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February, 2017

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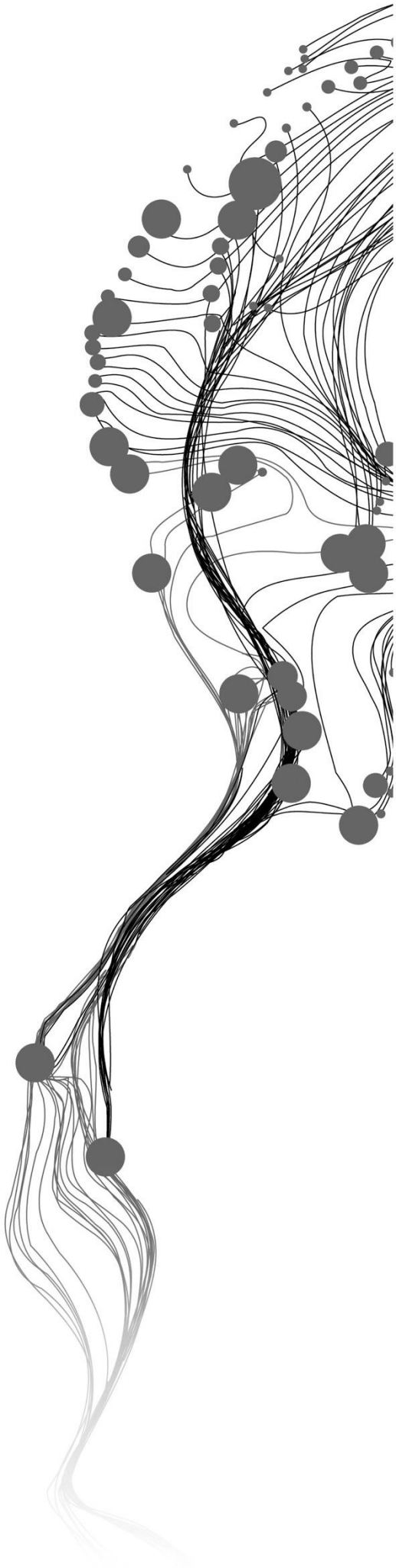

Equity Based Analysis of Adults' Travel Behaviour in the Netherlands

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ABSTRACT

Transport literature has long addressed issues of equity, limited mobility and accessibility which can result in decreased number of opportunities, activities, as well as social exclusion. In this research, we focus on the Dutch travellers' realized travel behaviour in 2015. A cluster analysis is used to identify the differences in terms of travel behaviour between different groups. Of specific interest is identifying the impacts of socio-economic conditions on different travel behaviour of various social groups. The spatial visualization of travel behaviour clusters and socio-economic condition clusters reflects spatial distribution characteristics of different clusters. Simultaneously, online accessibility maps are used for evaluating accessibility levels by car and public transport to reflect transport supply in different areas.

The results indicate that socio-economic condition has a significant impact on individuals' travel behaviour, Low-income and low educated travellers tend to choose public transport and non-motorized modes of transport. On the contrary, most of the high-income and high educated travellers are car users and multi-modal users, who are prone to travel longer, further and more often. At spatial level, the share of low-income and low educated travellers is highest in the northeast of the country. In the city centre of Amsterdam, The Hague, Rotterdam and Utrecht, more travellers choose public transport and less people are travelling by private car. In terms of transport supply, accessibility maps visualize the catchments that can be reached by car and public transport through the road network and public transport network within certain time ranges in the morning peak. As a result, travellers travelling by car or by public transport can reach smaller catchments in the northeast of the country. Thus, the road network and public transport network in the eastern and northern part of the Netherlands show a lower performance compared with the ones in the Randstad region. Insufficient transport supply reduces individuals' opportunities, especially for the low-income and low educated populations. The effective and efficient transport system in the Randstad region might help to reduce the usage of the car.

Based on the results, because of a less sufficient transport system, travellers who have low socio-economic conditions in the northeast part of the country have reduced accessibility, especially compared with the travellers in the Randstad region. Consideration of transport-related equity in this study stresses the plight of disadvantaged people. In the future, transport investment should give the priority to disadvantaged people, planners and policy makers should aim to improve accessibility and further equity between groups, especially equity of accessibility and mobility.

Key words: Equity, Travel behaviour, Socio-economic condition, Transport supply, Cluster analysis

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1. INTRODUCTION

The objective of this chapter is to introduce the theme and context of this research briefly. First, it describes the problem of transport inequity and the basic elements of inequity in terms of traditional transport planning. Secondly, it proposes relevant research objectives and questions in this research. Finally, it explains the significance and the structure of the study.

1.1. Background and Justification

Rapid development of cities and expanding of urban populations have placed upon urban planners the arduous task of organizing and distributing limited urban resources in an equitable, sustainable and suitable way. Equity and efficiency are the main criteria to evaluate transport policies and transport infrastructure projects (Rietveld, Rouwendal, & Vlist, 2007). Thus, planners have a responsibility to distribute urban infrastructure resources to balance the different needs of various people to ensure the effective and efficient use of infrastructure resources.

Inequitable distribution of transport resources may cause various problems in social, spatial and environmental aspects. Such as social polarisation, spatial segregation, spatial inequity and air pollution. For instance, inequitable distribution of transport infrastructure is recognized as an important influence on transport disadvantage and social exclusion (Lucas, 2012). Poor level of accessibility to public transport may cause a negative impact on individuals to participate in diverse social and spatial activities (Hananel & Berechman, 2016) A lack of public transport may drive people to use vehicles that cause traffic congestion contributing to inefficient energy use and air pollution.

However, there does not have to be a trade-off between growth and equity (OECD, 2015). Over the past decades, travel in the Netherlands, and particularly in the Randstad region which includes several large cities in the west of the Netherlands, such as Amsterdam, Rotterdam, Utrecht, the Hauge, Amersfoort, has increased significantly, causing relevant impacts, such as traffic congestion and its-related emission (Ha, van den Bosch, Quang, & Zuidgeest, 2011). And in the period 2010-2015, 80% of infrastructure investments were located in the Randstad (Mouter, 2017). The remaining 20% investments were implemented outside the Randstad region.

In addition, inequity is particularly evident in cities, which accomplished with development (Martínez, 2005). Urban planners have a responsibility to make sure that urban infrastructures are adequately built and monitored for efficient and effective operation of daily urban functions (El-Gohary, Osman, & El-Diraby, 2006). Planners and policy makers also need to make sure that transport system is fair when accessibility levels do not differ too strongly across population groups (Mouter, 2017). Thus, these factors have stimulated a consideration of equity in public transport planning, which assist in mitigating social disparities and spatial segregation. In this research, transport-related inequity is going to focuses on whether there are big differences in terms of accessibility levels among the travellers who have different

socio-economic conditions. And whether people who have low socio-economic conditions have impediments in accessibility and mobility.

Over the past decades, transport researches and policy makers have devoted increasing attention in terms of equity (Pereira, Schwanen, & Banister, 2016). Martens (2016) proposed that inequity in transport are reflected in four indicators: travel speed, potential mobility, accessibility and ultimately, revealed mobility. Accessibility and potential mobility capture a person's capacity which can accomplish a broad range of actions, but these two concepts do not imply the actual realization of this capacity (Martens, 2016). In traditional transport planning, planners focus on increasing travel speed, potential mobility and accessibility for persons with access to the road system or freedom of choice in terms of various opportunities (Martens, 2016). They ignore the persons who are excluded from transport system. For instance, people who have low socio-economic conditions cannot afford travel cost and people who live in a small community or rural area have constraints in accessing to public transport. Thus, the traditional rules result in a vicious circle (Martens, 2006). Maintenance of travel speed, potential mobility and accessibility for persons with access to transport system is likely to strengthen these inequity, which increase disparities between persons with access to, and persons excluded from, the dominant transport system (Martens, 2016).

Numerous literature on transport-related social and spatial exclusion shows that the constraints in terms of travel demand include not only household budgets (time, money), but also households' access to different transport modes and availability of transport supply and services (Martens, 2016). Lack of affordability and accessibility to adequate transport system can leave people in social and spatial exclusion (Kenyon, Lyons, & Rafferty, 2002). In the developed world it has been observed that highway development favoring automobiles has been prioritized over public transport (Sanchez, Stolz, & Ma, 2004). Traditional transport planning benefits premium modes (private car), which have higher speed and longer distance links that "save times" for already mobile persons, thus, offers few benefits to the poor and they were excluded from the planning process (Ahmed, Lu, & Ye, 2008). Thus, in order to analyse inequity in transport planning, it is key to start from individuals' travel behaviour and analyse the detailed reasons which cause the specific travel behaviour among different groups or people.

1.2. Research Problem

Thomopoulos, Grant-Muller, & Tight (2009) concluded eleven categories of equity that are found in literature (e.g. horizontal equity, vertical equity, territorial equity, spatial equity, social equity, etc.). It is necessary to choose one of the definitions that is most suitable to evaluate transport-related inequity. Manaugh, Badami and El-Geneidy (2015) mentioned that there is a lack of specific indicators to assess inequity in terms of transport infrastructure projects. Despite efforts in research to address the need of equity consideration in transport systems, very few have suggested indicators that can be used to measure inequity in transport planning, in particular among the groups who are excluded of public transport, due to their low accessibility to transport infrastructure (Bocarejo & Oviedo, 2012). Hananel and Berechman (2016) proposed that an equitable transport system should produce fair outcomes rather than benefit individuals who are already well off. Transport-related inequity may have different impacts on various people, because of their different characteristics.

Thus, an analytical framework should be proposed to analyse the reality of people's travel behaviour and explore its relations with individual's social (socio-economic) and spatial (accessibility) attributes. What is the socio-economic status of individuals that have similar travel behaviour and whether the specific travel behaviour is affected by the different treatment of transport system? Hence, by comparing the causes of different travel behaviour, the differences in terms of socio-economic conditions and transport supply can reflect transport-related inequity.

1.3. Research Objective and Question

The main objective of this research is to evaluate transport-related inequity, by analysing individuals' travel behaviour. The study focuses on the differences in terms of socio-economic conditions and peoples' accessibility to the transport system, and tries to explore relations between these three concepts which helps to reflect transport-related inequity.

Sub-objectives and research questions of this research are:

1. Analysis of travel behaviour in study area.
   1.1. What are the main characteristics in trems of travel behaviour in the study area?
   1.2. How can we identify travel behaviour typologies?
   1.3. What are the main differences between travel behaviour typologies?

2. Analysis travellers' socio-economic condition in study area.
   2.1. What are socio-economic conditions associated to different travel behaviour typologies?
   2.2. How can we identify socio-economic typologies?
   2.3. What are the relations between socio-economic typologies and travel behaviour typologies?

3. Analysis transport supply in study area.
   3.1. What are the spatial distribution characteristics of socio-economic typologies and travel behaviour typologies?
   3.2. What are the main differences in terms of transport supply between different regions within study area?
   3.3. What is the transport-related inequity in the study area?

1.4. Conceptual framework

Numerous studies have already identified that person or group mobility are affected by their unique socio-economic characteristics, for instance, income, education, health and remote location (Hananel & Berechman, 2016). And people live in smaller cities or rural areas which have more limited access to public transport (Pyrialakou, Gkritza, & Fricker, 2016). Thus, individuals captive to public transport or dependent on other modes of transport do not have the flexibility to travel and, due to routing and budget constraints, are less able to participate in various spatial activities and labour market entry, are more prone to social exclusion (Hananel & Berechman, 2016).

In order to analyse transport-related inequity, the conceptual framework that shown in the triangle in Figure 1 can helps to explore the relations between key concepts. Starting from the analysis of individuals' travel behaviour, travellers who have similar travel behaviour are clustered in homogenous groups. Then,

the study is going to focus on the causes for the differences in terms of travel behaviour in both social and spatial aspects.

The differences of socio-economic conditions between several travel behaviour groups can be used to check whether the specific group of people possesses particular socio-economic conditions. In the next step, the differences in socio-economic conditions between several travel behaviour groups can be used to check whether the specific group of people possesses particular travel behaviour. In the next step, the spatial visualization of various travel behaviour groups and socio-economic groups can be used for analysing spatial distribution characteristics. Also, whether the people who have similar travel behaviour or socio-economic condition are concentrated in the same regions is going to be analysed in this step. Meanwhile, transport supply with respect to accessibility is used for comparing the transport infrastructures in different regions at spatial level. At last, the relations within this triangle can reflect the performance of transport infrastructure in the study area.

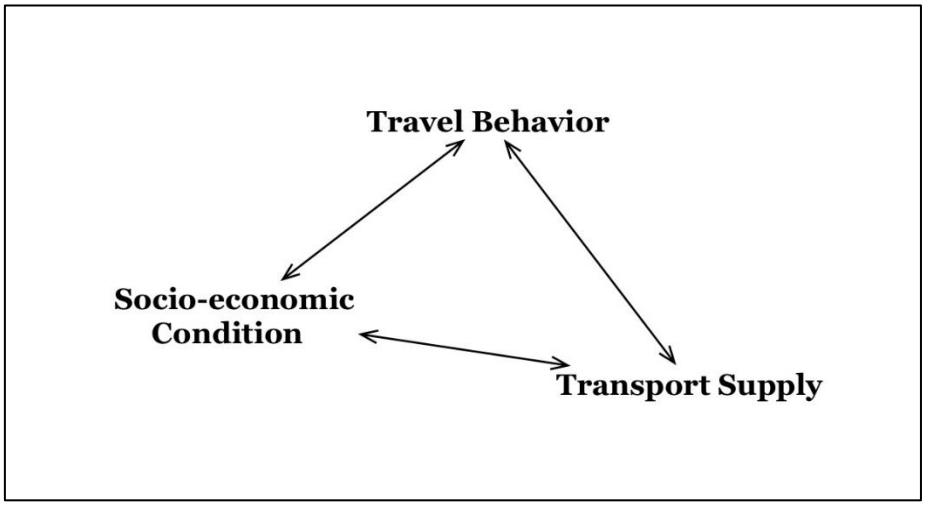


Figure 1 Conceptual representation

1.5. Significance of the Study

Starting from analysing individuals' travel behaviour, the findings of this study may reflect transport-related inequity in the study area. By exploring relations between individuals' travel behaviour, socio-economic conditions and regional accessibility levels, the study discusses the impact of socio-economic conditions and transport supply on travel behaviour. As a result, the spatial visualization of people's travel behaviour and socio-economic conditions may reflect their spatial distribution characteristics. Meanwhile, accessibility maps can reflect unequal treatment to various groups of people in terms of transport supply. Thus, people have different socio-economic conditions may perform various travel behaviour and experience different transport supply. In the future, based on the results, transport investment should give the priority to the identified disadvantaged groups.

1.6. Thesis outline

After this introduction part, Chapter 2 provides the literature review of the key concepts in this research, starting from the concept of equity, this chapter identify the concepts of transport-related inequity and corresponding measurement which is going to be discussed in this study. This will be followed by giving details on the concepts of travel behaviour and socio-economic condition. Based on the reviewed concepts, the concept of transport-related inequity in this research should be identified in this chapter. Chapter 3 describes the related methodology than is applied in this research. It also introduces the Two-step cluster analysis in SPSS, which is the main method used in this research. The rest of this chapter explains the details about the available dataset and the concrete steps of data analysis with respect to travel behaviour, socio-economic conditions and transport supply. Based on the background and the methodology, Chapter 4 presents the results of the data analysis, which reflect the relations between individuals' travel behaviour, socio-economic conditions and transport supply. Chapter 5 concludes the main findings in this research. Based on the research objectives and questions, transport-related inequity should be discussed. At last, relevant recommendations are proposed to future transport planning.

2. LITERATURE REVIEW

The objective of this chapter is to provide an overview of the key concepts in this research. By identifying the definition of inequity, the exploration of the theoretical perspective will underline the rest of the research.

2.1. What is inequality?

To understand Transport Equity, it is important to define the equity concept and differentiate it from other related overlapping or interchangeable concepts. In the next section, the relevant concepts are reviewed and discussed.

2.1.1. Equality and Equity

Equity has been a major concern of transport planning and is required by legislation in many countries (Delbosc & Currie, 2011). While, different definitions of equity can result in various priorities for route and service allocation, because of several types of equity, evaluation of transport equity is difficult (Litman, 2005a). There is an extensive body of literature devoted to the impacts of inequity in transport systems. However, transportation equity or equality does not have a single, widely accepted definition (Pyrialakou et al., 2016). In general, there are two main categories of the notion of justice in transport field: equity and equality. Although these definitions are used interchangeably, there is a requirement to define them separately. Equality refers to the homogeneous distribution of resources. Teunissen et al., (2015) use equality in relation to achieving equal levels of access among different groups and individuals.

On the other hand, equity relates to equality of opportunities, or choices available to all (Hananel & Berechman, 2016). In the transport field, most planners, decision-makers and policy makers considered equity as one of the main objectives (Litman, 2005). Numerous definitions of equity have been found in literature within the context of transport planning.

In the context of Europe, territorial equity with respect to territorial cohesion is mentioned (Ec, 2002). After that, the Renewed Sustainable Development Strategy refers social equity and cohesion (Ec, 2006). Some national transport policy documents focused on accessibility, equal rights on access to transport system, and in general, it mentioned two categories of equity: horizontal equity and vertical equity (Thomopoulos & Grant-Muller, 2013). Horizontal equity refers to the equal distribution of public funds for transport infrastructure among different regions, while vertical equity needs to retain a minimum level of transport links within all parts of a region or country (Thomopoulos & Grant-Muller, 2013). Hananel and Berechman (2016) argued that horizontal equity was viewed as an equal treatment of people in the same socio-economic strata, however, vertical equity is defined as the equal treatment to people in different socio economic strata. It is important to identify the distinct notion of equity, the corresponding transport-related equity is summarized in Table 1.

Table 1 Summary of the transport-related equity

Equity Types	Features
Horizontal Equity	Individuals, groups or regions should be treated in a comparable way; Equal treatment of equals.
Vertical Equity	Disadvantaged individuals, groups or regions deserve protection. People should be burdened according to their ability to contribute, and this may lead to schemes where taxes may be progressive.
Spatial Equity	Geographical location of an individual, group or region affected by transport infrastructure project.
Social Equity	The concept refers to the impacts on personal, economic or social characteristics of an individual, group or region.
Solidarity	An increased focus on solidarity issues will be facilitated by setting the EU transport policy in the context of the wider EU cohesion policy.
Territorial Equity	Results from the notion of individual equity when it is projected on relatively homogenous regions need to get similar funds for (public) transport.

Adjusted from Nikolaos Thomopoulos and Grant-Muller (2013), Litman (2005), Ec (2002), Litman (2005).

2.1.2. Transport-related inequity

In terms of transport, travel offers a means to reach various opportunities, for instance, employment, education, shops and leisure activities. The role of different transport modes is to help individuals or groups to improve mobility to fulfill their specific trip purpose. Transport system and its corresponding mobility play a vital role in urban development (Rode et al., 2014). Wang and Chen (2015) also mentioned that transport plays a pivotal role in shaping human interactions, economic mobility and urban sustainability. Therefore, many cities in the world committed to establish more sustainable transport system to improve social and spatial interactions (Gossling, 2016). And the transport field has long regarded equity issues as central to decision-making on investments and services provision (Hananel & Berechman, 2016).

In the context of transportation, equity is concerned with distributional questions and relevant individuals' travel behaviour. Smith (1997) proposed that the central issue in distributive justice is how to identify differential treatment or differences among groups or people which are relevant to the particular attributes to be distributed. An extensive body of transportation literature also has addressed issues of social equity. Considerations of equity emphasize disadvantaged populations with respect to further equity between groups and individuals, especially equity of opportunities and mobility (Hananel & Berechman, 2016). Thus, in this research, in order to check the distributional differences among groups of people with respect to mobility in the study area, it will focus on the concept of transport-related inequity, which is defined as people who have different socio-economic conditions are experiencing different levels of accessibility and mobility, especially the disadvantaged travellers experience impediments in accessibility and mobility. In many cities, political ambitions to create a more suitable urban transport system and

reduce transport-related inequity, which only benefits transport users, while putting considerable burdens on others (Gossling, 2016).Thus, the real situation of people's travel behaviour may reflect the affordability and availability in terms of transport infrastructure.

2.2. Transport-related exclusion

A lack of mobility is inextricably linked to social disadvantage and exclusion (Lucas, 2012). Travel provides the means to reach essential opportunities, and transport acts as a catalyzer in distributing the social and economic benefits which are created by means of transport (Beyazit, 2011).

A wide range of studies mentioned that transport-related inequity might create transport disadvantaged groups who have a risk of suffering social exclusion. Numerous studies have identified that socio-demographic variables such as gender, age, income, education and employment play a significant role in transport mode choice decisions (Arbués, Baños, Mayor, & Suárez, 2016). It is important to note that high income travellers have higher opportunity costs which implies that they are prone to choose faster transport such as private vehicles (Bhat, 1997). Mallett (2001) also proposed that low-income people are more dependent on public transport. Low-income people are forced to walk significantly more than medium or high-income households. And highly educated individuals are prone to use public transport more often (Arbués et al., 2016).

In another study by Lucas (2012), low-income households experience impediments in accessibility to work, education, shops and leisure and cultural activities, as a result of limited physical mobility, which therefore was identified as a major contributor to social exclusion. The transport-related social exclusion focuses more on the results of transport disadvantage, which is defined as "process by which people are prevented from participating in the economic, political and social life of the community because of limited accessibility to opportunities, services and social networks, due to whole or in part to insufficient mobility in a society" (Kenyon, 2006). Bocarejo and Oviedo (2012) state that social exclusion may prevent disadvantaged groups from participating in normal social activities. Social exclusion may result in disparities, unevenness and dissimilarity among various groups of people (Martínez, 2005).

On the other hand, various literature recognizes that transport benefits will be unevenly distributed in space and thus that inevitably different regions will have different accessibility levels and residents within these regions will experience various mobility levels (Jones & Lucas, 2012). Pyrialakou et al. (2016) mentioned that a great part of small urban areas and rural areas presents a low density of opportunities and transport disadvantaged residents of such areas might experience the impacts of low transport supply; as a result, these people travel longer distance in their daily activities. Disadvantaged residents also suffer the results of an automobile oriented community and tend to share unevenly higher cost and lower benefits (Litman, 2005; Pyrialakou et al., 2016). And high usage of an automobile in low-income households reflects that an automobile can be a necessity in such areas, disadvantaged people might be forced to suffer highly transport cost (Pyrialakou et al., 2016). Thus, providing improved spatial access to disadvantaged groups can contribute to the social equity of these groups and reduce social exclusion (Teunissen et al., 2015).

2.2.1. Measurement of transport-related inequity

Individuals' travel behaviour in terms of modal choice was defined by De Witte, Hollevoet, Dobruszkes, Hubert and Macharis (2013) as "the decision process to choose between different transport alternatives, which is determined by a combination of individual socio-demographic factors and spatial characteristics, and influenced by socio-psychological factors". The existing empirical evidence identified that socio-economic variables, trip characteristics and land use factors affect individuals' travel behaviour with respect to modal choice decisions (Arbués et al., 2016).

Numerous studies have evaluated levels of transport-related inequity, which are shown in Table 2 below. Through assessing the distribution of accessibility, Golub and Martens (2014) defined the rate of "access poverty" among the population. The analysis was utilized to compare the accessibility between public transport and automobile. Authors mapped low-income communities within a low accessibility area, which can be used for the further transport planning decision making process. Delbosc and Currie (2011) proposed using Lorenz curves to measure the spatial supply of transit. In this way, they assessed the equity of public transport provision. On the other hand, by using an economic capability approach, Hananel and Berechman (2016) combined equity considerations into decision making in relation to public transport provision. Affordability was employed as an indicator to identify the disadvantaged populations and thus aim to equity of accessibility and mobility among these target populations. Accessibility and affordability were also used as a complementary means to assess the public transport. Thus, authors aimed to identify disadvantaged populations and further priorities for transport investments. In contrast, using spatial analysis and GIS tools, Teunissen et al. (2015) mapped levels of inequality in access to three sustainable transportation initiatives in Bogota, Colombia among six socio-economic strata. Among these studies, most of the authors tried to measure provision of transport, in this way to find different distribution among groups of people. But all the transport infrastructures and services taken together provide or fail to provide persons with accessibility (Martens, 2016). In this research, the starting point is the analysis of individuals' travel behaviour, and explore the reasons which are relevant to the particular differences among various groups.

Table 2 Measurement of transport-related inequality

Study	Definition of equity	Area and data	Objectives	Measures and methods
(Golub & Martens, 2014)	Access to opportunities by public transit and automobile	San Francisco Bay Area Demographic and destination datasets available from planning agencies	Evaluate the fairness of the investment scenarios	Using a "transport poverty line" and measured areas which are "access-impoverished"
(Delbosc & Currie, 2011)	The transit supply compared between different age, income and vehicle ownership groups	Melbourne, Australia A database of bus and tram stops and train stations A database of public transport service frequencies Census data about population and employment	A system-wide assessment of over transit supply to the population	Using Lorenz curves to measure the relative supply of transit to the population Compared horizontal equity and vertical equity
(Hananel & Berechman, 2016)	Authors stress the plight of disadvantaged populations, and thus with the aim of further equity between groups and individuals, especially equity of opportunities and mobility	King county in the State of Washington Census data about household income and travel cost	Propose a new framework for incorporating equity considerations into decision-making association with transport service provision	Based on the Capability Approach, authors try to identify the affordability threshold to give priority to the disadvantaged population in terms of using public transport
(Bocarejo & Oviedo 2012)	Transport disadvantages in cities that experience transport-related inequity	Bogota, Colombia OD Travel Survey of Bogota Census data about socio-economic characteristics and income level Information on the number of jobs and locations	Propose a new accessibility analysis tools for unequal mobility conditions and policy responses for their mitigation	The concepts of accessibility and affordability as a complementary means for evaluating public transport investment, which helps to identify transport disadvantages and priorities for project generation
(Teunissen, Sarmiento, Zuidgeest, & Brussel, 2015)	Equal access to transport system for all socio-economic strata	Bogota, Colombia GIS data on bus lines and bus stations as well as feeder lines	Analyzing levels of inequity in access to three sustainable transportation initiatives	Spatial information and GIS have been used for analyze levels of inequity in access to sustainable transportation initiatives

2.3. Travel behaviour analysis

Concerning travel behaviour, the important thing is to understand the behavioural patterns of travellers (Molin, Mokhtarian, & Kroesen, 2016). Starting from the late 1960s or early 1970s, many authors focused on travel behaviour research, most of them started from an individual level and tried to explore reasons that cause changes in terms of travel behaviour (Wittwer, 2014).

Nowadays there is growing interest in analysing the variability of individuals' travel behaviour (e.g., Molin et al., 2016; Haustein & Nielsen, 2016; Buehler & Hamre, 2014; Feng, Dijst, Wissink, & Prillwitz, 2016). Wittwer (2014) mentioned that travel behaviour reflects individuals' socio-demographic factors and their corresponding travel demand. In another study, it was indicated that travel behaviour with respect to modal choice is influenced by traveller socio-economic condition, trip attributes and geographical factors (Arbués et al., 2016). Feng et al., (2016) proved that the changes of socio-economic conditions influence the travel modal choice of various social groups.

2.3.1. Travel behaviour changes

Numerous studies have focused on travel behaviour changes, for instance, modal choice, daily travel distance, travel duration. Based on the Dutch National Travel Survey, Susilo and Maat (2007) found that total daily travel distance and commuting distance increased by 7.5% and 23% from 1993 to 2005. In Europe, the differences in modal choice among 28 countries are demonstrated by Haustein and Nielsen (2016), then these EU member countries that have similar travel behaviour were clustered into the same group. At last, the travel-related variables and socio-economic backgrounds are used for analysing the variability. While traditional studies focused on explaining the differences with respect to travel behaviour, there is a particular interest in answering the question of which travellers are single-mode user and multimodal user. Molin et al. (2016) proposed socio-demographic is one of the main factors which can affect travellers' modal choice.

2.3.2. Multi-modal user and Single-modal user

"Multimodality is defined as the flexible use of various modes of transport within a certain time period, where intermodality is the use of multiple modes in the course of a single trip" (Molin et al., 2016 Pg. 15). Thus, in order to identify a traveller as multimodal, there is a need to the consideration of time period. Some studies focused on the relations between socio-economic condition and (multi)modal choice. Blumenberg and Pierce (2013) found the evidence that people who are in low socio-economic conditions are less multimodal than those who are in high socio-economic conditions. In addition, Molin et al. (2016) proposed that travellers who always use the same mode of transport or who only use one mode may have incorrect knowledge of other modes. In order to identify different travel groups with respect to their modal choice decisions, many researches applied cluster analysis to distinguish multi-modal groups and single-modal groups (e.g., Diana & Mokhtarian, 2009; Wittwer, 2014; Buehler & Hamre, 2014).

2.4. Socio-economic analysis

There is no consentaneous definition of socio-economic status; it is defined broadly in terms of social, cultural and economic resources, the extent to which individuals or groups have access to these resources (Department of Employment, 2009). Sociologists use this term to refer to the relative position of an individual within a hierarchical social structure, based on their access to wealth, prestige and power (Mueller & Parcel, 1981). Caro (2009) used individuals' accessibility to education, occupational prestige and family wealth to identify their socio-economic status. Oakes and Rossi (2003) proposed socio-economic status to reflects one's access to collectively desired resources, material goods, money, power, friendship networks, healthcare, leisure time, or educational opportunities. Socio-economic status aims to locate one's position in the social hierarchy (Oakes, 2008). Thus, in this study, there is a need to identify specific indicators to measure peoples' socio-economic status which may have impact on their travel behaviour.

2.4.1. Indicators of socio-economic status

The use of indicators can simplify complex and abstract phenomena into quantifiable measures (Martínez, 2005). Based on specific objectives, the chosen indicators can reflect the unobservable characteristics, which are intended to be analysed and communicated. Innes (1990) also proposed that an indicator is simply a set of rules for organizing data so they can be assigned meaning.

Socio-economic indicators available from authoritative data sources are often used to reflect specific characteristics and propose a systematic approach to decision making. In order to measure inequity in terms of transport, GIS-based indicators can be used to do data organization, spatial analysis and visualization (Herold, Couclelis, & Clarke, 2005). GIS-based indicators can be used to construct the combination of different data source, for instance, census and administrative data (Martínez, 2009).

Many studies proposed to use relevant indicators to measure socio-economic conditions in terms of transport-related inequity. (Smith, 1997) mentioned six criteria in which each of them include six sub-aspects to assess social well-being. Kearns, Gibb, and Mackay (2000) proposed six initial indicators to measure deprivation for Scotland, which include housing, health, education, crime, unemployment and the number of cars in a household. After that, Langlois and Kitchen (2001) address another six dimensions to measure urban deprivation in which information on demography and language are added.

It is found that there is a relation between household structure and individuals' travel behaviour. In order to check the impact of socio-economic conditions on household structure, Statistics Netherlands (CBS) proposed ten aspects, which include income, gender, welfare, education, crime and health. In the framework for OECD well-being, there are two dominant aspects (material living conditions and quality of life) and eleven indicators to measure well-being among OECD countries (Organisation for Economic Co-operation and Development, 2011). Also in the report of World Development Indicators 2016 from the World Bank, more than ten indicators are used to analyse sustainable development and quality of people's life. In the Netherlands, OECD proposes measuring well-being across five main dimensions: income, employment, education, environment and access to services (OECD, 2015). Table 3 concludes the indicators mentioned above.

Table 3 The chosen indicators to measure socio economic conditions (✓: used indicator, ✗: unused indicator)

	Income	Employment/ Unemployment	Education	Social participation	General Mortality	Housing	Crime	Number of cars	Language	Gender	Environmental Quality	Infrastructure
(Smith, 1973)	✓	✓	✓	✓	✓	✓	✗	✗	✗	✗	✗	✗
(Kearns, Gibb, & Mackay, 2000)	✓	✓	✓	✗	✗	✓	✓	✓	✗	✗	✗	✗
(Langlois & Kitchen, 2001)	✓	✓	✓	✗	✗	✓	✗	✗	✓	✗	✗	✗
(Foundation & Rotterdam, 2013)	✓	✓	✓	✗	✓	✗	✓	✗	✗	✓	✗	✗
(OECD, 2011)	✓	✓	✓	✓	✗	✓	✓	✗	✗	✗	✓	✗
(World Bank, 2016)	✓	✓	✓	✗	✓	✓	✓	✗	✗	✓	✓	✓
(OECD, 2015)	✓	✓	✓	✗	✗	✗	✗	✗	✗	✗	✓	✓

2.5. Conclusion

This chapter provided an overview of the key concepts in this research. In order to analyze transport-related inequity, the core question is how we can measure the differences in treatment among the various groups. Transport acts as a bridge which can distribute social and economic benefits. Transport-related inequity means that a lack of mobility and transit supply may restrict individuals or groups to accessing social opportunities. Therefore, these people may have a risk of social and spatial exclusion, which increases disparities among individuals and societies. Traditional transport planning benefits only a share of traffic participants (Gossling, 2016). Thus, this study starts from analysing individuals' travel behaviour rather than focusing on transport system itself. Firstly, socio-economic condition is identified as a social aspect which has an impact on travel behaviour. On the other hand, transport supply is treated as one of the spatial aspects that induce variations in people's travel behavior. Therefore, individuals' socio-economic conditions and their accessibility levels should be identified with respect to specific travel behavior. At last, the spatial visualization of people or groups who have different socio-economic conditions, travel behavior and their corresponding accessibility levels may reflect transport-related inequity in a study area.

3. METHODOLOGY

This chapter describes the methodology that was followed in this study. Two analysed of travel behaviour are proposed: a descriptive analysis of travel mode choice, trip duration and trip purpose which served as background, for the second analysis, a cluster analysis to group individuals with similar travel behaviour. After that, socio-economic conditions and regional transport supply can be treated as social and spatial aspects, which induce differences in travel behaviour. Relations between key concepts can help to address the research questions in this research.

3.1. Hypotheses

In order to understand travel behaviour in the Netherlands, some hypotheses are proposed to guide the analysis. It is assumed that transport-related social and spatial inequity issues are present in the Netherlands. Individuals who have different socio-economic conditions may show distinct travel behaviours. People who have low socio-economic conditions are prone to choose non-motorized modes of transport. In addition, people who have higher socio-economic conditions are prone to choose faster transport. On the other hand, individuals' travel behaviours are affected by the transport supply. People who have low socio-economic conditions are mostly affected by deficient transport supply, as a consequence, they are under most risk of suffering social and spatial exclusion.

3.2. Data sets and preparation

In this research, the Dutch National Travel Survey (in Dutch: OViN, formerly called OVG/MON) is used to address the research questions. Since 1978, this travel data is collected by Statistics Netherlands (in Dutch: Centraal Bureau voor de Statistiek - CBS). Starting from 1995, 7000 households in the Netherlands have been interviewed each month and asked to fill in a trip-based diary for one day. Around 40,000 respondents participate in this survey every year, which includes the addresses of visited locations and main activities, trips in terms of departure and arrival times, order in which transport modes were used, distances covered and the socio demographic characteristics of the respondents.

The OViN data is commonly used in Dutch transport studies. For instance, (Schwanen, Dieleman, & Dijst, 2001) analysed the effect of urban structures on individuals' modal choice, travel distance and travel purpose. For the present research, the latest data OViN 2015 was selected. The spatial resolution of this data is four-digit postal code. In 2015, 37350 Dutch travellers participated in this survey, which recorded their socio-demographic characteristics and one-day travel diary.

3.3. Descriptive analysis of Travel behaviour

Firstly, descriptive statistics will be used to introduce basic attributes of the dataset. Based on the one-day travel survey, this analysis includes number of trips, trip duration, trip purpose and corresponding modal choice as a basis of individuals' travel behaviour.

After data preparation, this study focuses on four types of modal choice: private car, public transport, bike and walking; five types of trip purpose: work, education, shopping, leisure activities and services; and five categories of trip duration, which range from within 10 minutes to more than two hours. For all the trips, the modal split is assumed to reflect travellers' preference in relation to different modes of transport. Then, the relations between modal choice and corresponding trip duration, trip purpose can show the general situation of travellers' modal choice in the Netherlands. For instance, what kinds of trips take longer and which mode of transport is the priority for various trip purposes.

3.4. Cluster analysis of Travel behaviour

The aim of this analysis is to identify homogenous travellers' clusters based on their travel behaviour. Numerous studies have shown that individuals' perception of mode choice is affected by both internal and external factors, for instance, personality characteristics, travel-related attitudes, travel experiences and the knowledge of relevant mode of transport (Collantes & Mokhtarian, 2007; Molin et al., 2016). Pronello and Camusso (2011) argued that the deep understanding of people's travel behaviour involves the combination of physical and social aspects, which reflected in people's movement and accessibility.

Cluster analysis is one of the multidimensional methods of statistical analysis that allows classifying the similar observations into the same group (Brauksa, 2013). Observations with similar attributes are grouped together, and the different chosen indicators can lead to different cluster results (Brauksa, 2013). The cluster analysis can offer several possibilities and based on relevant coefficients, the optimal number of cluster can be identified and further analysed. With respect to relations between travel behaviour, socio-demographic and variables of land-use, Wittwer, (2014) used cluster analysis to identify the typologies of young adults' travel behaviour. Thus, in order to explore transport-related inequity, this study aims at presenting a set of travellers' typologies using indicators which reflect travellers' attitude.

3.4.1. Steps for the travel behaviour cluster analysis

The objective of the travel behaviour cluster analysis is to distinguish homogenous mobility cluster controlled by modal choice and corresponding trip duration. Figure 2 presents the steps for the travel behaviour cluster analysis. After the selection of the travel behaviour variables in the first step, only travellers aged older than 15 were selected. In the Netherlands, people aged 15 and older are permitted to find employments, thus, in this study, only these adults who are allowed to work are taken into account.

The OViN 2015 dataset recorded individuals' one-day travel diary, which includes number of trips, trip duration and related trip modal choice. After data preparation, the frequency of use each mode and corresponding average trip duration are followed by target travellers. Then, frequency of use of each mode and average trip duration in terms of using various modes are treated as two types of input indicators in cluster analysis in SPSS. Because of a large dataset which has more than 1000 cases and the mixture of continuous and categories variables which are trip duration and frequency of use of each mode, a method of Two-step cluster analysis in SPSS will be used for doing the analysis. This analysis technique involves two steps, the first step is the process of pre-clustering which can reduce the size of the matrix. All the cases in the same pre-cluster are treated as an entity that can be used as input to a Hierarchical cluster analysis. As a result, the optimal number of clusters will be presented, which will divide the sample on a particular number of cluster of travel behaviour.

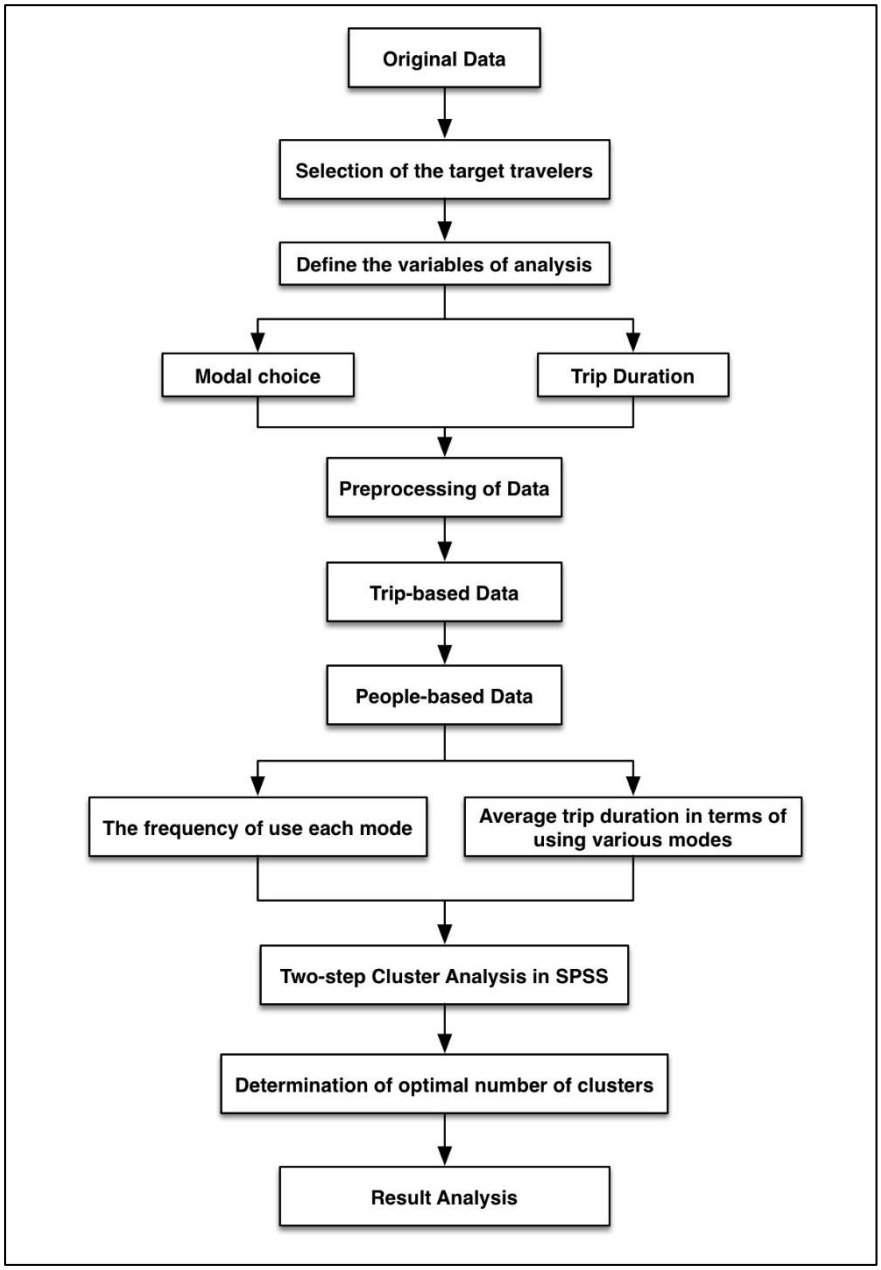


Figure 2 Steps for the travel behaviour cluster analysis

3.5. Socio-economic condition analysis

After the cluster analysis of travel behaviour, the optimal number of clusters will be identified and labelled; In order to explore relations between individuals' socio-economic conditions and their travel behaviour, the relevant socio-economic indicators should be chosen to evaluate the socio-economic conditions for these groups of travellers.

Based on the available OViN 2015 data, which combines census and travel diary data, firstly, there is a need to identify relevant indicators to analyse socio-economic conditions in the whole of the Netherlands. Based on the reviewed indicators, it was found that income and educational level are the two most important indicators. Income is recognized as an important and essential component of the well-being and societies, which can expand individuals' consumption possibilities (Organisation for Economic Co-operation and Development, 2011). A higher income level encourages people to participate in more social activities. Income levels also ranked as the most important aspects of inequity (Martínez, 2005). In addition, income can bring non-economic benefits, such as higher education, health status and living conditions (Organisation for Economic Co-operation and Development, 2011). With respect to improving socio-economic conditions, individuals' educational level, employment and income level are especially relevant. Moreover, a higher level of education also increases the chance of employment and thereby a higher income as well (Boelhouwer, 2010). Thus, in this research the analysis about socio-economic conditions in terms of transport-related inequity focuses on two main indicators: income and educational level. The description and rationale of the chosen indicators are shown in Table 4 below.

Table 4 The rational of chosen indicators

Indicators	Description	Rationale
Household income	After-tax annual household income	The higher income level means people have more disposable income to afford other activities. For the population below poverty line, they should satisfy their daily needs at first.
Education level	Completed highest education level of the respondent	A person with high educational levels is assumed to have higher possibility to get a job with higher wage.

3.6. Cluster analysis of Socio-economic condition

Several studies use cluster analysis to identify homogenous groups of respondents. Rovan and Sambt (2003) applied cluster analysis to analyse the socio-economic differences among Slovenian municipalities, and the identified groups can be clearly ranked with regards to their socio-economic indicators. Another study chose socio-economic indicators to search for similarities across different people (Brauksa, 2013). Thus, in this research, cluster analysis is also used to examine the socio-economic condition differences among travellers, and to classify them into homogenous groups on the basis of socio-economic indicators. The steps for the socio-economic cluster analysis are shown in Figure 3. After data preparation, household income and finished the highest educational level are treated as input indicators in Two-step cluster analysis in

SPSS. At last, the optimal number of clusters can be decided, and travellers who have similar socio-economic conditions are clustered in the same group.

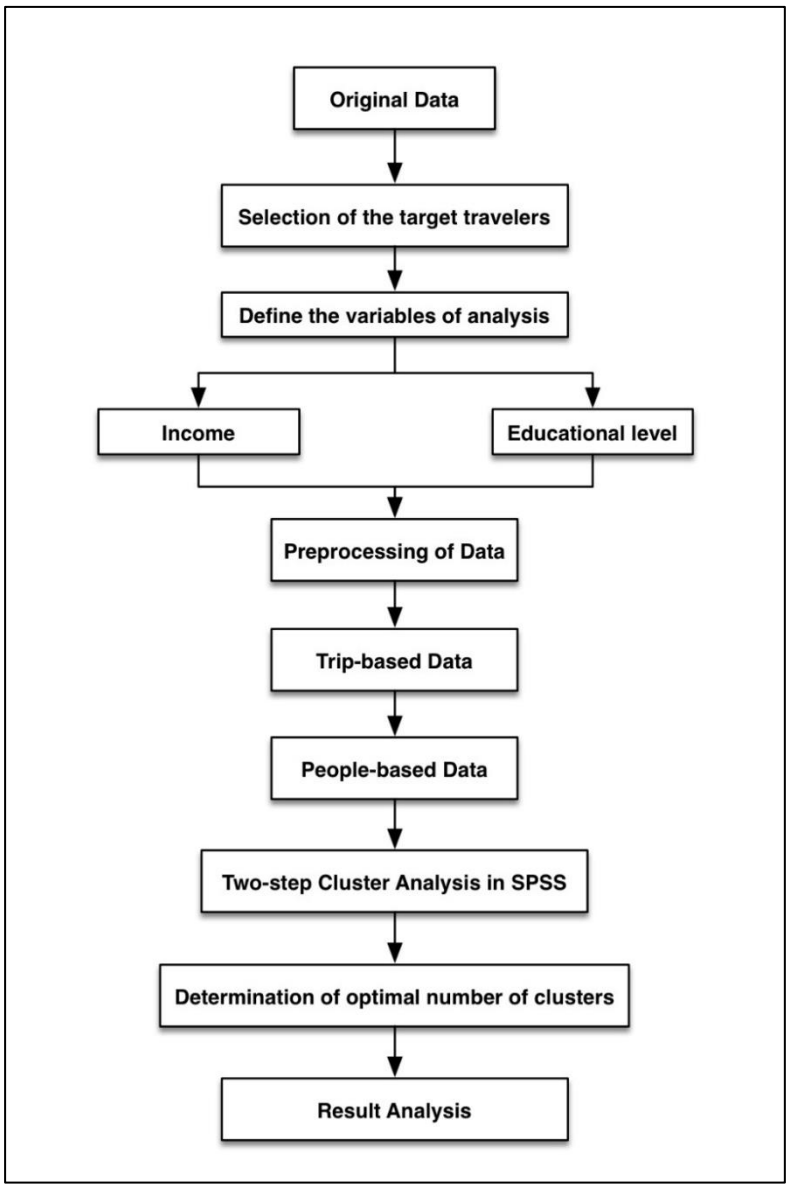


Figure 3 Steps for the socio-economic condition cluster analysis

3.7. Cross-table analysis of Socio-economic condition clusters and Travel behavior clusters

Cross-table analysis of socio-economic condition clusters and travel behaviour clusters can reflect transport-related inequity issues in social aspect. It has a function to analyse the modal share within different socio-economic clusters, and the socio-economic conditions of different travel behaviour clusters. In addition, to identify whether there are big differences between socio-economic clusters in terms of travel behaviour, for instance, trip duration, distance and total travel duration and distance.

All the travellers have informed their home location, in four-digital postcode numbers. For all the four-digital postcode areas, percentage of travellers within different socio-economic condition clusters and travel behaviour clusters can be calculated. Therefore, the spatial distribution characteristics of travellers can be visualized through maps. Travellers with similar characteristics spatially aggregated. At last, based on the results, the proposed hypotheses will be assessed and reflections about the transport-related inequity issues in the Netherlands will be drawn.

3.8. Transport supply

Spatial visualization of socio-economic conditions clusters and travel behaviour clusters is assumed to reflect the spatial distribution of travellers in the Netherlands. While, transport supply is identified as one of the spatial aspects that may cause inequity. Thus, based on the spatial distribution characteristics of all the travellers, the target areas should be selected to do comparisons in terms of transport supply.

In this situation, accessibility maps reflecting transport supply were analysed via Dutch National Accessibility Map (http://www. Bereikbaarheidskaart.nl/). These maps were produced in 2008. Through the website, catchments which can be accessed by car or public transport from every four digital postcode areas in certain time ranges can be visualized on maps. As a result, the accessible range of areas can be compared between target areas. These results can be used for analysing whether individuals' specific travel behaviour is affected by the different treatment of transport system at spatial level.

3.9. Conclusion

In conclusion, all the methodologies proposed in this chapter are going to explore transport-related inequity in the Netherlands. Descriptive analyses serve as a background for cluster analysis. And cluster analysis is being used for identifying groups with similar socio-economic conditions and travel behaviour. Then, cross-table analysis of resulting clusters (socio-economic conditions and travel behaviour) can reflect transport-related inequity. In addition, online accessibility maps are used to reflect transport-related inequity for various groups of travellers at spatial level. Thus, transport-related inequity in the Netherlands will be explored by the combination of travel behaviour, socio-economic condition and transport supply aspects.

4. ANALYSIS AND RESULTS

In this chapter, the results of the various analyses that were performed will be presented. First, the results of the descriptive analysis of travel behaviour in the Netherlands will be discussed. Then, the clusters of socio-economic condition and travel behaviour will be identified. The relationship between travellers' socio-economic conditions and travel behaviour will be analysed to confirm whether if reflects transport-related inequity at social level. Accessibility maps will then be used for assessing differences of transport supply for different regions in the Netherlands, with the purpose reflecting about transport-related inequity in the Netherlands.

4.1. Descriptive analysis of Travel behaviour

4.1.1. Travel behaviour

Despite a relatively high proportion of people opting for sustainable urban mobility styles in some European countries, the private car is still the dominant mode of transport (European Environment Agency, 2015). It is reported that, the Netherlands holds the European record of cycling use, with 31% of the population relying on the bicycle for their daily activities (Haustein & Nielsen, 2016). Based on the available dataset, a detailed analysis of individuals' travel behaviour in the Netherlands helps on getting a better understanding of individuals' travel motives and barriers.

The OViN 2015, a one-day diary survey dataset, comprised, 30282 respondents, making 99413 trips. On average, each of the respondents made 3.28 trips in one day. The average total travel distance was 39 kilometres, while the mean total travel duration was 82 minutes per person per day and mean trip duration was 23 minutes.

First, the relations between modal choice, trip duration and trip purpose will be illustrated based on the cross-table analysis, serving as a background for the cluster analysis of travel behaviour. In order to analyse the relations between individuals' travel behaviour and socio-economic conditions in the Netherlands, Figure 4 illustrates the modal split based on 77840 trips. The private car is the priority mode of transport and more than half of the trips are covered by car, otherwise only 5% of trips are taken by public transport, which is the lowest among four modes of transport.

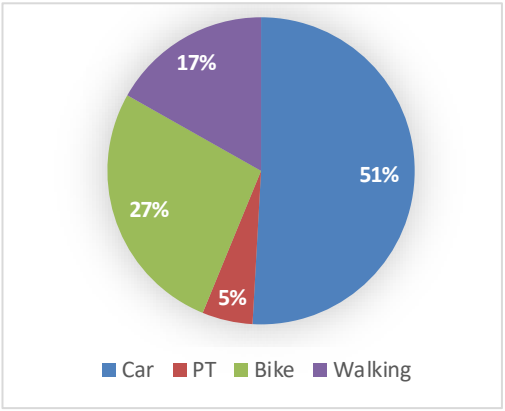


Figure 4 Percentage of Modal choice

4.1.2. Modal split by Trip duration

In the report from Statistics Netherlands, in 2015, most of the Dutch people travel nearly half an hour to and from work. Because of different trip purpose, corresponding trip durations are different, for instance, education trip will take 27 minutes, leisure activities and shopping trip will take 23 minutes and 10 minutes, respectively (Statistics Netherlands, 2015). Based on 42475 trips, trip duration range from 0 to 960 minutes, and average trip duration is 29 minutes. Reclassify the various trip duration into five categories (0-10min, 10-30min, 30-60min, 60-120min, more than 120min).

In 2015, sample adult travellers made 42475 trips. It is not surprising that car is the predominant mode of transport and more than 49% of total trips are covered by the car. Only 5.3% of total trips are covered by public transport. Modal split by trip duration is shown in Figure 5 below. It is obvious that 80% of the car trips and walking trips, the corresponding trip duration are less than 30 minutes. And nearly 90% of bike trips can be finished in 30 minutes. Compared with these three modes of transport, public transport trips have longer trip duration, more than 73% of the trips have more than 30 minutes' trip duration. Nearly half of the bike trips and walking trips have the shortest trip duration (0-10 minutes).

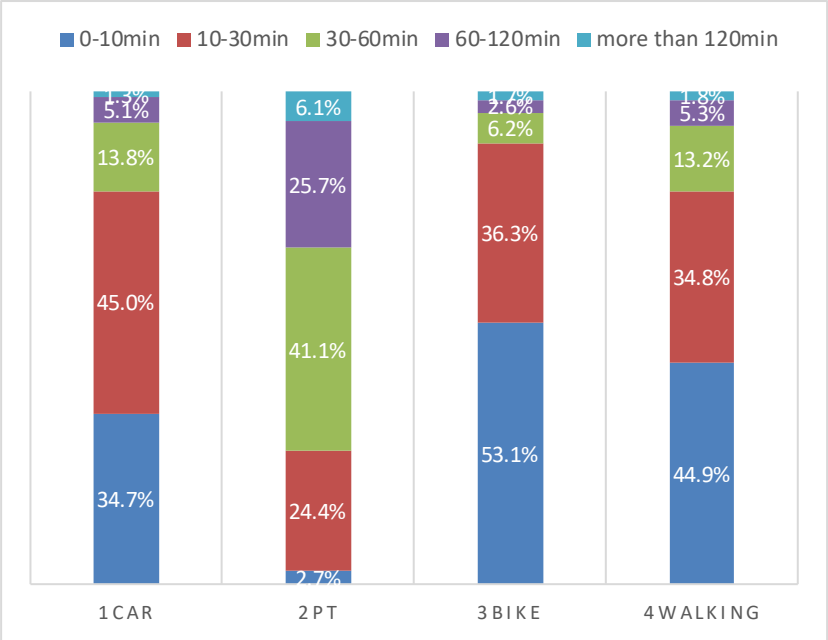


Figure 5 Modal split by trip duration

4.1.3. Modal split by Trip purpose

The report from Statistics Netherlands mentioned most important travelling motives, which are work, school, shopping and leisure activities such as hobbies or sports (Statistics Netherlands, 2015). Based on the available dataset, in this research, it will reclassify all the purpose as five main categories: work, education, shopping, leisure activities and services.

After the selection, there are 42475 trips. Modal split by five different purposes are shown in Figure 6. For the purpose of working and service activities, more than 61% of the trips are covered by the private car. For the purpose of shopping and leisure activities, only few people choose travelling by public transport, they are prone to travelling by car, by bike and walking. On the contrary, for education trips, more than 78% of total trips are covered by non-motorized mode of transport. And 27% of educational trips are covered by public transport, which is the highest compared with the other purposes. Also for shopping and leisure activities, more than half of the respondents choose to use car and walking, only 2% of trips are covered by public transport. It can be assumed that the other three modes of transport are not limited by a certain time schedule. Or there is no directly public transport between two locations especially for leisure activities.

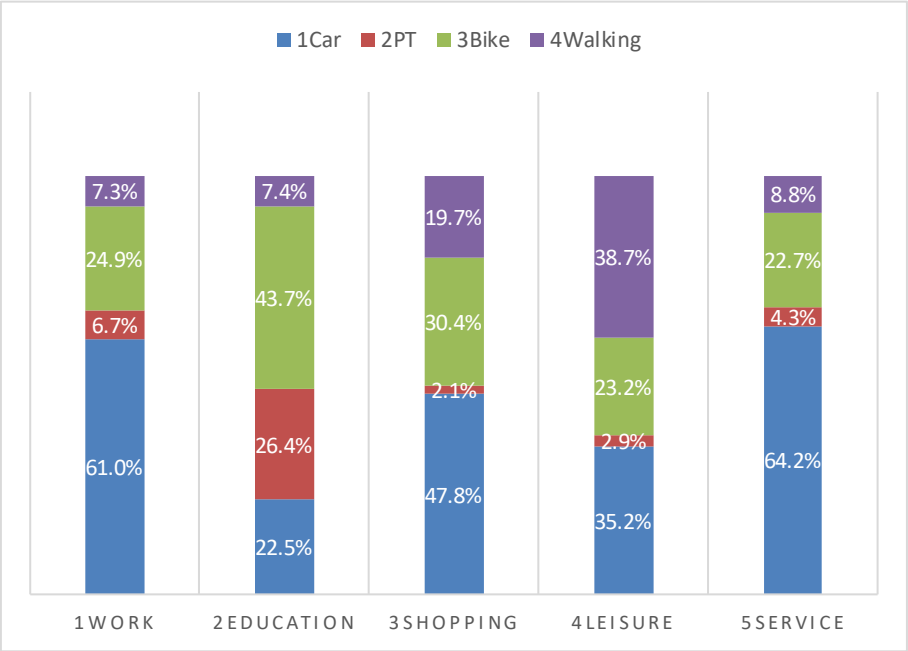


Figure 6 Modal split by purpose

4.1.4. Relations between Modal choice, Trip duration and Trip purpose

As can be seen in the analysis above, people who travel by public transport have longer trip duration. More than half of the commute trips are covered by cars, and few people use public transport when they are shopping or taking leisure activities. The cross-table analysis is being used to check the relations between modal choice, trip duration and trip purpose.

For five different trip purposes (commute, education, shopping, leisure activities, services), the modal split within different time range are shown in Figure 7. It is obvious that, for commute trip, shopping trip and services trip, car is the predominant mode of transport within five time ranges. With the increase of trip duration, more travellers are prone to choose travelling by public transport.

For the shorter education trips (duration: 0-30 minutes), more than half of the trips are covered by bike. With the increase of trip duration, there is a significant increasing in the usage of public transport, and lesser people choose travelling by bike. For leisure activities, most of the people choose travelling by bike or walking.

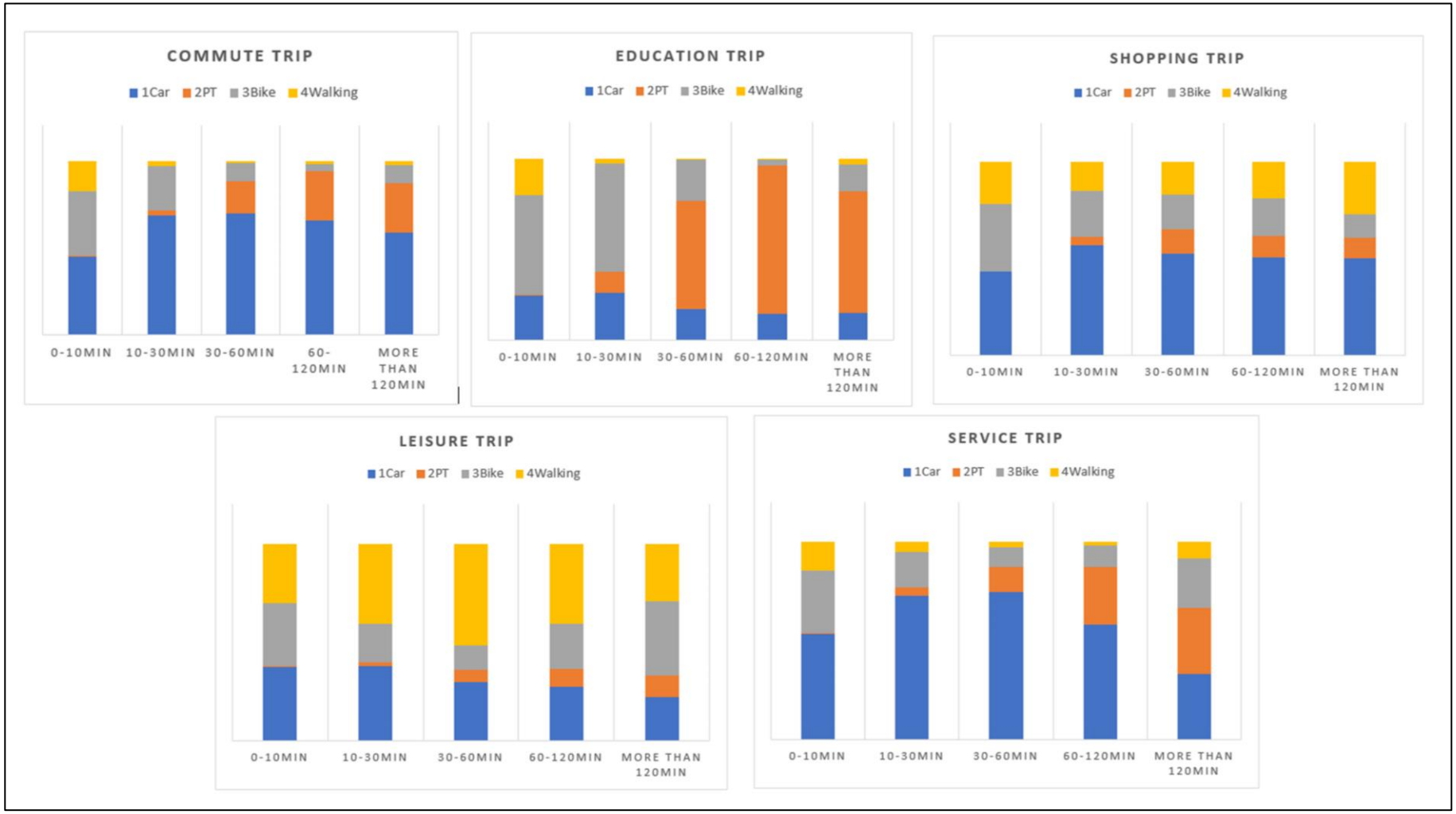


Figure 7 Cross table analysis of modal choice, duration and purpose

4.2. Travel behaviour typology

In order to identify travellers with similar travel behaviour, Blumenberg and Pierce (2014) used a one-day travel diary data, focusing on the low-income groups, whereas Buehler and Hamre (2014) used a one-week travel diary data for the same purpose. The present research will follow these approaches by using a one-day diary data collected in the Netherlands (OViN, 2015), with a purpose of creating a travel behaviour typology. Each person informed their modal choice (car, public transport, cycling and/or walking), the frequency of each mode and the average duration of each trip. After the data was cleaned for missing values, the total sample yields to 23,066 individuals who made 75,677 trips (average of 3.3 trips per person). The descriptive analysis developed in the previous section supported the present cluster of travel behaviour.

Two-step cluster analysis was performed on SPSS, which includes four categorical variables (travel modes) and four continue variables (average duration of each trip). The number of clusters can be automatically identified by SPSS, and the best cluster solution is the one that has the higher value of "ratio of distance measure" and lower value of "Bayesian criterion" (Trpkova, 2007). Based on this, the graph on Figure 8 illustrates these performance measures of clustering from 2 to 7 groups. The best performance was observed for 5 clusters. In addition, another popular measure in SPSS is the Silhouette coefficient, which is a measure of both cohesion and separation (Everit, Landau, & Leese, 2001). "Good Cluster Quality" in Figure 9 means that the within-cluster distance are small and the between-cluster distance are large (Everit et al., 2001). Thus, in this study, five was identified as the optimal number of cluster.

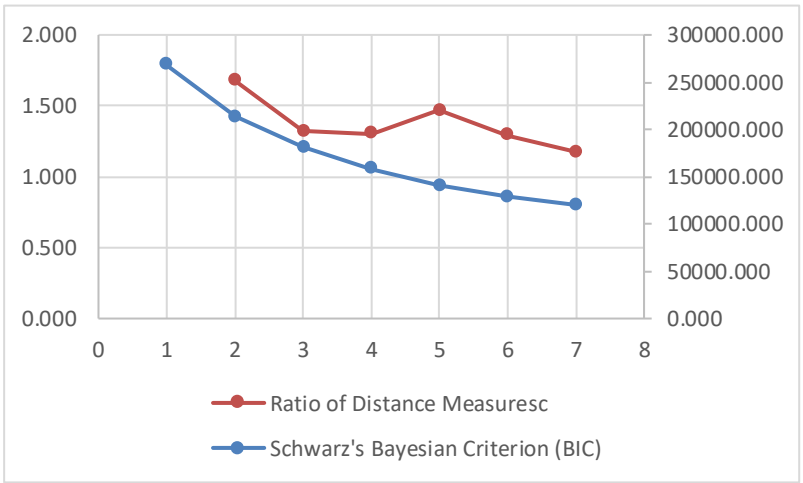


Figure 8 Changes of Ratio of distance measure and BIC

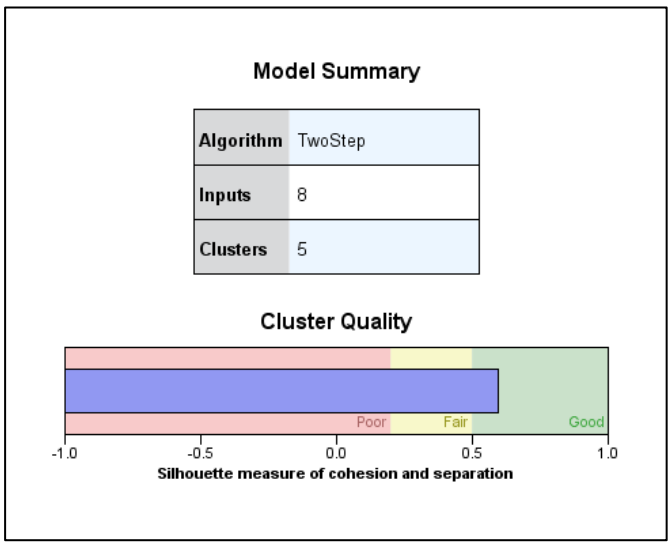


Figure 9 Quality of mobility cluster (five clusters)

The results of travel behaviour cluster analysis are shown in Figure 10 to 14 while Table 5 presents a summary, which visualizes the number of travellers in each cluster, the number of trips for each mode of transport and the corresponding trip duration. As can be seen the modal share by each cluster in Figure 11, all the travellers in cluster 5 are single modal users, and nearly all the travellers in cluster 1 travelling by bike. Except travelling by public transport, travellers in cluster 2 are prone to choose travelling by car, by bike or walking. While, travellers in cluster 3 are predominantly public transport users. For the people in cluster 4, most of them prefer walking. Thus, the five identified clusters were labelled as "BIKE", "CAR, BIKE, WALKING", "PT MM", "WALKING" and "CAR". A suffix MM of multi-modal is added behind public transport as the number of trips for the other three modes of transport are similar and the public transport is a predominant mode of transport.

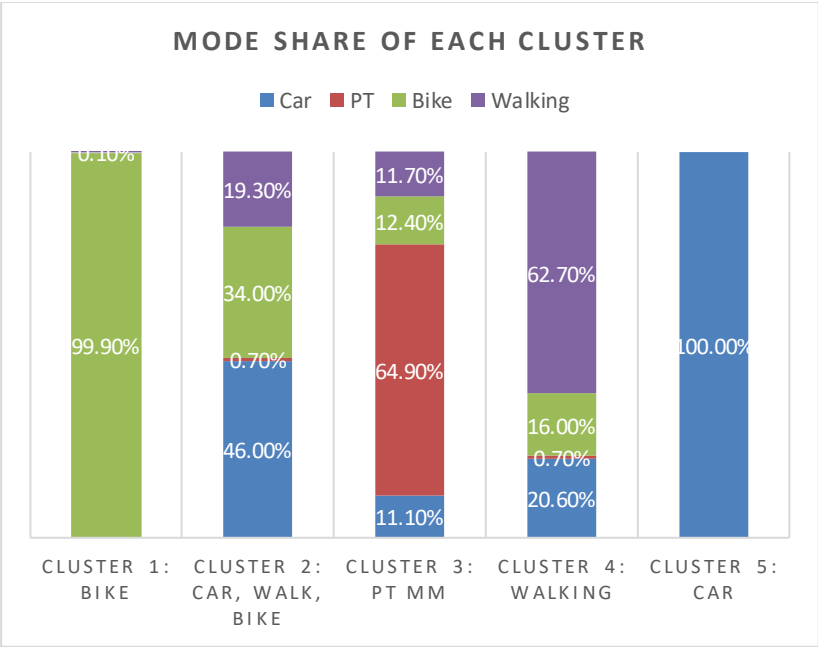


Figure 10 Modal share by each cluster

The number of travellers and trips among five identified clusters are shown in Figure 11, the predominant travellers are car users, who made the largest number of trips in cluster 5. Only 8.6% of total travellers are in cluster 3 and they made lesser number of trips. Except travellers in cluster 3 and 5, the other travellers are relatively evenly distributed in cluster 1, 2 and 4. But travellers in cluster 2, who are the multi-modal users made more trips. Figure 12 below visualizes the average number of trips per person per day, for all the five cluster, each people made 3.28 trips per day. People in cluster 2 who use car, bike and walking made five trips every day, which is higher than the other clusters. And people who are prone to travelling bike, public transport and car made lesser number of trips.

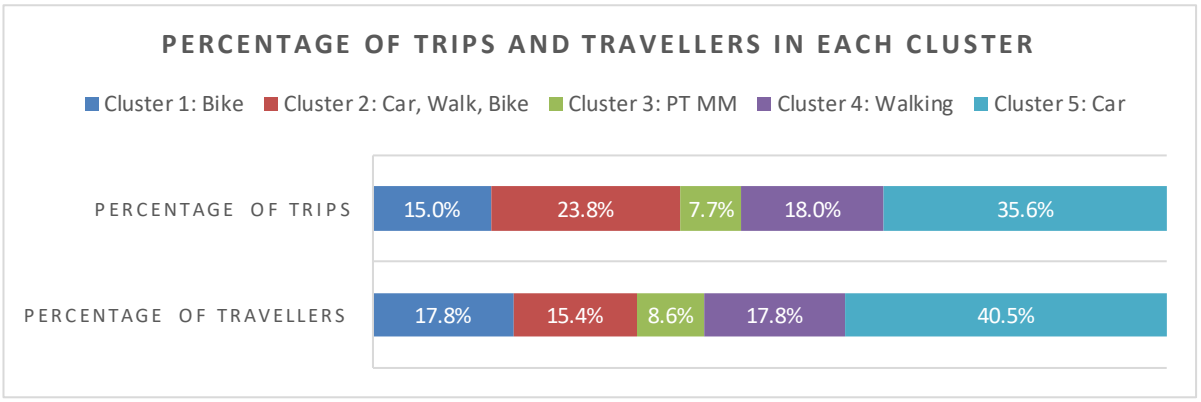


Figure 11 Percentage of trips and travellers in each cluster

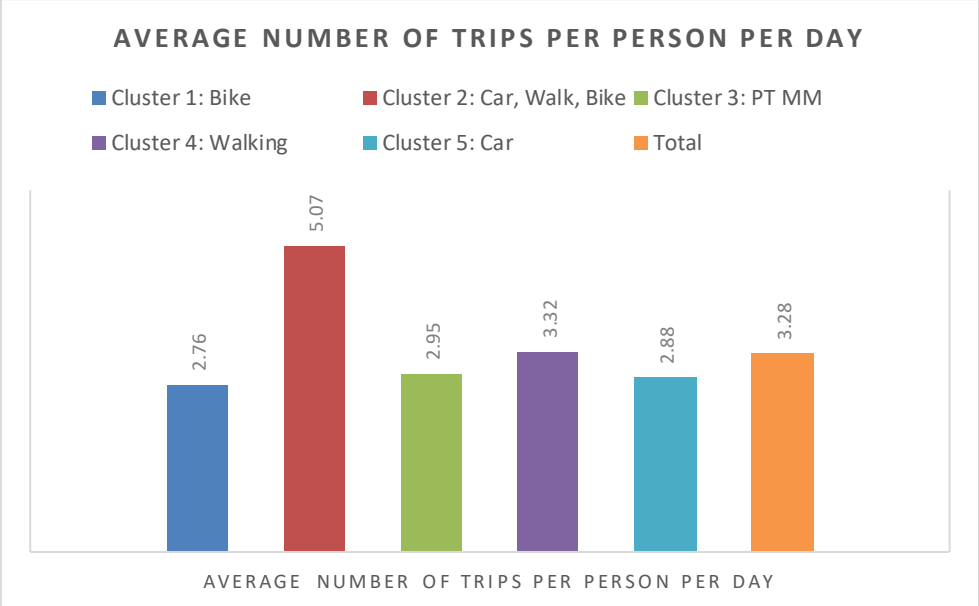


Figure 12 Average number of trips per person per day

Figure 13 visualizes the number of trips shared by four modes of transport in each cluster, and Figure 14 illustrates the corresponding mean trip duration and its' value of standard deviation. As can be seen that, mainly car trips are grouped in cluster 5, but the car trip duration is 26 minutes which is lower than the duration in cluster 2. Similar as cluster 5, nearly all the trips in cluster 1 are bike trips and the mean trip duration is 18 minutes, which is lower than the period in cluster 2. Only few people in cluster 2 travelling by public transport, people in this cluster made longer car trips and bike trips, and they made five trips per day. On the contrary, people in cluster 3 are predominantly public transport users who have the longest mean trip duration (64.2 minutes). Also, people in cluster 4 have relevant longer walking trips.

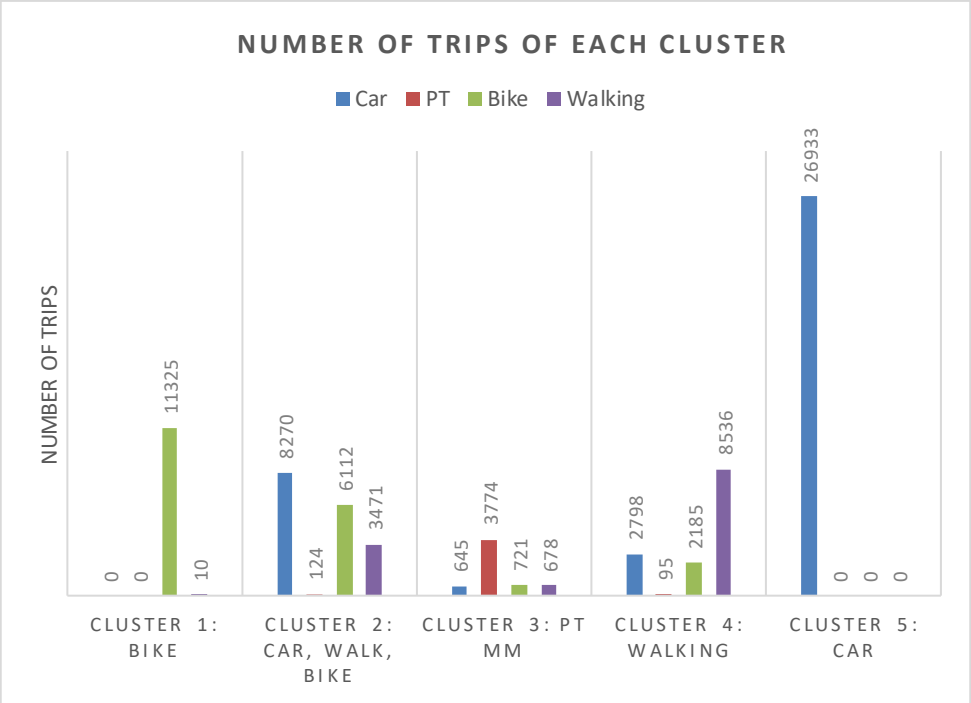


Figure 13 Number of trips shared by different modes in each cluster

Figure 14 Mean trip duration of each cluster (standard deviation)

In conclusion, Table 5 below visualizes the whole information for each cluster and the descriptions of each cluster are in the following:

The BIKE group

The first group is labelled as "BIKE" group with 17.8% of respondents. Nearly all the people in this cluster choose to travel by bike, and the average trip duration is 18 minutes.

The CAR+BIKE+WALKING group

The second cluster is labelled as "CAR+BIKE+WALKING" group, which is multi-modal user groups, and includes 15.4% of respondents. The characteristic of this specific groups is that people choose travelling by car, bike and walking, and trip duration by car and by bike are quite long compared to the period in the other clusters.

The PT MM group

The third cluster is labelled as PT MM group, which only has 8.6% of respondents. Nearly 65% of the people in this group choose travelling by public transport. Respondents in cluster three also choose to travel by car, bike or walking, but the average trip duration are quite short. And the trip duration in terms of using public transport is 64 minutes which is much higher than the trip duration of the other three modes of transport in this group.

The WALKING group

The fourth group is labelled as "WALKING" group with 17.8% of the people. Mainly people in this groups choose walking and only few of them travelling by public transport. The average walking trip duration is 28 minutes.

The CAR group

The fifth cluster is labelled as "CAR" group, which is the largest group with 41% of total respondents. This cluster only containing the car users, who are car drivers and car passengers. The average trip is 26 minutes.

Table 5 Result of travel behavior cluster analysis

Cluster	Sample size		Car	PT	Bike	Walking
1.Bike	4107 (17.8%)	Number of trips (%)	0	0	11325 (99.9%)	10 (0.01%)
		Average duration min (stdev)	0	0	18.1 (17.5)	0 (0.2)
2.Car, Bike, Walking	3543 (15.4%)	Number of trips (%)	8270 (46%)	124 (0.7%)	6112 (34%)	3471 (19.3%)
		Average duration min (stdev)	29.4 (52,9)	0.8 (6.4)	21.6 (61.1)	9.5 (18.3)
3.PT MM	1975 (8.6%)	Number of trips (%)	645 (11.1%)	3774 (64.9%)	721 (12.4%)	678 (11.7%)
		Average duration min (stdev)	4.3 (12.8)	64.2 (52.9)	2.6 (8.2)	3.8 (14)
4.Walking	4098 (17.8%)	Number of trips (%)	2798 (20.6%)	95 (0.7%)	2185 (16%)	8536 (62.7%)
		Average duration min (stdev)	7.1 (15.7)	0.5 (4.8)	4.2 (11.5)	27.8 (43.8)
5.Car	9343 (40.5%)	Number of trips (%)	26933 (100%)	0	0	0
		Average duration min (stdev)	26.3 (22.1)	0	0	0

4.3. Socio-economic condition analysis

In light of different travel behaviour, numerous research tried to explain the impact of socio-demographic indicators on individuals' travel demand. Lucas, Bates, Moore, and Carrasco (2016) used an indicator of income to explain the inequity in their travel behaviour, and they found that higher income groups show a higher propensity to participate in social and leisure trips compared with the people who have lower income level. Whereas, Cheng, Bi, Chen, and Li (2013) found that low-income people have lower mobility, and they tend to make fewer and shorter trips. On the other hand, Wittwer (2014) used a indicator of educational level to check its impact on individuals' modal choice, especially for the young adults' in Germany.

It is obvious that travellers in travel behaviour cluster 2 are prone to travelling by car, bike and walking, they made relevant longer trips. It is also considered that people in cluster 2 made on average 5 trips in

one day, which is much higher than the ones in the other groups. Thus, the present research will follow these approaches by using the indicators of income level and educational level, with a purpose of exploring the impacts on different travel behaviour. Descriptive statistic is used for identifying the income level and educational level for each travel behaviour cluster.

Based on the result in Figure 15, people have different income levels performed various travel behaviour. For the low-income travellers, more than 22% of the traveller choose walking, 20% of them are prone to travelling by bike and 10% of them travelling by public transport, which is higher than the ones in the other two income levels. Therefore, more than 52% of the low-income people choose environmental friendly mode of transport. With the increase of income, lesser travellers are prone to travel by public transport, bike or walking. Nearly half of the high-income travellers are car users, and 17.5% of them are multi-modal users. With the decrease of the income level, lesser people travelling by car. Also, there is a decrease number of mixed modal users.

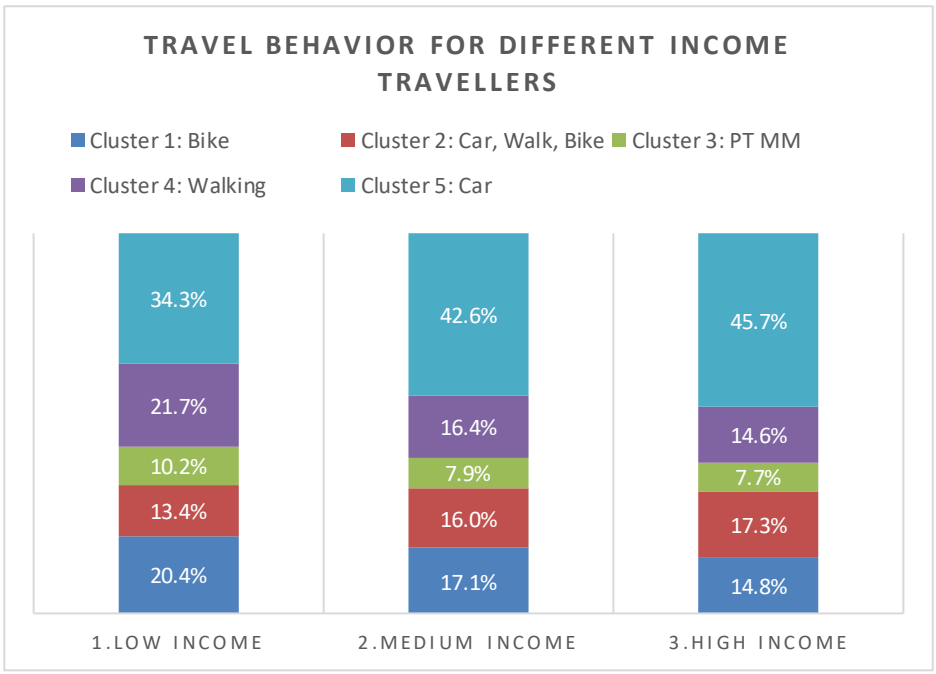


Figure 15 Travel behaviour for different income travellers

The impact of educational level on travellers' travel behaviour are visualized in Figure 16 below. For the people who only finished primary school, 33% of them are bike users and only 13.4% of them are multi-modal users. With the increase of educational level, there is a sharply decrease in the number of the people who travelling by bike. And there is a linear increase in the number of multi-modal users. Only 15% of the people who have Bachelor degree are prone to travelling by bike and more than 42% of them choose car, 17.3% of these travellers are multi-modal users. It is obvious that people have relative higher educational level performed similar travel behaviour, and the car is the priority to them. And there is a big difference between low and high educated people in terms of travel behaviour. People have lower education level are more rely on the non-motorized mode of transport.

In conclusion, individuals' income level or educational level have different impact on their travel behaviour. For instance, low-income travellers and low educated travellers are limited to non-motorized mode of transport. With the increase of their income level or educational level, people's travel behaviour performed more flexible. In the next step, the analysis is going to explore whether there are limitations for the low-income or low educated travellers in terms of travel duration and travel distance.

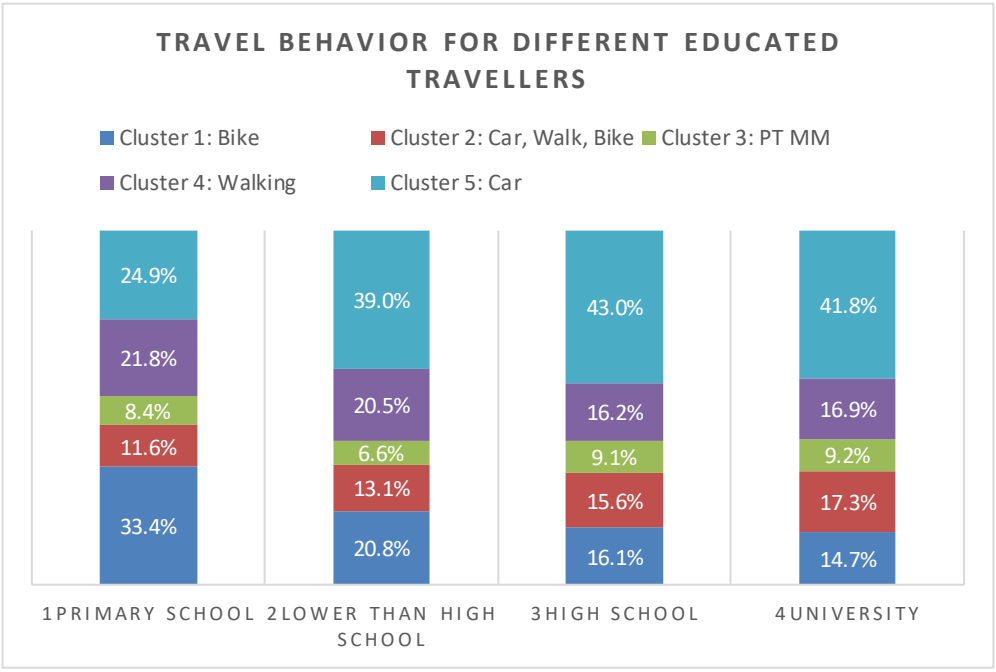


Figure 16 Travel behaviour for different educated travellers.

Based on the descriptive analysis above, Figure 17 and 18 below explore the corresponding mean total travel duration and distance in terms of different income groups and educated groups. With the increase of travellers' income level and educational level, there is a liner increase in their daily total mean travel duration and travel distance. It is obvious that people have high income or high educational level are prone to travel longer and further. Compared to these people, low-income and low educated travellers tend to make lesser and shorter trips, which means they have less mobility.

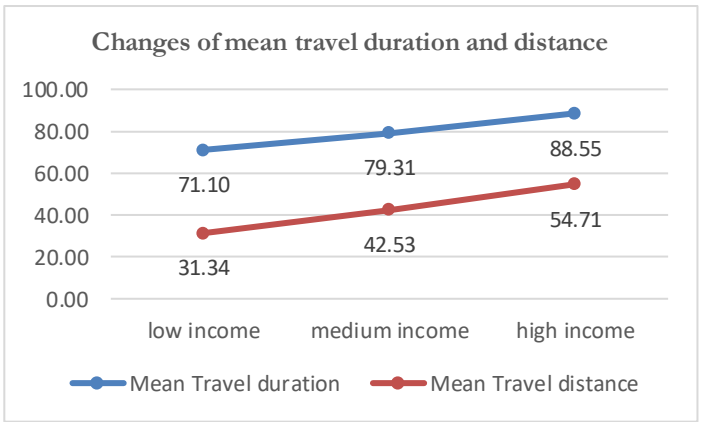


Figure 17 Changes of travel duration(min) and distance(km) in terms of income levels

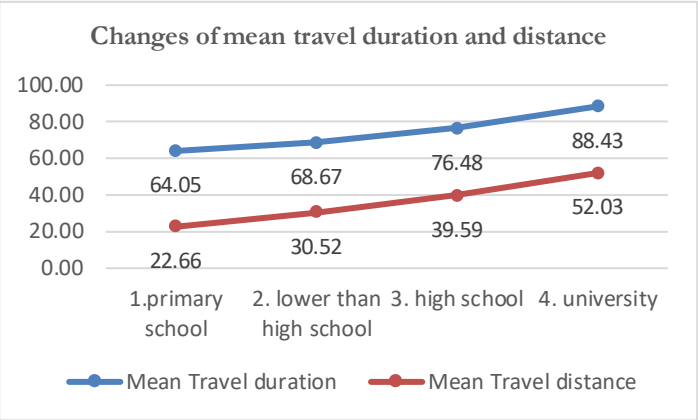


Figure 18 Changes of travel duration(min) and distance(km) in terms of educational levels

4.4. Socio-economic typology

Focusing on the same travellers in travel behaviour cluster analysis, based on the chosen socio-economic indicators, the cluster analysis is also used for grouping the people who have similar socio-economic conditions in the same cluster.

Two-step cluster was performed on SPSS, which includes two categorical variables (income level and educational level). Same as the travel behaviour cluster analysis, the number of clusters can be automatically identified by SPSS, and the best cluster solution is the one that has the higher value of "ratio of distance measure" and lower value of "Bayesian criterion" (Trpkova, 2007). Based on this, the graph on Figure 19 illustrates these performance measures of clustering from 2 to 5 groups. The best performance was observed for 2 clusters. In addition, another popular measure in SPSS is the Silhouette coefficient, which is a measure of both cohesion and separation (Everit et al., 2001). But as a result of two cluster, the quality of the cluster is just shown as "Fair Cluster Quality" in Figure 20, which means the distribution of samples is not explicitly. Thus, the second highest value of Ratio of distance measure, which is four clusters can be taken into account. As can be seen in Figure 21, the model summary about four cluster has a "Good Cluster Quality", which means the within-cluster distance are small and the between-cluster distance are large (Everit et al., 2001). Four can be treated as the optimal number of socio-economic cluster analysis.

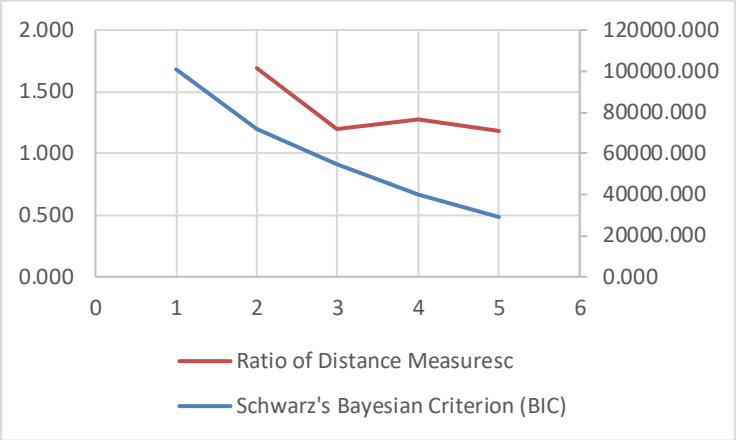


Figure 19 Changes of Ratio of distance measure and BIC

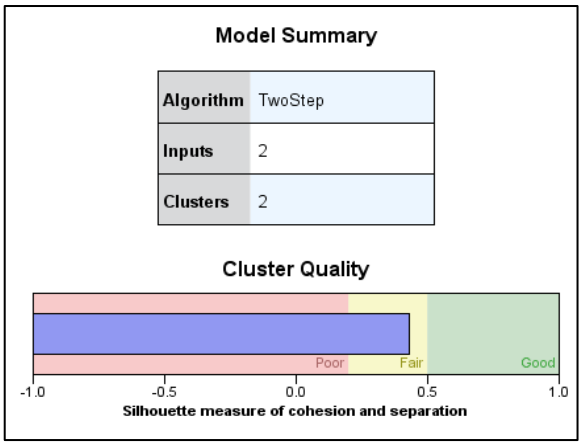


Figure 20 Quality of two clusters

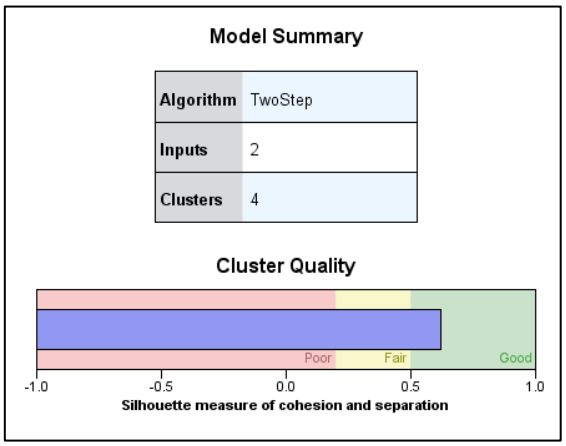
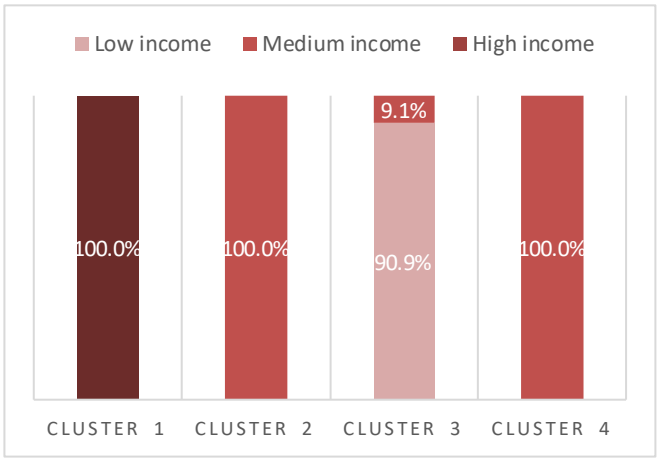


Figure 21 Quality of four clusters

As can be seen, the distribution of travellers in terms of three income levels and four educational levels in Figure 22. All the high-income travellers are in cluster 1 and people have medium income level are distributed in cluster 2 and 4. In cluster 3, nearly 91% of travellers have low income. For the different educational level, all the travellers in cluster 4 finished their high school. Most of the people who have Bachelor degree are in cluster 1 and 2. Nearly 85% of the travellers in cluster 1 have a higher educational level and 65% of the travellers in cluster 2 have Bachelor degree. On the other hand, 20% of travellers in cluster 3 just finished primary school. Thus, four socio-economic condition clusters are labelled as "High income, Highest education", "Medium income, High education", "Low income, Low education" and "Medium income, Medium education", respectively. Also, Table 6 below illustrates the number of travellers in four socio-economic condition clusters, and the descriptions of each cluster are in the following.



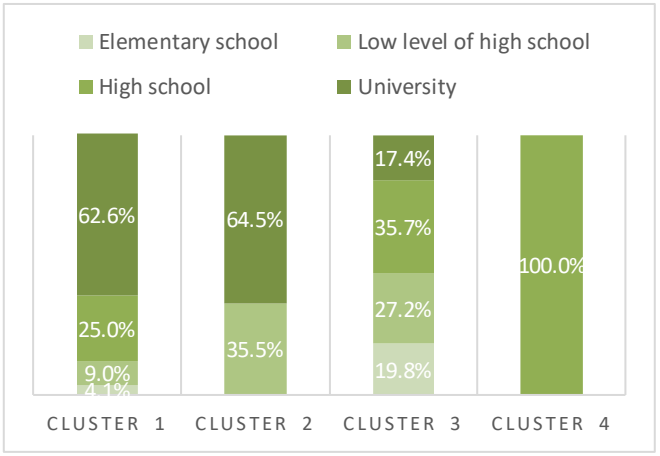


Figure 22 Income levels and educational levels of four clusters

Table 6 Number of travellers in four clusters

	Number of people	% of total people
1 High income, Highest education	2863	12.4%
2 Medium income, High education	7325	31.8%
3 Low income, Low education	7558	32.8%
4 Medium income, Medium education	5320	23.1%

High income, Highest education cluster:

The first cluster is the smallest cluster, which only includes 12.4% of the total population. All of the people in this cluster have high income level (€ 40000-more than € 50000), nearly 88% of them have higher educational level and 63% of them achieved Bachelor degree.

Medium income, High education cluster:

For the people in cluster two, all of them have medium income level (€ 20000-€ 40000). More than 65% of them finished their university, but the other 35% of them have relevant lower educational level.

Low income, Low education cluster:

The third cluster includes 33% of the total population. It should be mentioned that 91% of the people in this cluster have low income level (less than € 10000-€ 20000). But these people have various educational

levels, the predominant people finished high school. And 20% of them just finished primary school which is the lowest educational level.

Medium income, Medium education:

Cluster four includes 23% of the people, all of them have medium income level (€ 20000-€ 40000). And all the people in this cluster finished their high school.

4.5. Relations between Travel behavior typology and Socio-economic typology

Based on the cluster analysis results of travel behaviour and socio-economic characteristic in 4.2 and 4.4, cross-table analysis is used for exploring relations between travel behaviour typology and socio-economic typology. Figure 23 visualizes modal share within four socio-economic clusters, travellers in cluster 1, 2 and 4 who have a relatively higher income level and educational level have similar travel behaviour. Compared with travellers in these three clusters, people in cluster 3 have lower socio-economic conditions and they performed different travel behaviours. 33% of travellers in cluster 3 travelling by private car, which is lesser than the people in the other three clusters. Also, 10% of these travellers travelling by public transport, which is higher than the ones in other clusters. More than 43% of them rely on the non-motorized mode of transport and a lesser number of people in cluster 3 are multi-modal users.

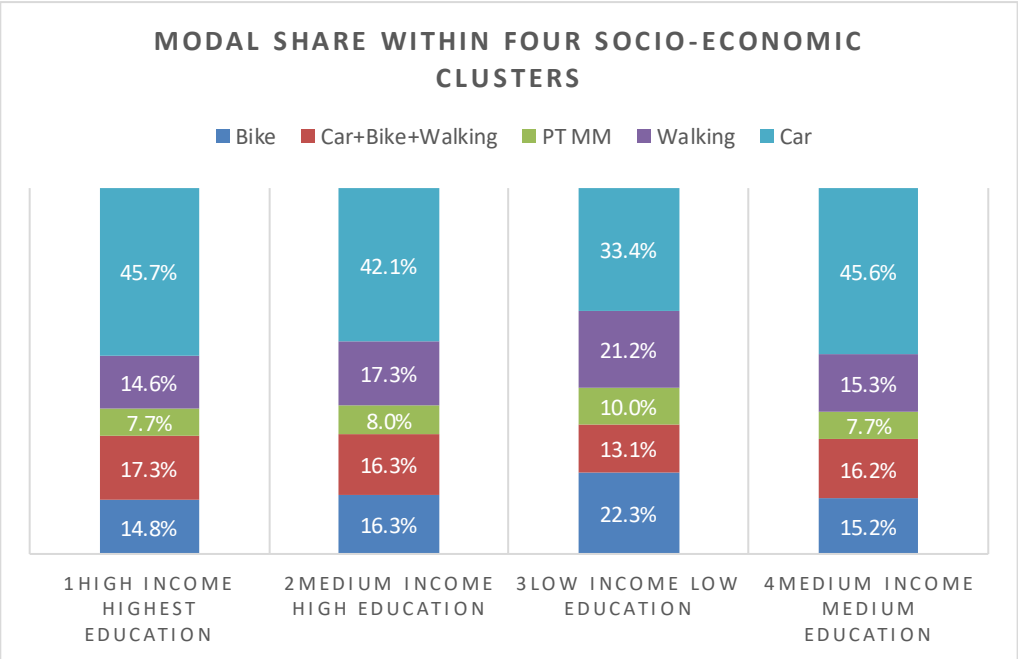


Figure 23 Modal share within four socio-economic clusters

On the other hand, Figure 24 illustrates the share of socio-economic clusters in different five travel behaviour clusters. It is obvious that travellers who have low-income and low educational level are less multimodal users than those who have high income and high educational level. For instance, travellers in Bike, PT MM and Walking clusters, the predominant travellers are low-income and low educated people.

On the contrary, people who are multi-modal users and car users, 14% of them have high income level and highest educational level.

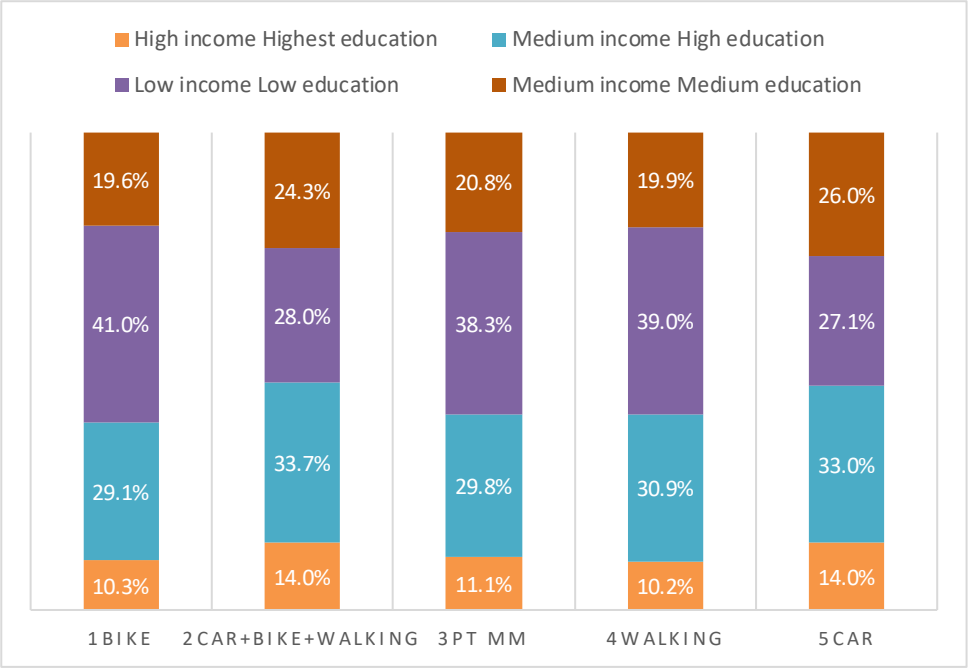


Figure 24 Share of socio-economic clusters within travel behaviour clusters

Based on the analysis above, people in socio-economic condition cluster 1, 2 and 4 who have higher socio-economic conditions have similar travel behaviour compared with the travellers in cluster 3, who have lower socio-economic conditions. The present analysis is going to analyse the differences in terms of total daily travel duration and distance, trip duration and distance. The result is shown in Figure 25, it is obvious that low-income and low-educated people in cluster 3 have shortest travel duration and travel distance in their total daily travel process. For the travellers in cluster 4, 2 and 1, with the increase of travellers' income level or educational level, people tend to travel longer and further. On the other hand, it also visualizes the mean trip duration for all the travellers in each socio-economic cluster. Low-income and low educated travellers in cluster 3 have shortest trip duration (22 minutes). With the increase of socio-economic condition, there is a linear increase in the mean trip duration from cluster 4 to cluster 2 and 1. For the high income and high educated travellers in cluster 1, they have the highest mean trip duration (27 minutes).

Figure 26 check the number of trips people made per person per day, all the travellers in four clusters made average 3.28 trips and there is no big difference between four clusters in terms of number of trips. The low-income and low educated travellers in cluster 3 made 3.2 trips, which is a little bit lower than the ones in other clusters. For the people in cluster 1 and 2, who have relatively high income and educational levels made 3.3 trips. Thus, it can be identified that people have high income and high educational levels are prone to travel longer and further. On the contrary, low-income and low educated travellers have lower mobility and they tend to travel shorter distance.

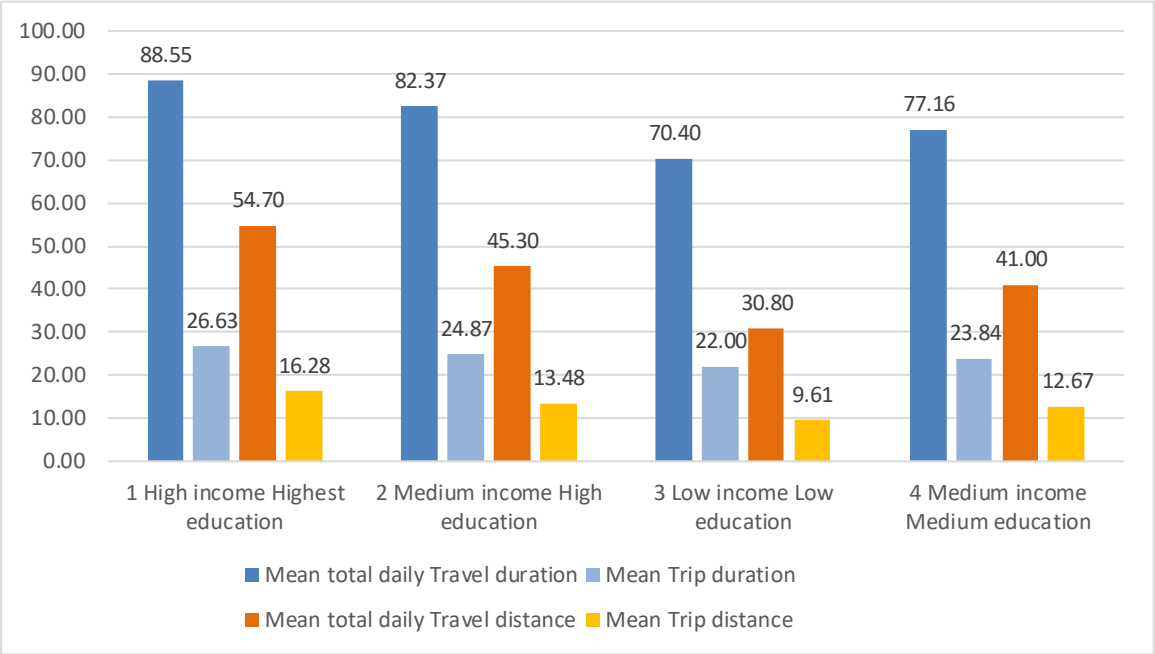


Figure 25 Mean (total) daily travel duration(min) and (total) distance(km) within four socio-economic clusters

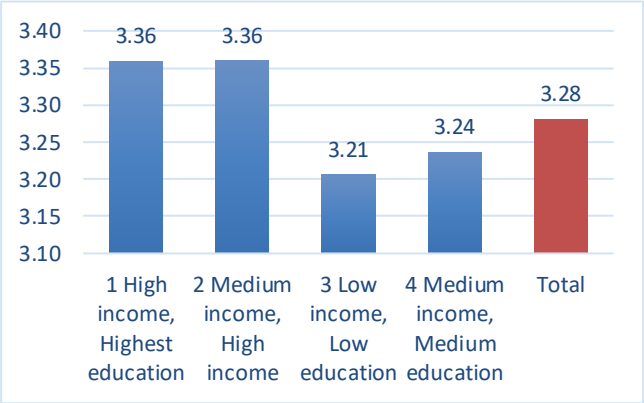


Figure 26 Number of trips per person per day

4.6. Spatial visualization

Based on the cluster analysis of socio-economic condition and travel behaviour, each of the travellers is belonging to the specific socio-economic cluster and travel behaviour cluster. Also, each traveller informed the four-digital postcode area of their home location. Within 3207 four-digital postcode areas, there are 23066 individuals, which are belonging to four different socio-economic clusters and five travel behaviour clusters. Then, based on 3207 postcode areas, the percentage of people within specific socio-economic cluster and travel behaviour cluster can be calculated respectively.

From literature, in the Randstad region (urbanized region in the western part of the Netherlands) which includes several large cities such as Amsterdam, Rotterdam, Utrecht, The Hague, Amersfoort and the others. Over the past decades, travel in the Randstad region has increased significantly, and 80% of transport investments have implemented in this region; however, the remaining 20% of transport investments are implemented outside the Randstad (Ha et al., 2011; Mouter, 2017).

Figure 27 visualizes the spatial distribution of percentage of travellers within four socio-economic clusters, and Figure 28 and 29 illustrate the percentage of travellers within five different travel behaviour clusters. As can be seen in Figure 27(a), within some four-digital postcode areas in the western and central part of the Netherlands, more than 33% of travellers have high income and highest educational level. But in the northern and eastern part of the Netherlands, few travellers have higher socio-economic conditions. On the contrary, in Figure 27(d), in the eastern and northern part of the Netherlands, more than 33% of travellers have low-income and low educational level. For the people in socio-economic cluster 2, who have medium income and high educational level are distributed in all around the Netherlands. Also, same for the travellers in cluster 4, these people are evenly distributed in the whole country. Because of the differences in terms of transport investments between the Randstad region and the outside the regions (north, east and south of the Netherlands), spatial visualization of travel behaviour clusters in the following tends to explore whether the travellers in these two regions have big differences with respect to travel behaviour.

Ha et al., (2011) mentioned that, for the Randstad, there are several types of transport facilities, such as railways, subways, tramways and buses within and between these regions, and the city centre of the Amsterdam, The Hague, Rotterdam and Utrecht are named as the Green Herat area, which have higher accessibility than the outside of the Randstad region. Figure 28(b) visualizes the distribution of number of public transport users, in the most part of the Netherlands, only few people choose travelling by public transport. But in the central city of Amsterdam, The Hague, Rotterdam and Utrecht, more than 25% of travellers choose travelling by public transport, which is much higher than the people in the other areas. On the contrary, the only car users are visualized in Figure 29(b), in the centre of the Amsterdam, The Hague, Rotterdam, Utrecht, and Amersfoort, less than 25% of travellers are car users. Around these city centres, more people choose travelling by car. For the bike users, multi-modal users and the walking people in Figure 28(a)(c) and Figure 29(a), they are distributed in the whole country.

However, based on the data analysis results, it can be identified that travellers who have lower socio-economic conditions tend to travel fewer and shorter. And they are prone to choose cheaper modes of transport, such as bike, walking and public transport. Based on the spatial analysis, the largest share of the low-income and low educated travellers are concentrated in the eastern and northern part of the Netherlands, which are far away from the Randstad region. On the other hand, travellers who have higher socio-economic conditions tend to choose faster mode of transport, and a large amount of them are mixed modal users. The spatial distribution characteristics of these people are not obviously, but few of them are concentrated in the northern and eastern part of the Netherlands.

In terms of the spatial distribution of travel behaviour clusters, it is obvious that predominant public transport users are concentrated in the city centre of Amsterdam, The Hague, Rotterdam and Utrecht, and within these centres, lesser people choose travelling by car, especially in the Randstad region.

In summary, the largest share of the travellers who have lower socio-economic conditions are located in the northeast of the Netherlands. As a basis of data analysis, these people are prone to use more public transport and lesser car. But the usage of the public transport within the Randstad region is high, rather than the people who have lower socio-economic conditions and live in the northern and eastern part of the Netherlands. Meanwhile, in the city centre of Amsterdam, The Hague, Rotterdam and Utrecht, more travellers are prone to choose public transport and lesser of them travelling by private car.

Thus, of particular interests is to check whether transport facilities are equitable distributed between the Randstad region and the northern and eastern part of the Netherlands. Based on the degree of urbanization, there is a need to choose several sample cities to do comparisons in terms of transport supply.

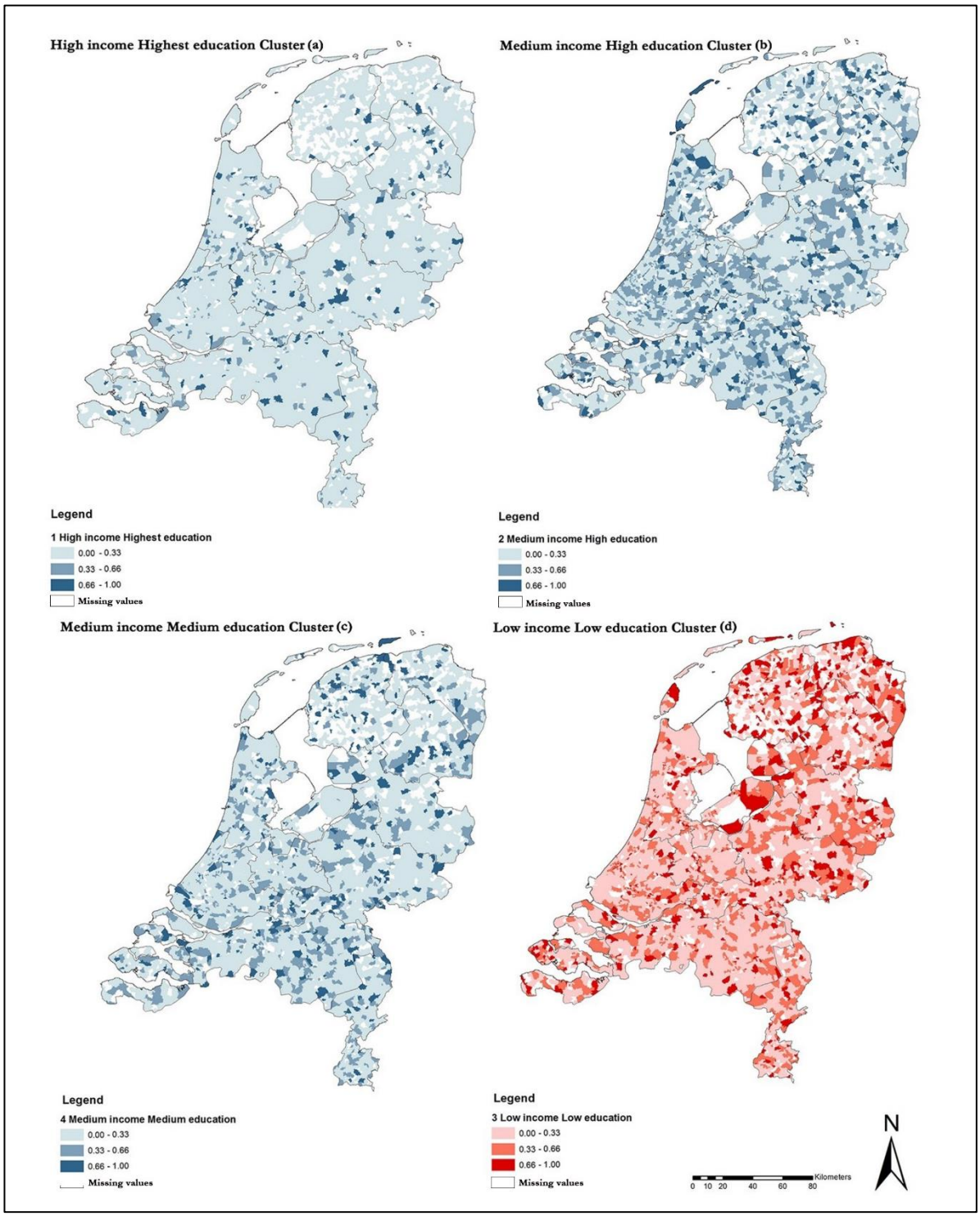


Figure 27 Spatial visualization of socio-economic clusters

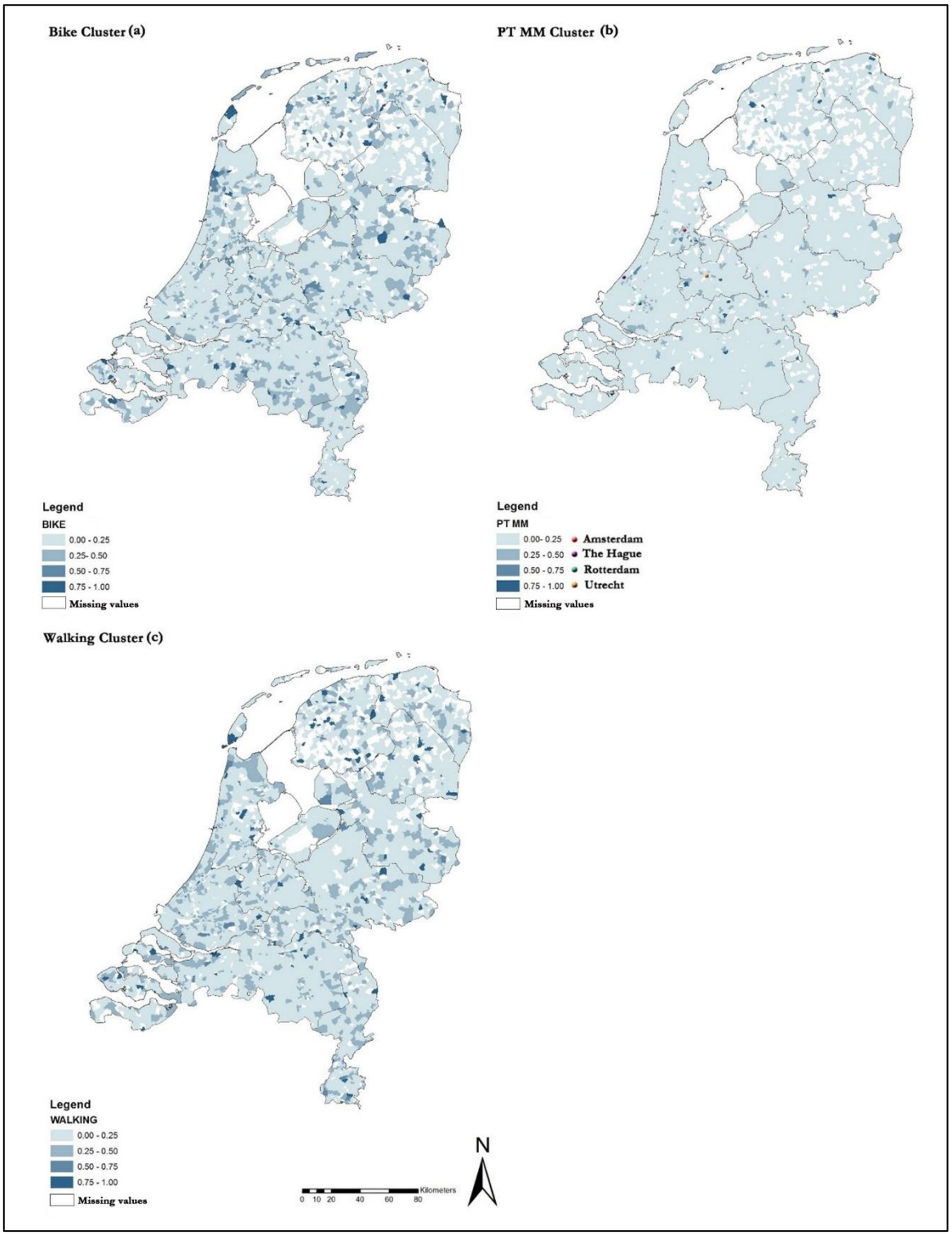


Figure 28 Spatial visualization of Bike, PT MM and Walking cluster

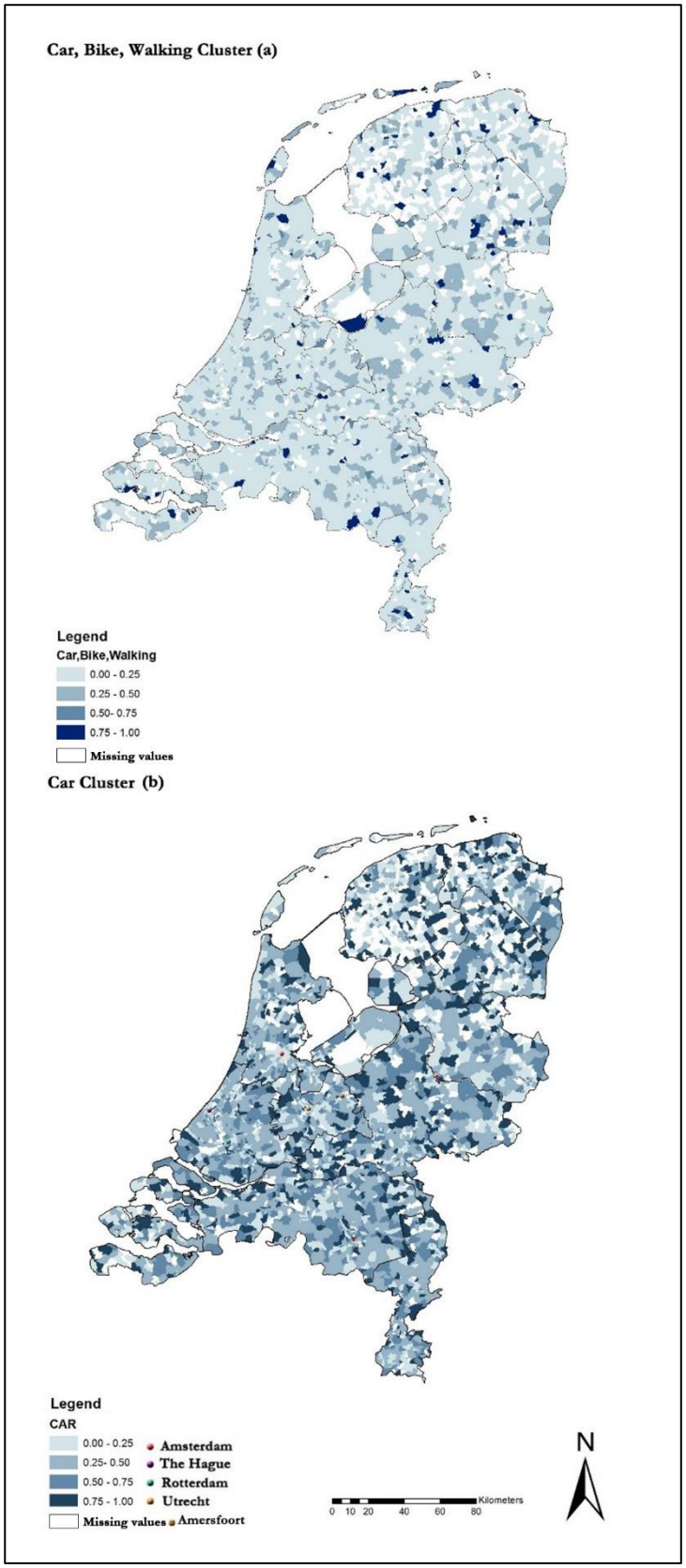


Figure 29 Spatial visualization of Car, Bike, Walking and Car cluster

4.7. Transport Supply

In order to check transport supply, firstly, Figure 30 illustrates the average number of vehicles per household within four socio-economic clusters. All the 23066 travellers have an average number of 1.32 private cars. The average number of private car in high income and highest educational level cluster is two times higher than the ones in the low-income and low educational level cluster. Thus, it can explain that low socio-economic condition travellers tend to travel by non-motorized mode of transport, rather than the private car. But for the travellers who have low socio-economic conditions and concentrated in the north and east of the country, they might have limitations in travelling longer and further, because of lower car ownership.

Figure 30 illustrates the average number of vehicles per household in 3207 four-digital postcode areas. It can be seen that in the city centre of Amsterdam, The Hague, Rotterdam and Utrecht, the car ownership are lower compared with the households which located surrounding these areas. There is a need to check whether people in the Randstad region have sufficient high quality public transport system, which might lead them travelling by public transport rather than the car. If so, the effective and efficient public transport system might help to reduce the usage of the car, thus, the corresponding negative impacts of vehicles will be reduced. Thus, comparisons of transport supply between the Randstad region and the northern, eastern part of the country can be explored to analyze transport-related inequity.

Based on the available dataset, Figure 32 visualizes the urbanized levels in the whole Netherlands, from highly urbanized level to none urbanization. It can be seen that nearly all the highly-urbanized areas are located in the western part of the Netherlands. In the next step, the analysis is focusing on the transport supply of the different sample cities.

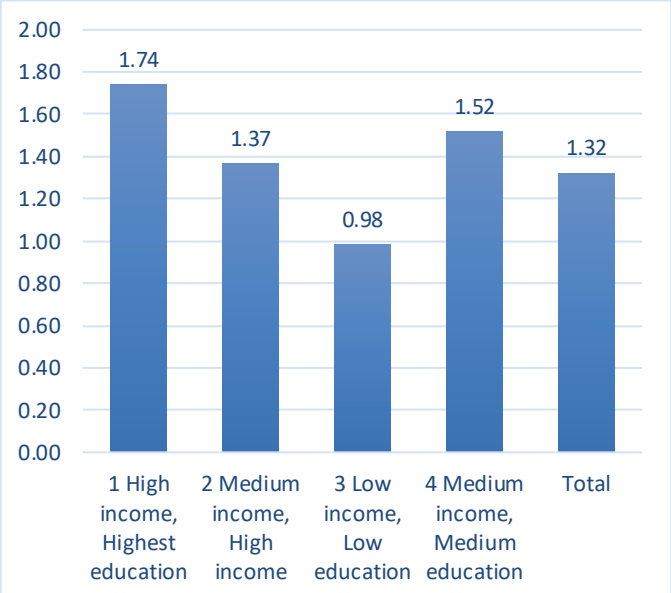


Figure 30 Average number of vehicle per household

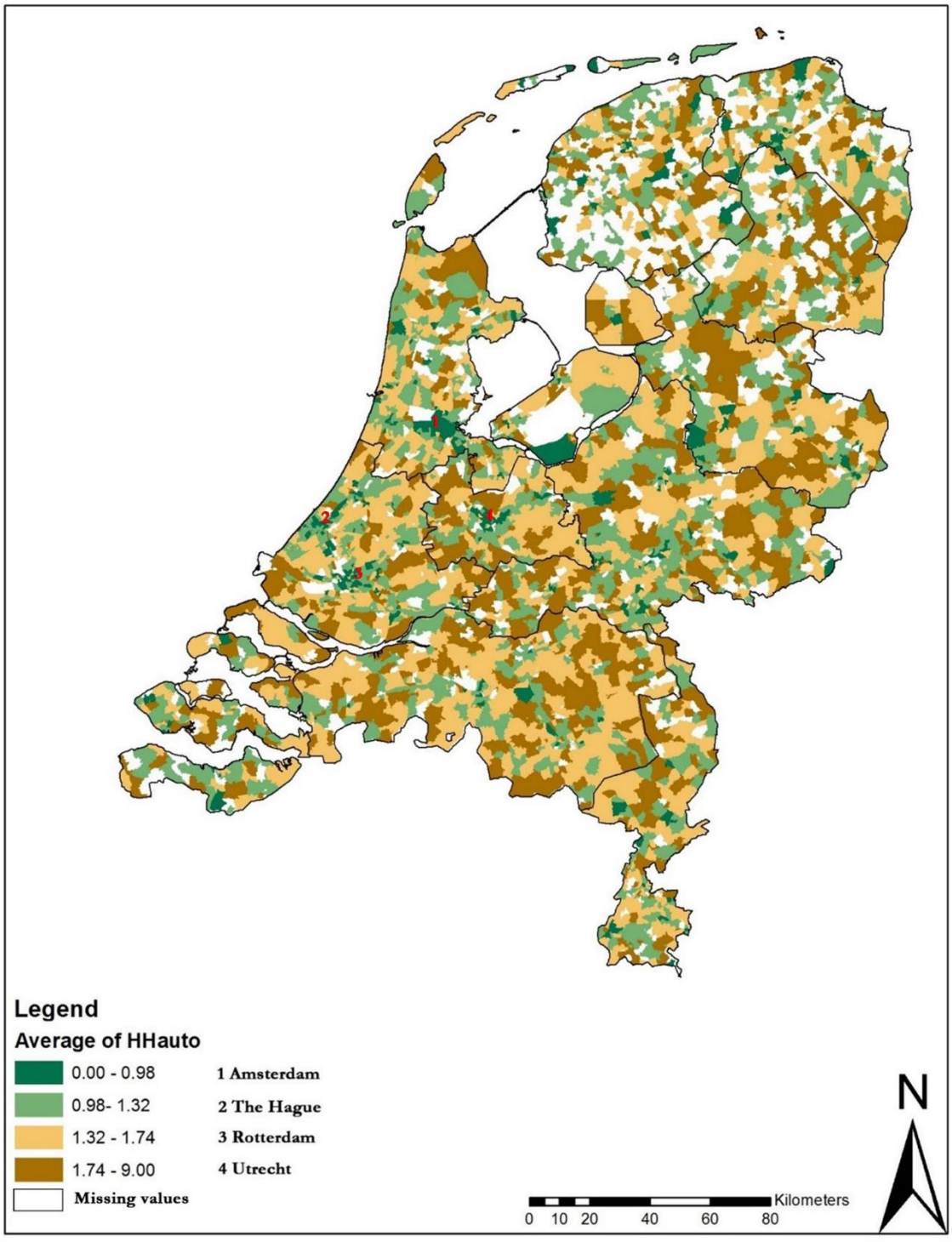


Figure 31 Average number of private car per household

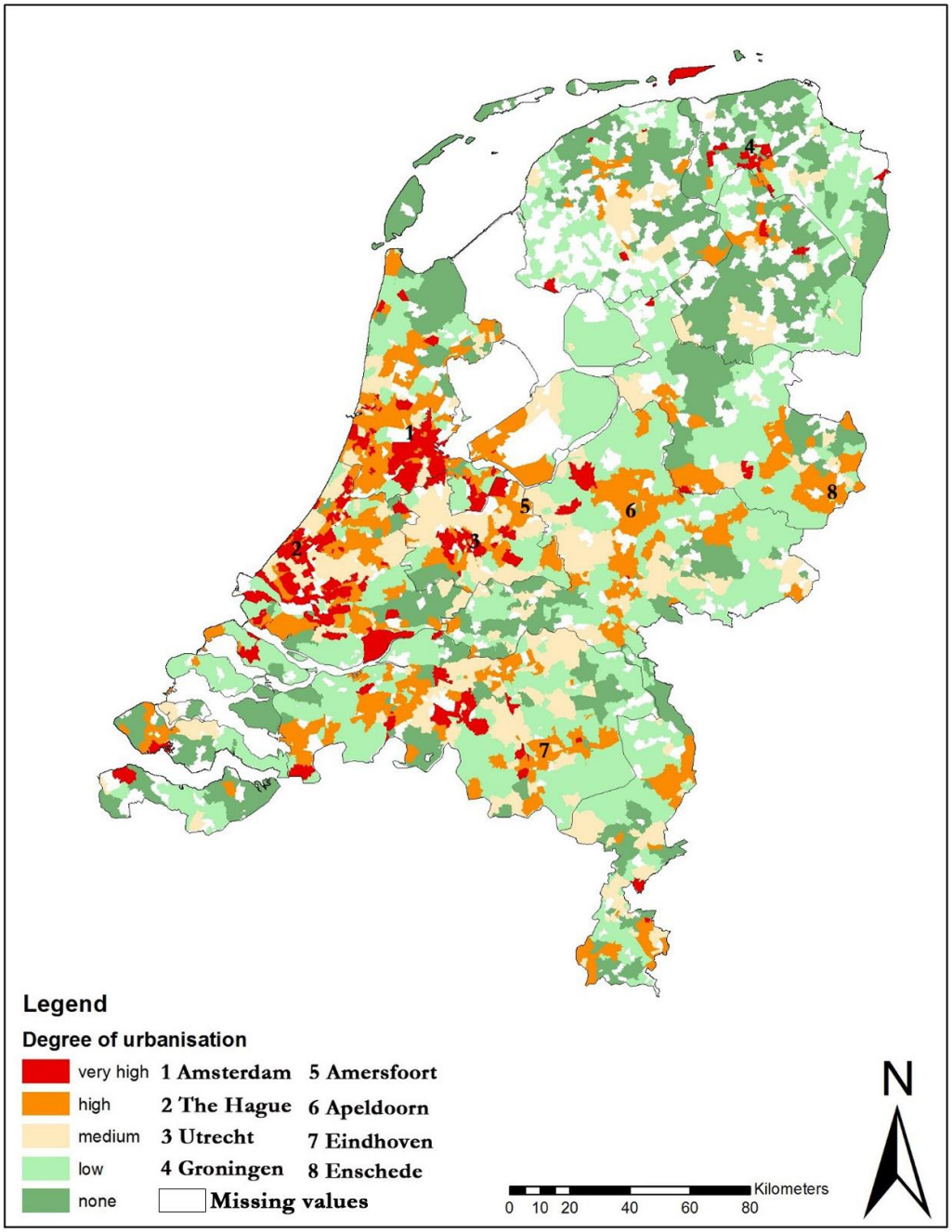


Figure 32 Degree of urbanization in the Netherlands

The analysis of accessibility by car and public transport can be used to reflect the quality of transport system and the level of transit convenience. Based on the degree of urbanization, the chosen sample cities within two different urbanized levels are shown in Table 7. For the city at very high urbanized level, there are four sample cities: Amsterdam, The Hague, Utrecht and Groningen. And another four cities: Amersfoort, Apeldoorn, Eindhoven and Enschede can be treated as the sample cities at high urbanized level.

Table 7 Sample cities of transport supply analysis

Urbanized level: Very high	**PC4_code**
Amsterdam	1012
The Hague	2511
Utrecht	3511
Groningen	9726
Urbanized level: High	**PC4_code**
Amersfoort	3818
Apeldoorn	7311
Eindhoven	5611
Enschede	7511

Firstly, the comparison of transport supply between four highest urbanized cities are shown in Figure 33 and 34. The chosen cities are Amsterdam, The Hague, Utrecht and the Groningen. Figure 33 and 34 visualized the catchments that can be covered through the road network and public transport network within certain time ranges in the morning peak. As can be seen that, people who are travelling by car in Amsterdam and Utrecht can reach most parts of the country within two hours. Departure from The Hague in the morning peak, travellers can reach the western and the central part of the Netherlands. But, for Groningen, total areas that can be reached within different time ranges are quite small, especially compared with the other three cities. Also, the scales that can be covered through public transport system in Groningen is smaller than the other cities. Public transport system in Utrecht performed much better, which built a better connection between the western and eastern part of the country. The catchments that can be covered within certain time in Amsterdam and The Hague are similar. Compared with these three cities, travelling by public transport in Groningen can only reach the northern part of the country.

The transit system of the cities in the Randstad regions performed much better than Groningen. People in the Randstad region can travel further and reach more opportunities compared with the people in Groningen. Thus, there is a lack of transport infrastructures for the people in the northern part of the Netherlands, especially for the travellers who have lower socio-economic conditions.

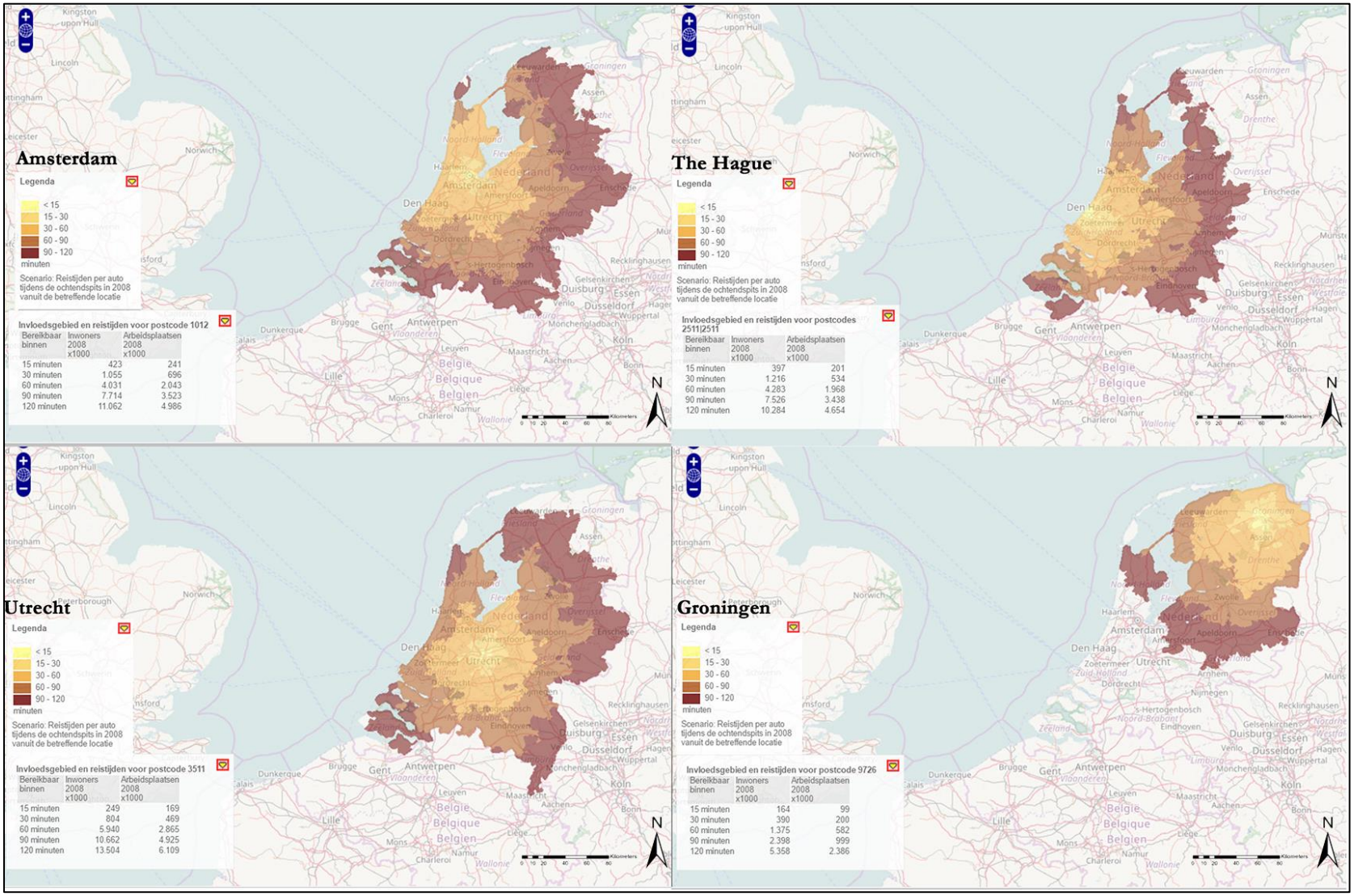


Figure 33 The accessibility areas by car in the morning peak

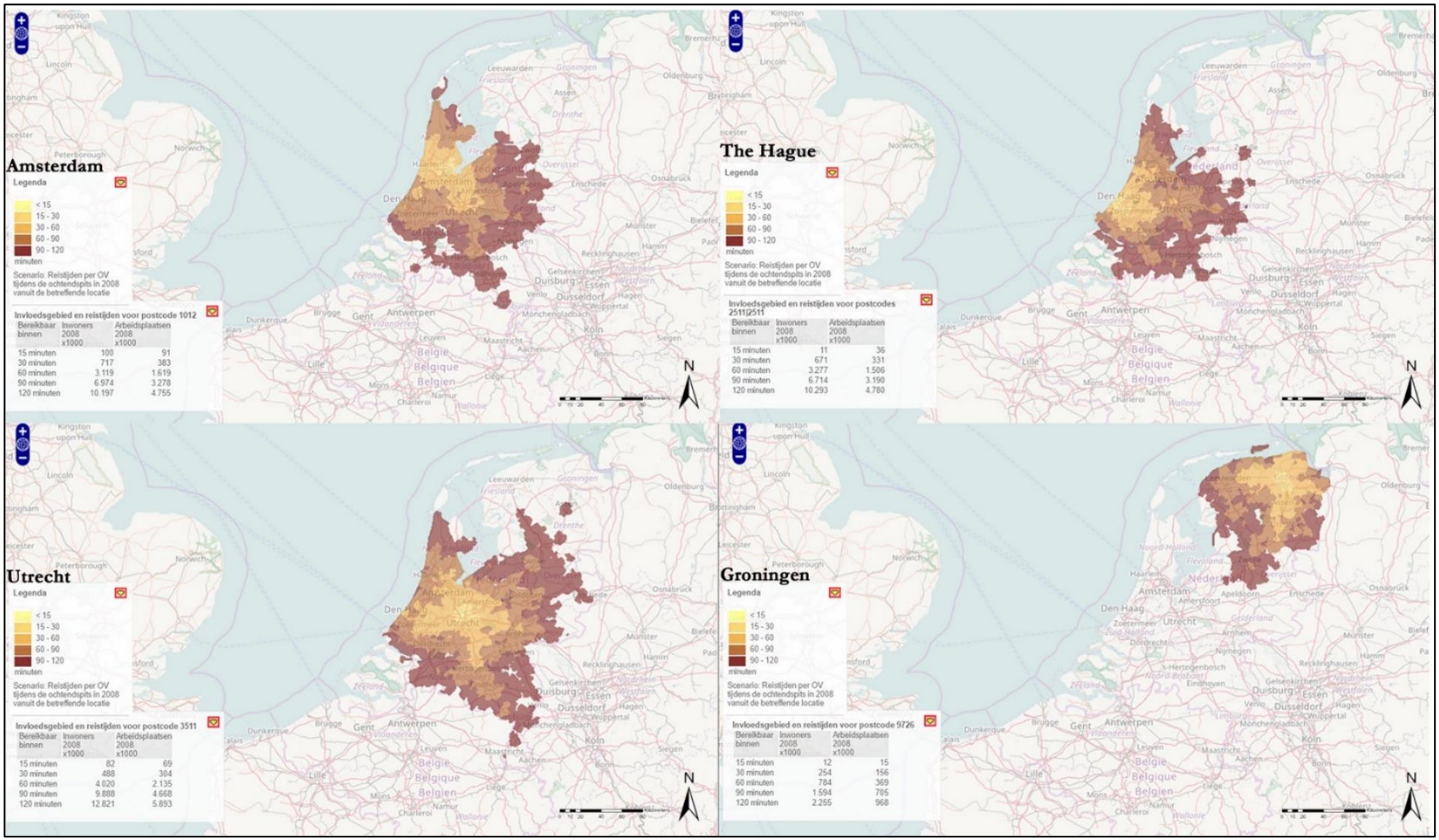


Figure 34 The accessibility areas by public transport in the morning peak

Amersfoort, Apeldoorn, Eindhoven and Enschede are sample cities at high urbanized level. Figure 35 and 36 visualized the catchments that can be covered through the road network and public transport network within certain time ranges in the morning peak. The analysis of accessibility for transport system can reflect the level of transit convenience between these four cities. Departure from the Amersfoort and Apeldoorn, people who travelling by car can reach the majority parts of the country in two hours. And travellers in Eindhoven can access the southern and the central part of the country. Also, for the travellers in Enschede, people who are travelling by car in two hours cannot reach the western part of the Netherlands.

Compared with travelling by car, people who use public transport in these four cities can reach lesser places. Public transport system in Amersfoort performed well, people choose travelling by public transport can access the western and eastern part of the country. The catchments that can be covered by public transport within certain time in Apeldoorn is smaller. People travelling by public transport in Eindhoven can reach the southern part of the country and the Randstad region. But travelling by public transport in Enschede, travellers can only reach the surrounding areas in the morning peak.

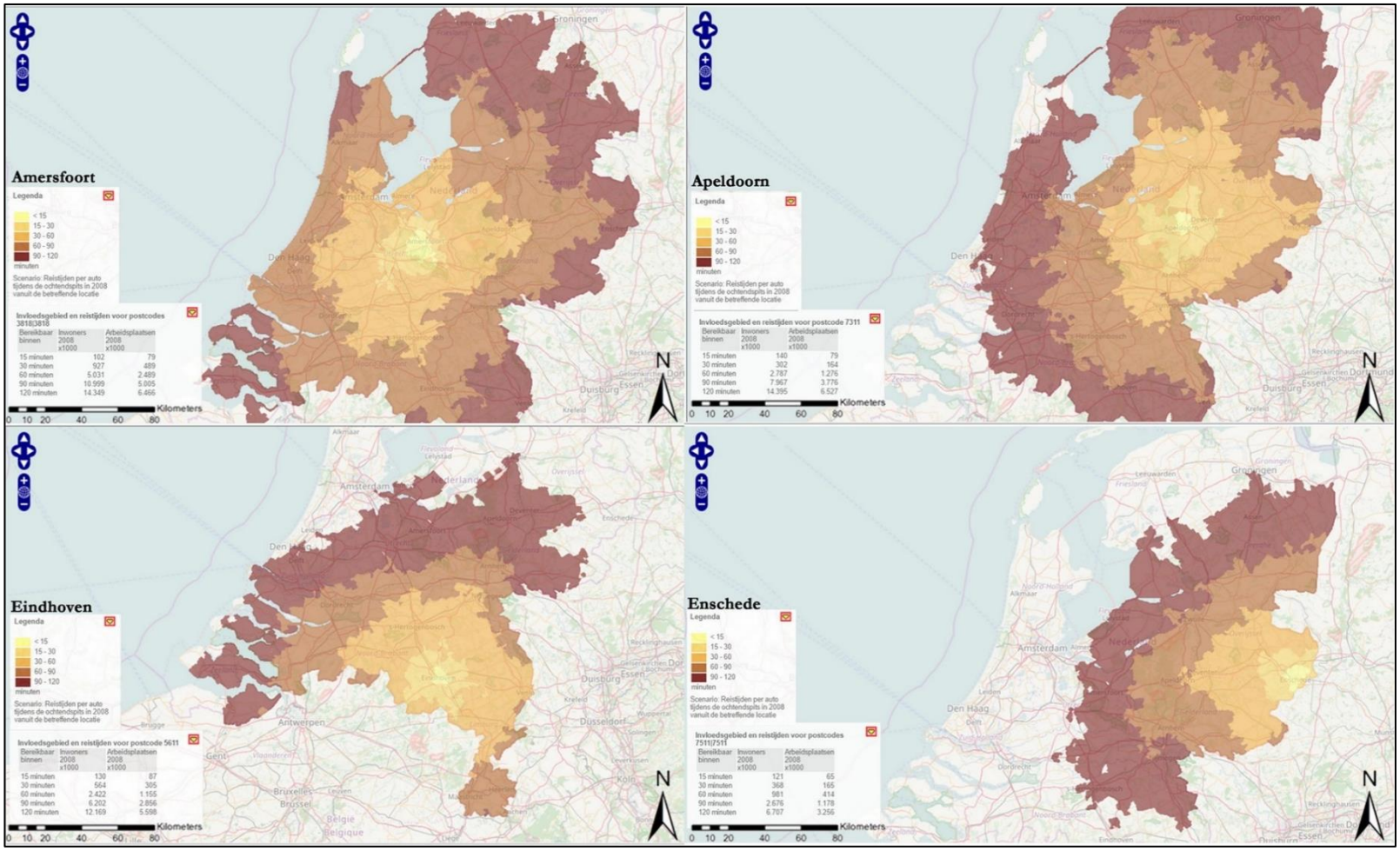


Figure 35 The accessibility areas by car in the morning peak

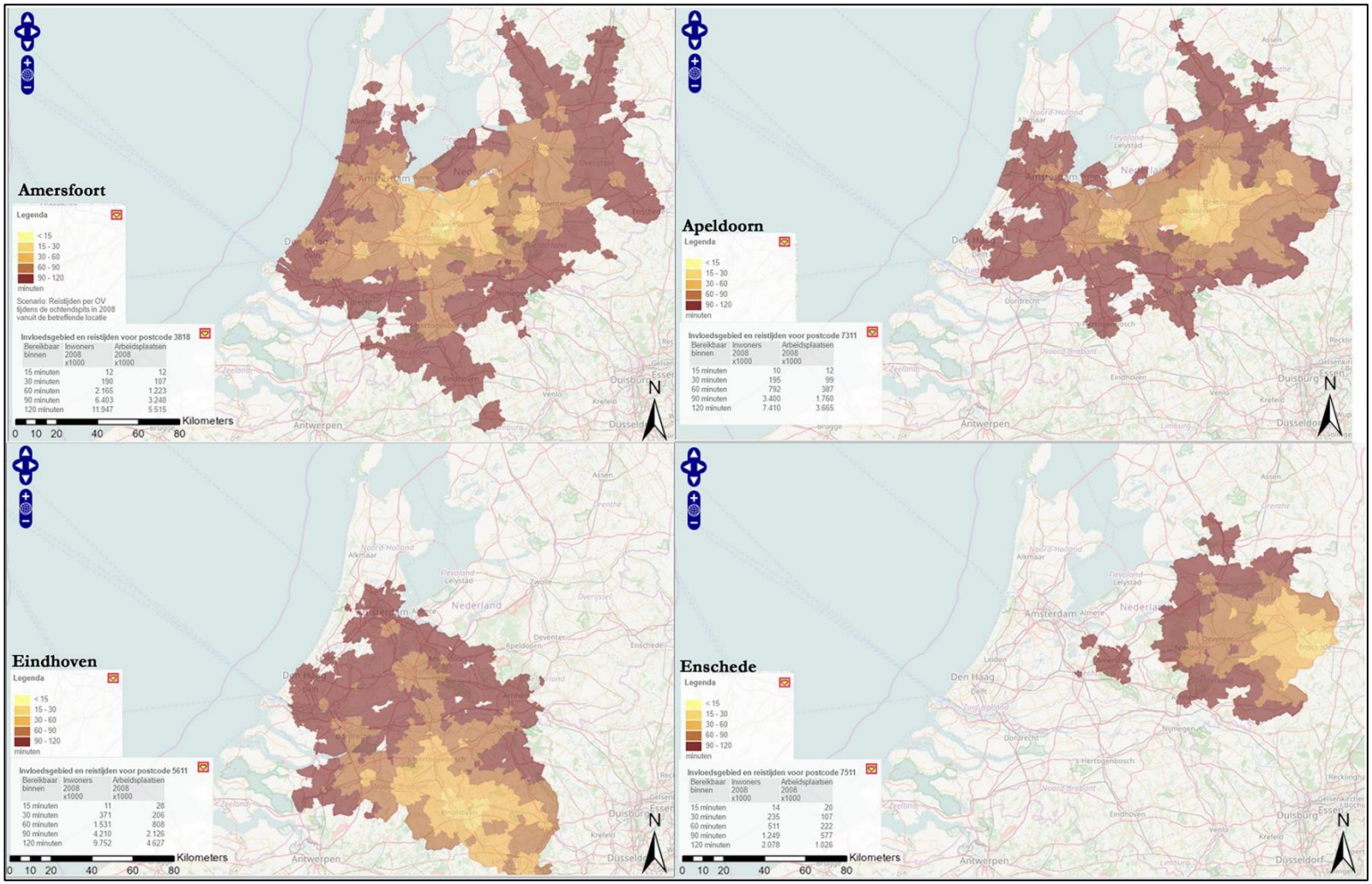


Figure 36 The accessibility areas by public transport in the morning peak

4.8. Conclusion

Based on the analysis above, the car is the priority mode of transport in the Netherlands, and the mainly people who are travelling by public transport are students. All the Dutch travellers tend to choose different modes of transport to fulfill their travel demand. According to the cluster analysis of travel behaviour and socio-economic condition, it can be seen that travellers' socio-economic condition have impact on their travel behaviour. People who have lower socio-economic conditions are prone to choose travelling by public transport and non-motorized modes of transport, and they tend to travel lesser and shorter. Compared with the people who have higher socio-economic condition are predominantly car users and multi-modal users, they are prone to travel longer and further. With the increase in travellers' socio-economic conditions, lesser people tend to traveling by public transport, by bike or walking.

After that, spatial visualization of travel behaviour clusters and socio-economic condition clusters reflected the spatial distribution characteristics of all the travellers in the Netherlands. The largest share of the low socio-economic condition travellers are concentrated in the northern and eastern part of the country. On the other hand, in the city centre of Amsterdam, The Hague, Rotterdam and Utrecht, more than half of the travellers are prone to travelling by public transport. Also, within these city centres, lesser number of people tend to travel by car, and their car ownership is lower. Thus, accessibility maps are used for exploring the differences in term of transport supply between different areas, especially between the cities in the Randstad region and the northern and eastern part of the country.

As a result, there are differences in terms of transport supply between the Randstad region and the northeast of the country. Travellers in the western part of the Netherlands can reach more areas through the road network and public transport network within certain time in the morning peak. Based on the comparisons, transport systems in the Randstad region are more effectively and efficiently than the ones in the northeast of the Netherlands.

It can be concluded that, because of less sufficient transport system, travellers who are in the northeast of the Netherlands have poor accessibility, and these people have lower socio-economic conditions; thus, they tend to choose the cheaper modes of transport. Therefore, it can be assumed that, due to the less sufficient transport system in the northern and eastern part of the country, some travellers who have low socio-economic condition might choose the cars to fulfill their travel demand, as a result, they need to afford more travel costs, and their disposable income may reduce. The subsequent traffic pollution and congestion may increase. On the contrary, because of the high quality of the transport system in the city centre of Amsterdam, The Hague, Rotterdam and Utrecht, more people tend to travelling by public transport and fewer of them use the car, which performed green travel pattern.

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

This chapter will highlight the main findings of this research. At the end of the chapter, relevant limitations will be discussed and recommendations for further research and transport decision making proposed.

The main objective of the research is to evaluate transport-related inequity in the Netherlands by analysing realized travel behaviour. In this research, a two-step cluster analysis was applied to identify different travel groups and to explore the effects of socio-economic conditions and transport supply on the probability of belonging to each of the five identified clusters.

With regards to the specific objectives, the following corresponding conclusions can be drawn

1. **Analysis of travel behaviour in the Netherlands**

Travel behaviour analysis was carried out, which provided the background for the following analysis steps in this research. For all the sample adult travellers, the car is a priority mode of transport in the Netherlands, and the bicycle is also a widely-used mode of transport. But only few travellers choose travelling by public transport, most of the public transport users are students, who have the longest trip duration. Then, modal choice and corresponding trip duration are treated as two variables to do travel behaviour cluster analysis. Among five identified travel behaviour groups, two of them are single modal groups who only use car and bicycle, and the other three are multimodal groups, which are mixed modal users (car, bike, walking), mainly public transport users and walking people. The only car users have longer mean trip duration than the cyclists. For the people who are mixed modal users have relative longer driving and cycling trip duration, and they made more trips in their daily travel process. Public transport users have the longest trip duration, but only a small number of travellers tend to use public transport.

2. **Analysis travellers' socio-economic condition in the Netherlands**

Based on the identified travel groups, Two-step cluster analysis is also used for grouping the people who have similar socio-economic conditions into the same cluster. Income level and educational level are identified as two indicators to analyse travellers' socio-economic conditions. It was identified that socio-economic condition had statistically significant relations with groups' travel behaviour. People who have low-income and low educational level are predominantly non-motorized transport and public transport users; they tend to travel shorter and less often. With the increase in socio-economic condition, most of the travellers tend to choose car and multiple modes of transport, and they are prone to travel longer and further.

3. Analysis transport supply in the Netherlands

In this step, the spatial visualization of five travel behaviour groups and four socio-economic condition groups reflects the spatial distribution characteristics of these clusters. The largest share of the low-income and low educated travellers are concentrated in the northeast part of the Netherlands. On the other hand, predominant public transport users are clustered around the city centres in the Randstad region, for instance, the city centres of Amsterdam, The Hague, Rotterdam and Utrecht. Also, in these city centres, fewer people choose travelling by car. Based on the results presented in this research, with the help of online accessibility maps, we next discuss the effects of transport supply on groups' travel behaviour. Firstly, the visualization of car ownership shows that in the city centres within the Randstad region, individuals' car ownerships is lower than the ones in the other areas. On the other hand, accessibility maps identified the differences in terms of transport supply between the Randstad region and the northeast regions. The road network and public transport network in the morning peak in the Randstad region have better performance than the ones in the northern and eastern part of the Netherlands. Departing from the central stations in Groningen and Enschede in the morning peak, travellers can reach fewer catchments. Thus, transport infrastructure in the eastern and northern part of the Netherlands have relatively poorer conditions, and less sufficient transport infrastructure might force travellers to use car.

Therefore, in the context of transportation, travellers in the northeast Netherlands can be identified as disadvantaged travellers who have a relatively low socio-economic condition and experience a less sufficient transport system. Uneven distribution of transport infrastructure in the Randstad region and the northern and eastern part of the Netherlands may result in disadvantaged travellers having fewer opportunities and mobility, and these people may have constraints in accessibility and mobility. In order to achieve equal opportunities, disadvantaged people tend to share the higher cost and lower benefits. Thus, transport-related inequity issues have adversely impact on sustainable transport development in the Netherlands.

5.2. Limitations and Recommendations

There are some limitations to be drawn from the current study. In this research, the latest dataset OViN 2015 was used to do the analysis; In the future, datasets of the other years can also be used to do the same analysis. We can compare the trends in these years and check whether there are big differences in terms of travel behaviour between these years. On the other hand, the OViN data is the travel diary data only for one day, which cannot reflect the relatively regular travel behaviour. Based on the literature, some of the studies rely on one-week travel diary data or multiple-week travel diary data, which is a longer period survey. Some studies also require travellers to report their frequency of use various modes of transport. Thus, a relatively longer time period travel survey is more appropriate to do the analysis.

Secondly, this research has been done at country scale, which includes all the urban and rural areas in the Netherlands. But people who live in urban and rural areas have differences in terms of travel behaviour and they experience different transport supply, especially public transport. Also, in this study, we did not explicitly measure accessibility in specific areas. In further work, this analysis can be applied at different scales, such as state scale, city scale and urban scale rather than country scale. The more spatial dataset

could be collected and the definition of accessibility can be identified, thus, transport-related inequity issues can be analysed more precisely in a relatively smaller scale rather than the country scale.

Then, in terms of transport supply, accessibility is the only indicator that was taken into account to measure transport-related inequity at spatial level in this study. Actually, individuals' travel behaviours are affected by many variables, such as urban form. Numerous studies already identified that travel behaviour in monocentric and polycentric areas have big differences. In future work, more relative variables should be taken into account to measure inequity issues in a comprehensive way.

At last, in future research, we can identify the specific disadvantaged areas, in which people have low socio-economic conditions and are suffering from a poor level of transport system. Then, we can propose some recommendations to planners and policy makers. Transport investments should give priority to disadvantaged areas, which can improve people's accessibility to more opportunities and make contributions to social and spatial equity. Moreover, regional homogeneity in the design of public transport network may yield more equitable spatial access to public transport modes.

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