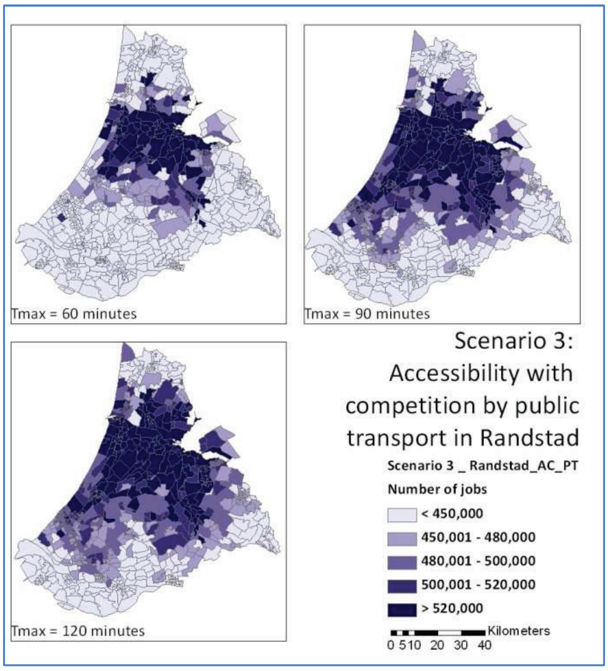



**Figure 37: Scenario 3_ Accessibility with competition by public transport in Randstad**

An extra scenario 3b is also done in Randstad case. In this scenario, Amsterdam is considered the only important centre in Randstad region. The hi-speed links are thus built with only three links to get to and from Amsterdam: Amsterdam-Rotterdam, Amsterdam-Utrecht, and Amsterdam-Den Haag. All other parameters and assumptions are the same as in scenario 2.

Results are shown in Figure 38 and 39. A similar impact happened in the green heart area. Although the areas near Rotterdam and Den Haag have lower accessibility than they have in scenario 2, the areas in the North of Amsterdam have higher. These results are somewhat similar to results of scenario 3 above. In addition, these results are quite comparative to results of scenario 2, in which improved infrastructure is applied for Randstad existing polycentric urban form. This scenario can suggest one of the advantages of monocentric urban form: To obtain higher accessibility for the equivalent areas, polycentric urban form may have to build more connections than monocentric urban form (in this case is six links in scenario 2 and scenario 3 and three links in scenario 3b).

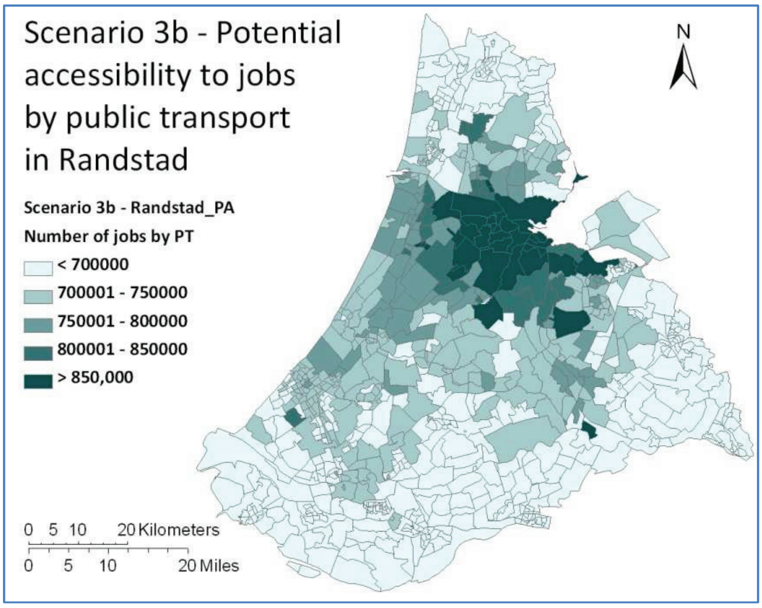



**Figure 38: Scenario 3b – Potential accessibility to jobs by public transport in Randstad**

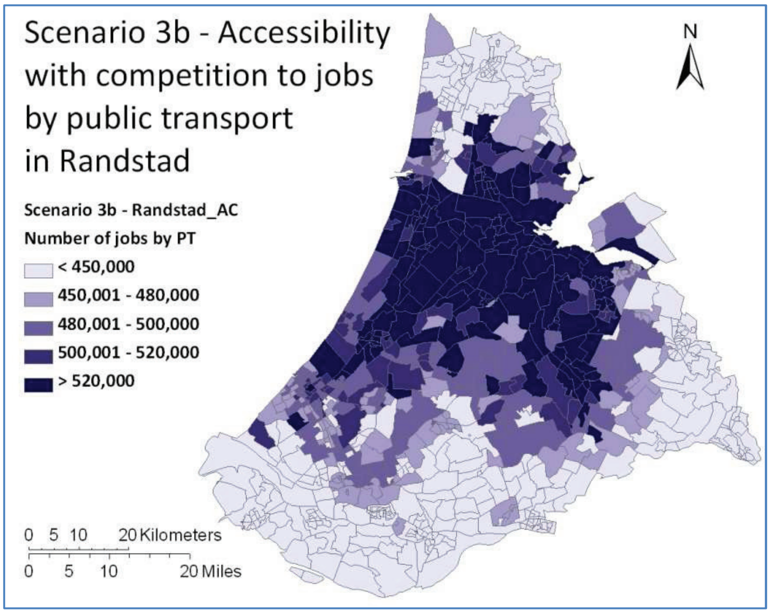



**Figure 39: Scenario 3b – Accessibility with competition to jobs by public transport in Randstad**

## 5.4 Scenario 4: Changed labour distribution

Similar to scenario 1, scenario 4 tests a case of moving labour instead of moving jobs. Seventy percent of workers are moved from Hanoi old centre to three new centres, while seventy percent of workers are moved from three old centres in Randstad (Utrecht, Rotterdam, and Den Haag) to Amsterdam. The labour distribution is illustrated in Figure 40 below.

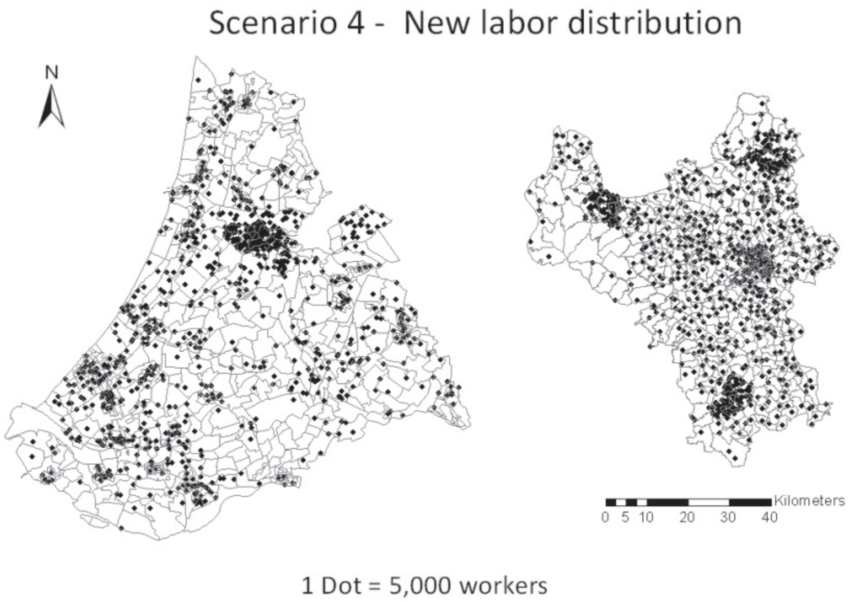



**Figure 40: Scenario 4 – New labor distribution in Randstad and Hanoi**

Job accessibility with competition in two study areas are calculated and presented in Figure 41-44. Both Randstad and Hanoi results in this scenario are unequally distributed. Areas with low accessibility before will have lower accessibility, while areas with high accessibility before will have higher accessibility in this scenario. Hanoi three new centres have worse accessibility, while Hanoi old centre has highest accessibility. All of these results are found because of the high differences of labour and jobs in the employment market.

Similarly situation is applied to Randstad: Amsterdam has lower accessibility than before due to higher competition, while Rotterdam, Utrecht and Den Haag and their nearby areas have higher accessibility. Changes are most visible around Rotterdam and Den Haag where the population is now less dense and the number of jobs stays the same.

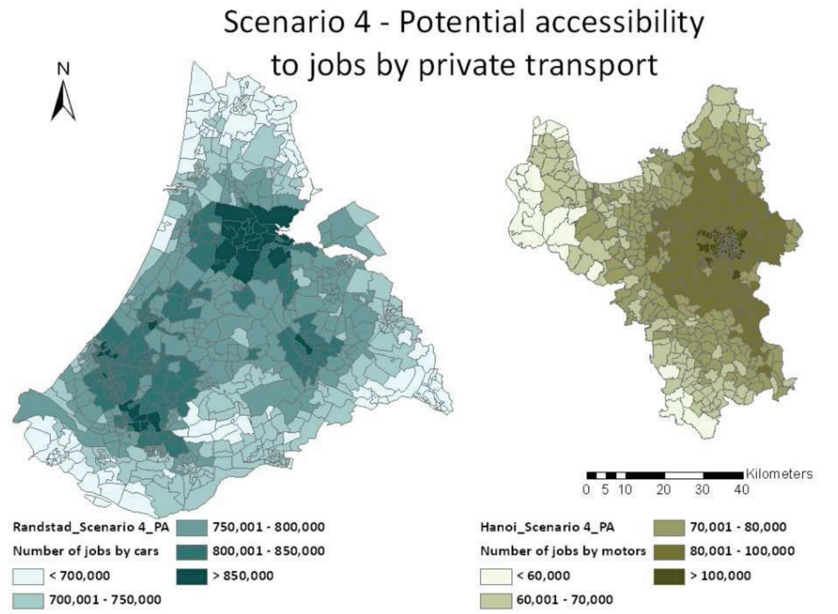



**Figure 41: Scenario 4 – Potential accessibility to jobs by private transport**

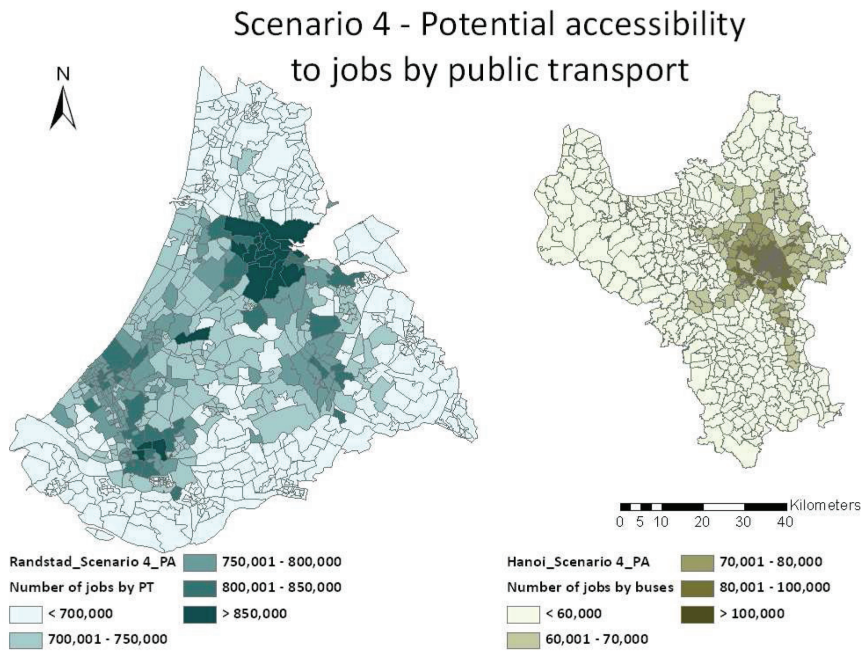



**Figure 42: Scenario 4 – Potential accessibility to jobs by public transport**

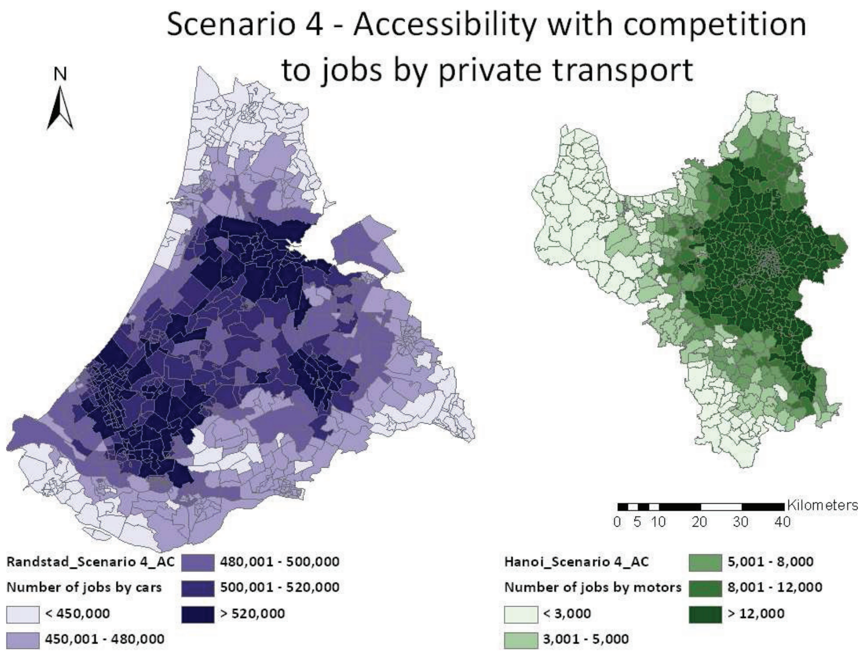



**Figure 43: Scenario 4 – Accessibility with competition to jobs by private transport**

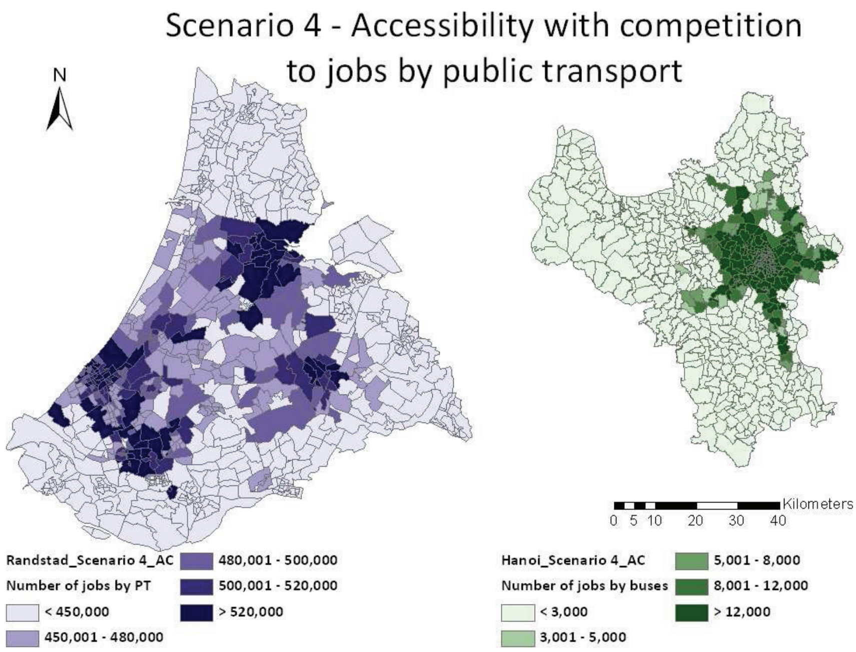



**Figure 44: Scenario 4 – Accessibility with competition to jobs by public transport**

### 5.5 Scenario 5: Changed job distribution and labour distribution

Scenario 4 depicted deficiencies, that scenario 5 tries to answer. Therefore, in this scenario, not only labour but also jobs are redistributed. Seventy percent of jobs and labour in Hanoi old centres are moved to three new centres: Son Tay, Soc Son and Van Dinh. Similarly, seventy percent of jobs and labour from Utrecht, Rotterdam and Den Haag are moved to Amsterdam. Results of this scenario are presented in Figure 45 to 48.

In this scenario, motorcycles have good accessibility in most of Hanoi. Only border regions have worse job accessibility within 90 minutes travel time threshold. In the opposite, travelling by bus has worse accessibility than before. Most of Hanoi has low job accessibility but the old city centre. This is due to the lack of bus service outside Hanoi old centre. Thus, in these areas, number of jobs that each zone can access with competition is derived mainly from jobs of that zone.

For Randstad, moving both labour and jobs to Amsterdam results in a monocentric result, which makes Amsterdam become another old Hanoi. Car has higher accessibility than bus in the areas near Rotterdam, Den Haag and Utrecht. However, there is a good thing that jobs accessibility by public transport in Amsterdam is not as different from car as Hanoi buses from Hanoi motorcycles. This happens by cause of better infrastructure conditions in Randstad public transport.

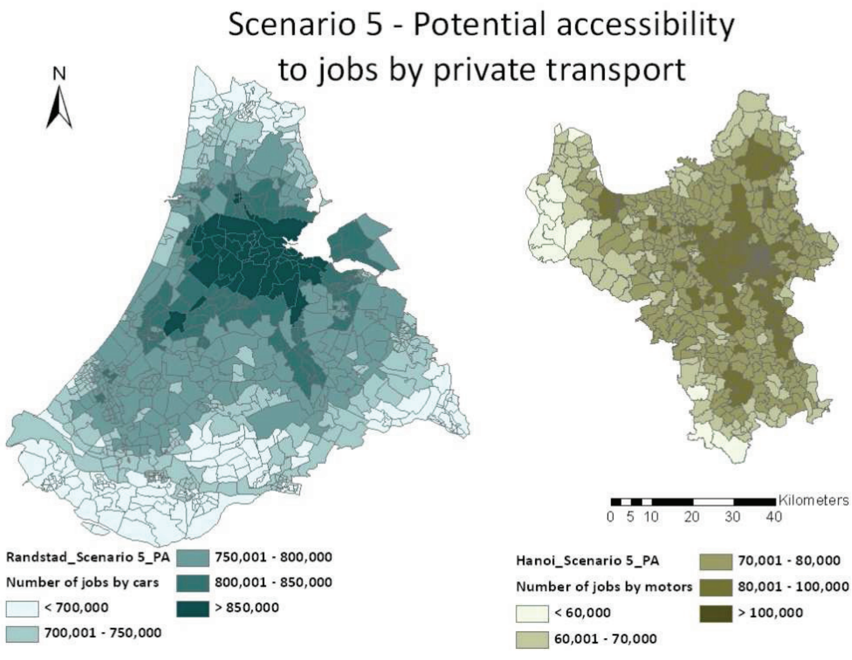



**Figure 45: Scenario 5 – Potential accessibility to jobs by private transport**

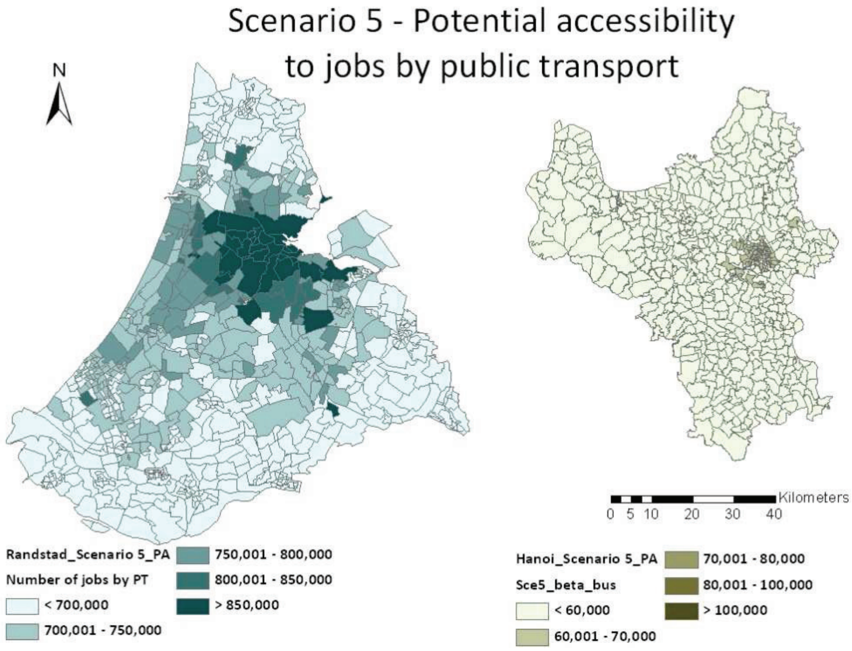



**Figure 46: Scenario 5 – Potential accessibility to jobs by public transport**

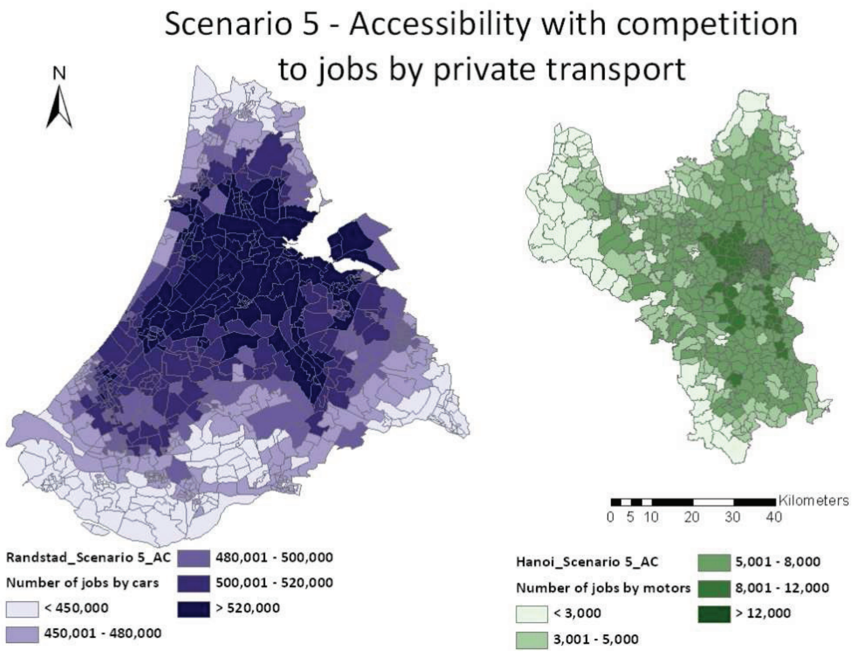



**Figure 47: Scenario 5 – Accessibility with competition to jobs by private transport**

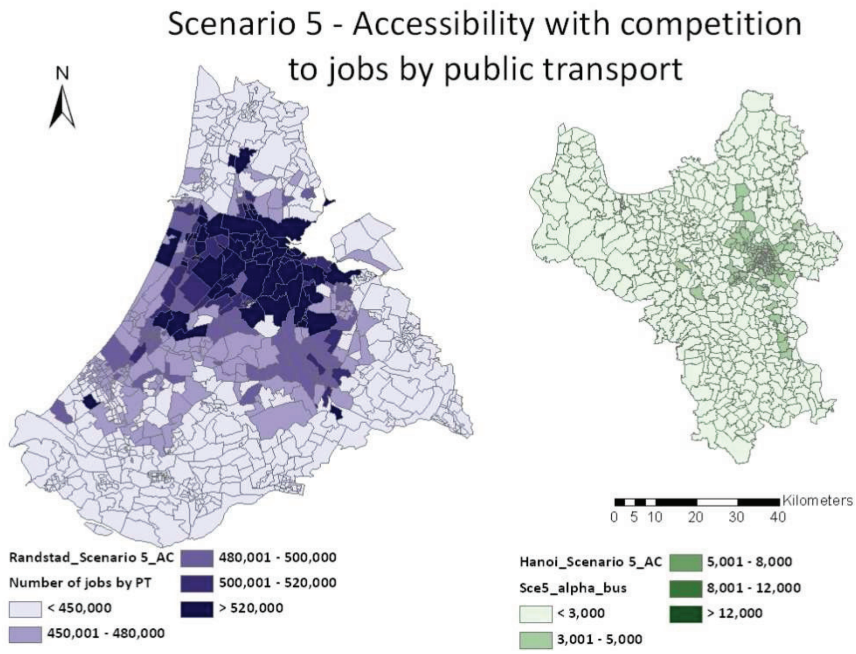



**Figure 48: Scenario 5 – Accessibility with competition to jobs by public transport**

In this scenario, high imbalance is found in Randstad. The southern most areas near Rotterdam and Den Haag suffer drastic lost in accessibility. However, the apparent improvement for Amsterdam region might not be the reality due to the fact that congestion is not yet modelled. In summary, imbalance area, will certainly desert the south, might or might not improve accessibility for Amsterdam where accessibility is already high. This scenario is probably not the best scenario for Randstad.

## 5.6 Discussion

Five scenarios are tested with different changing parameters: jobs, road conditions, labour, transport modes, or combinations of those. To summarize, these scenarios have revealed the following points:

1. For Hanoi area: Altogether motorcycles in most cases have higher accessibility than buses. In the viewpoint of working people who consider job accessibility the most important, scenario five may bring the best result. Job accessibility by motorcycles in scenario five is improved and more evenly distributed. Most of Hanoi has better accessibility. Only border areas which have worse connections to other centres have low accessibility.

   However, in the viewpoint of sustainable accessibility, scenario three contributes the most to sustainable transport which represents by accessibility by buses. Improving the bus network can obviously improve the accessibility of zones located near the network. More options can be investigated and implemented such as adding bus routes, building high speed train connecting centres, or improve the bus speed by improving the road conditions.

Scenarios one and two partly show some advancement in the suburban areas of Hanoi. However, solely applying of these scenarios does not result in a high enhancement. Scenario four is not practical in this research since competition of companies for workers is not included. Therefore, moving labour does not have impacts on employment market in the scenario, which is not tolerated in reality. More investigation should be done in this field to have a more accurate evaluation.

2. For the Randstad area: In scenario two, with the hi-speed links are built, the job accessibility will also increase in areas inside and near four big centres.

   In scenario one and five, Amsterdam is the only centre and has clearly higher accessibility than other areas. If scenario one is done, it can later lead to scenario five in reality. That is when people begin to move to areas where they have better job accessibility. Thus, these two scenarios have the same issues. Although the job accessibility of northern areas is increased, these scenarios turn Amsterdam to another Hanoi centre which is having problems with too high density of population, congestion, and other related social, economic or environmental problems. Unfortunately, high congestion level, which can result in an increase in travel time, is not included in the research' model.

   In the case of scenario four, accessibility seems to be equal with the non-scenario conditions. In this case, moving labour from big cities to big cities will mainly affect these cities and smaller areas nearby. It neither improves the conditions of border areas nor makes the conditions of these areas worse.

   Scenario 3b might bring the best solution among the scenarios. Moving jobs to Amsterdam centre and build three hi-speed links to three big cities; this scenario can save the cost of building hi-speed links as compared to scenario 2, but get similar increase in job accessibility as compared to scenario 3. This scenario emerge as representative for advantages of monocentric urban form. However, the congestion level is also not modelled here. Travel time, hence, may be much higher in reality. Other negative environmental and social consequences might happen. As Schwanen and his colleagues stated, compact urban form may result in more problems than it can solve (Schwanen, Dieleman et al. 2001).

# CHAPTER 6
# CONCLUSION

The main goal of this study is to evaluate the accessibility levels of private and public transport and to evaluate the impact of different urban forms on this accessibility. Literature on accessibility measures and impacts of urban forms were synthesized. Two accessibility measures were mainly described and used. The potential accessibility is found to be more suitable for public and decision-makers because it uses less data requirements and easier to understand as well as interpret. However, the accessibility with competition is preferred because of its more reasonable theory which includes the social factors. Two study areas with suitable urban forms are chosen: Randstad with polycentric urban form in the Netherlands and Hanoi with monocentric urban form in Vietnam.

To obtain the results, most of data in this research are obtained from different source and are secondary data. In addition, the research used a lot of assumptions to achieve the above results. Some important ones are related to assumed travel time, impedance function and $\alpha$ values. Other limitations include the lacking of network data and the highly different size of TAZ.

Firstly, it is also important to note that travel time used in Hanoi network is only estimated from literature review, it is not obtained from directly measured transport data. However, all of the areas have the same assumptions, and the research has the general purpose. For this reason, results can be acceptable but need to be interpreted with caution. The same situation was applied for choice of impedance function and $\alpha$ value for both Hanoi and Randstad. There is no calibration data available for both areas. Thus, the formulas are applied with considerable simplification. This can only be acceptable for the purpose of comparisons in this research. Further application of the results should be taken carefully.

The second limitation of this study is related to lacking of Randstad network. Although the cost matrices are obtained from a reliable source, the results could be better interpreted with transport network. More accurate results will be obtained for scenarios 2 and 3. In Hanoi case, the road network is totally digitized source based on official maps. Thus, lacking of some routes may happen, especially in the suburban areas.

Thirdly, the size of TAZ is quite variable in the study areas. In Hanoi, for example, the smallest zone is 0.67 kilometres square, while the biggest zone can be more than 40 kilometres square. In Randstad, the size of TAZ varies from 0.04 kilometres square to more than 98 kilometres square. This difference can result in a difficulty in compare the absolute values of accessibility. For example, old Hanoi city centre generally contains small zones, while the suburban areas are comprised of bigger zones. Therefore, differences per capita between old Hanoi centre and suburban areas may be even larger than the values shown in previous chapters. In Randstad, small zones and big zones scatter across the region. Hence, it is difficult to identify which zones will be affected the most by this assumptions. Moreover, in this study, each zone is assumed homogeneous in all fields such as population distribution, job distribution, and travel behaviour and travel time to other zones. This assumption is clearly not true in reality.

The primary obtained results in this study relates to job accessibility of two study areas using different transport modes and calculated with two measures. These results showed a large difference of job accessibility between private and public transport in Hanoi. More optimistic results are found in Randstad. Although car also has higher accessibility than public transport in general, it can have lower accessibility within big cities. This again proves for the good public transport in big cities in Randstad and insufficient conditions in some border areas.

One point should be noted is that Asian megacities in general and Hanoi in particular are changing to polycentric urban form due to their rapid urbanization and motorization, which can result in highly congestion levels and lead to environmental and social consequences (MORICHI 2005). In this situation, another question was raised in this study: How do these urban forms affect travel and accessibility level? And is polycentric urban form better in solving the existing problems in Hanoi?

To answer the above questions and to understand the impact of urban forms on accessibility levels of private and public transport, five scenarios were tested. Polycentric urban forms always give out a lesser difference in accessibility level of zones within regions. In other words, polycentric urban form always brings more balance results in accessibility to jobs. In adverse, monocentric forms make these differences bigger. Although there is still controversy on whether monocentric or polycentric urban forms is better, the results of this research shows that the network of monocentric form must be taken more carefully to achieve better accessibility.

In general, the results of Randstad and Hanoi accessibility have some common features and can be summarized as:

- Border areas always have the lowest job accessibility. This should be interpreted with caution in the reason that these areas may be affected also by regions outside of Hanoi and Randstad.
- Accessibility highly depends on the infrastructure conditions. Illustration is through the bus network in Hanoi and public transport in Randstad. Areas with well connections through these networks will have much better job accessibility.
- Both job and labour distribution are important and also strongly affect accessibility. Job moving in can result in an increase in accessibility, while labour moving in results in a decrease in accessibility.
- Results from the accessibility measure with competition are more difficult to interpret because this measure is calculated using the travel time threshold. Number of zones which are included in the competition will vary with the network. In theory, the number of zones competing for the job accessibility of a zone is unlimited and only depends on travel time threshold. However, travel time threshold depends on travel habit which is

always difficult to determine. In addition, it is not always reasonable to include competition of a zone which is too far from calculated zone.

- Competition for jobs really alters the results. Within a travel time limit and a specific α value, competition among zones makes the job accessibility more theoretical soundness. When travel time limits increase, more zones will be included in the competition for jobs. When travel time limit reaches the longest travel time in the area, all zones within that area will be included in the calculation of job accessibility with competition for each zone. However, the competition factor highly depends on employment size. One illustration is the case of Hanoi and Randstad. Due to much smaller employment market, results of job accessibility in Hanoi were changed much more remarkably when including the competition than Randstad.

Finally, by simulating the configuration of different urban form and transport conditions, the following learning can be withdrawn:

- In order to obtain an increase in accessibility of more sustainable transport, the public transport network firstly must be implemented. Although the number of proposed bus is limited, the results were enhanced quite clearly for some areas. More efficient options are included denser bus network, regional train, or hi-speed train in Hanoi area. For Randstad area, high speed train would improve the present situation.

- Hanoi, as a representative of monocentric urban form, is having problems of high congestion levels in the city centre. Both jobs and labour force concentrate in the city centre. The accessibility, thus, is much higher than rural and suburban areas. This can lead to more and more people moving there. As a result, congestions, pollution, other environmental as well as economic and social problems occur. Polycentric urban form or urban sprawl is one good option which might solve the problem.

- Urban forms will shape the accessibility level, which can have impacts on transport in general. In a more compact urban form, travel time to work is often smaller than in a polycentric urban form. In another words, people living in centres can reach more jobs within the same travel time when they live in a monocentric urban form. In addition, a monocentric urban form may take less time, money, and efforts to build the efficient public transport network in theory. Scattering centres require building more links to obtain the same level of accessibility in total. However, the matter of how to implementation and control the system effectively is not considered here. Congestion problem here should be highly noted

  Although polycentric urban form seems to be unfavourable on travel time to work and more car dependency; it can prevent from congestion and overcrowding areas, which can cause also pollution, noise and affect the quality of life.

- For Randstad, the most obvious and “safe” way to improve the accessibility is to build the express way between cities.
- Finally, the scale of region is important in evaluating different urban forms. As long as the density and locations of centres are suitable, the advantages of both polycentric and monocentric urban forms can be utilized. However, more research should be done to identify the “suitable” density and distances of centres.

On the whole, the above analysis in this study somewhat showed impacts of urban forms on transport using accessibility as a measure. Two transport modes were used for comparisons with the final goal of sustainable transport mode. Learning lessons were also withdrawn for urban and transport planning. Still, the study presented here should be complemented with further research on the other scenarios and travel time adjustment. Furthermore, as individual demands vary with time, geographical locations, and individual travel habits; it would be useful to include these variables in the measure to enhance the results. Further work should be done to include other sustainable transport options such as cycling and walking. In addition, more in-depth knowledge of possible centres for scenarios and their impacts on accessibility will be pertinent. More work should be done to perfect the comparison of private and public transport.

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# APPENDIX

APPENDIX 1 – Method to distribute jobs from districts to communes in Hanoi

APPENDIX 2 – Potential accessibility to jobs by public and private transport in Randstad and Hanoi – Scenario 3