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An Indicator Assessment of Sustainable Transportation in Korean Cities

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지 리 학 과

Nikola Medimorec

Abstract

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Nikola Medimorec
Geography
Seoul National University

In 2014 Korea passed the mark of 20-million registered vehicles. Private motorization caused many problems in cities and only a sustainable development can solve the issues. This study assessed comprehensively how well sustainable transportation is developed in the 7 largest Korean cities through designing a new indicator assessment, which used the most common sustainable-transportation-related indicators.

In recent years Korea has made several efforts to improve urban transportation. Representative of these remarkable measures were Seoul's public transportation reform in 2004 and the green growth paradigm in 2008 on the national level. Since then an index had been in official use, but it has a lack of comprehensiveness and limited usefulness for policy-making.

An analysis of 52 indicator compilations related to sustainable transportation identified traffic accidents, model split, air pollution and motorization as the most often-used measuring tools. 22 indicators, divided in the categories urban structure and transportation as well as the environmental, social and economic dimension, were brought together in the 'Korean Sustainable Urban Transportation Index'

(KSUTI). A survey of experts and citizens identified population density, accessibility of public transportation, CO_2 emissions and modal split as the most important indicators for the assessment of sustainable transportation in Korea.

Seoul received the best overall score. On the second rank was Busan and third was Daejeon. Gwangju was ranked the lowest. Regarding the categories, Seoul led the urban structure and the environmental dimension. The economic dimension was dominated by Ulsan and Incheon had the best result for transportation, while Busan had the best score for the social dimension.

A cluster analysis identified 5 groups of indicators, which divided the indicators into pro-sustainable and car-related aspects. Among the cities were three distinctive groups: Seoul was a public transport-dominated city. The 4 cities Daegu, Daejeon, Gwangju and Ulsan represent low-dense cities with a high dependence on private motorization. In between are Busan and Incheon as a group of good public transport but also many aspects of private motorization.

The KSUTI included more information and so it shows the advantages of a comprehensiveness assessment of transportation.

Keywords: sustainable transportation, Korean cities, indicator assessment, public transportation, motorization

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1 Introduction to the Research

In October 2014 the number of registered vehicles passed the 20 million mark in the Republic of Korea (hereafter Korea) (Yonhap News, 2014). Private motorization, which begun to grow around 1980 in Korea and accelerated quickly, causes various issues like congestion, high energy consumption, noise, accidents and even health problems. The second-largest producer of greenhouse gases is transportation and in that sector road transport accounts for 80 percent of CO_2 emissions (Hwang and Park, 2010). The Korean government has recognized the issue and a paradigm shift towards sustainable transportation was initiated and an assessment has been carried out annually since 2009.

The problem hereby is that the official assessment covers only a small number of aspects and therefore, it has a limited use for policy-making. The index fails to measure important facets like motorization or any aspects of the built environment, which have a major influence on transportation. I believe that the way in which sustainable transportation is addressed in the index does not reflect the wide-ranging character of that concept.

The main objective of this dissertation is to develop an alternative indicator assessment regarding sustainable transportation for Korea, which contains two more themes and twice the number of indices. It will be called the 'Korean Sustainable Urban Transportation Index' (KSUTI). This will be the first research about sustainable transportation to apply a large set of indicators to Korean cities.

I will attempt a less subjective procedure of indicator selection, which will discover the most often-used indicators in sustainable transportation-related assessments. The KSUTI is also going to show how the indicators and the cities can be grouped, which should simplify the policy-making task. Some example of measures and approaches show how a holistic approach can achieve a better system.

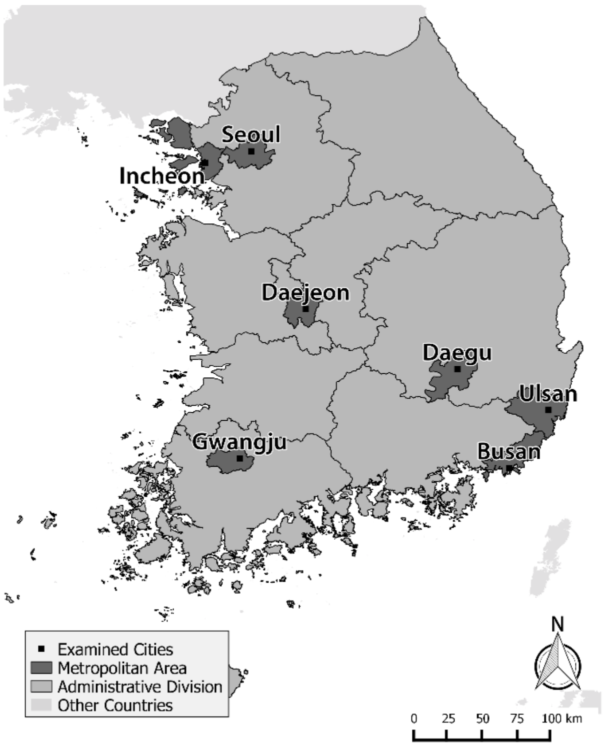
The research utilizes 3 methods: (1) survey-based selection strategy, (2) analytical hierarchy process (AHP) and (3) cluster analysis. First, the primary selection of indicators is based on a summary of indicator sets or indices in the field of sustainable transportation. The most often-used indicators are going to be identified and considered for the KSUTI. The final selection is determined by data availability and the indicators are going to be divided into 5 categories: urban structure, transportation, economic, environmental and social dimension.

Second, the indicators are weighted through an online-survey, which is based on AHP. Transport researchers, academics, government officials and citizens are will be included. The purpose is to calculate the weights of each indicator, which will be used to calculate the final score. The weights are multiplied with the standardized values (z-score and t-score of the values) to get a point score for the KSUTI.

Third, a cluster analysis will be employed. It assists in identifying indicators and cities with similar characteristics. While the first two parts are essential for compiling the KSUTI, the third part uses the final selection of indicators and their data to do an in-depth analysis and to discover policy measures for the groups.

The KSUTI will evaluate the 7 largest Korean cities: Busan, Daegu, Daejeon, Gwangju, Incheon, Seoul and Ulsan. They account together for 23.2 million inhabitants, which is half of the nation's urban population (KOSIS, 2014a). They are very important regional nodes and urban centers. The special status of a metropolitan city (or in the case of Seoul as the capital city) enables access to more data than for other municipalities.

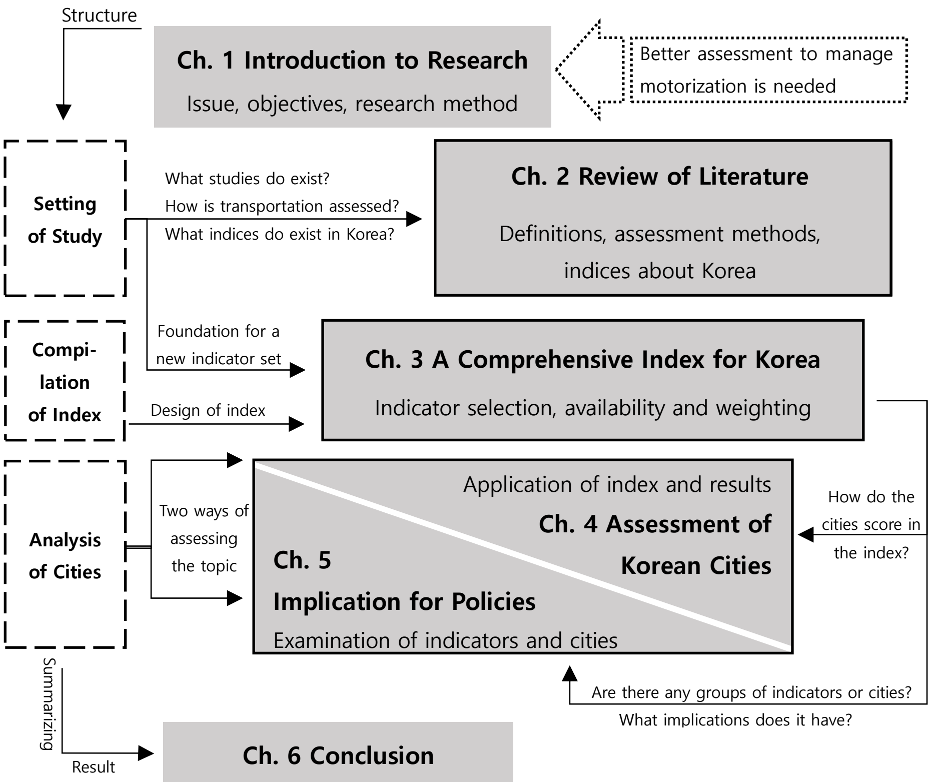
Figure 1: Map of Cities



Source: Made by Author,
Based on GADM, 2014; KTDB, 2014a.

The research is structured in 4 parts besides this introduction and the conclusion: The next chapter examines the literature about sustainable transportation-related indicator compilations. The third chapter begins with the development of sustainable transportation in Korea and then designs the new index. The fourth chapter applies the KSUTI to the cities, whose overall and category results will be shown. Then chapter 5 gives policy recommendation for groups of cities in order to show how sustainable transportation has to be promoted.

Figure 2: Structure of Thesis



Source: Made by Author.

2 Review of Transport Assessments

In the first part the definition of sustainable transportation, which fits the best for the purpose of this research, will be identified. The second part will review how the issues are assessed and show examples before the last part will examine what literature of transportation in Korea exist.

2.1 The Meaning of Sustainability for Transportation

The commonly-accepted definition of sustainable development was given in the Brundtland Report by the World Commission on Environment and Development (WCED):

> Sustainable development is "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*" (WCED, 1987, Ch. 2, 1)

Moreover, sustainable development consists of a balanced development of the environmental, economic and social dimension (Steg and Grifford, 2005). Transportation plays an important role for the economy and it has large impacts on the environment and the society (Greene and Wegener, 1997; Litman, 2008). The concept of sustainable transport can ensure good livability and equality in cities (Barter et al., 2003). But how is sustainability in transportation defined? Which definition fits the best for the purpose of assessing urban areas?

An attempt to define sustainable transportation was done by Black (1996), an academic in the field of transportation. He transfers the general definition by the WCED to transportation:

> Sustainable transportation is described as "*satisfying current transport and mobility needs without compromising the ability of future generations to meet these needs.*" (Black, 1996, 151)

This definition is very broad and it leaves room for interpretation. As Ch. 2.3 will show, Korea uses a similar definition of sustainable transportation. While the WECD intended to show the direction of sustainability, the definition of sustainable transportation has to be more specific about the aspects, which should be measured in an evaluation of transport systems. An alternative definition is given by the 'Organisation for Economic Co-operation and Development' (OECD). They began in 1994 with the 'Environmentally Sustainable Transport' (EST) project (OECD, 1999):

> EST is "*transportation that does not endanger public health or ecosystems and meets mobility needs consistent with (a) use of renewable resources at below their rates of regeneration and (b) use of non-renewable resources at below the rates of development of renewable substitutes.*" (OECD, 1997, 12)

The literature on EST (OECD, 1996; OECD, 1999; OECD, 2002; Wiederkehr et al., 2004) gives many advices on composing indices in the next subchapter. However, that definition mainly focuses on the impact to the environment. Neither the social dimension nor the economic aspects are considered. An indicator-set based on that definition would not show the comprehensive picture, which this dissertation attempts to do.

The European Union (EU) uses the following definition:

> Sustainable transportation is a system that *"allows the basic access and*

development needs of individuals, companies and societies to be met safely and in a manner consistent with human and ecosystem health, and promotes equity within and between successive generations;
is affordable, operates fairly and efficiently, offers choice of transport mode, and supports a competitive economy, as well as balanced regional development;
limits emissions and waste within the planet's ability to absorb them, uses renewable resources at or below their rates of generation, and, uses non-renewable resources at or below the rates of development of renewable substitutes while minimising the impact on the use of land and the generation of noise." (CST, 2005, 5f.)

Originally, this definition was made by the Canadian Centre for Sustainable Transportation (CST) in 1997 and the EU uses slightly different expressions. Both versions are widely used in the field of transportation (CST, 2005). The advantage of the definition is that it gives a comprehensive account of various issues and characteristics of transportation. Moreover, it supports performance measurement and goal-setting. Most importantly, literature regards this definition as useful for indicator systems and policy assessment (Lee et al., 2003a; Goldman and Gorham, 2006). This definition works well for assessments and the final set of indicators in Chapter 3 should represent that definition.

2.2 Ways to Assess Sustainable Transport

After having defined sustainable transportation, this subchapter will show the development of indicator initiatives and the principles of such assessments.

Indicators have been in use since the mid of the 20th century. At first assessments began with economic indicators, but they then developed to integrate social and quality of life indicators. The usage of health indicators as well as environmental and resource-related indicators began later and since the 1990s sustainable development dominates as the topic of indicator-based assessment. (Hall, 2006)

In transportation indicators were at first used for performance-based benchmarking of public transportation companies. Such benchmarking processes are still in use in the evaluation of local public transportation services (Karlaftis, 2004; Georgiadis, 2010) or global benchmarking of subway systems (Tsai and Mulley, 2013). Even though such studies do not have a direct connection to sustainable development, they lead to an improvement of performance and greater efficiency, which has benefits for the sustainability of transport systems. A global public transportation benchmarking was done by UITP, an international organization with public transportation organizations and related stakeholders as members. Being able to rely on their own database about their members, UITP compared the public transportation systems of 52 cities with 120 indicators (Vivier, 2006). The management consulting agency Arthur D. Little with their work about future mobility in 84 cities showed that sustainable transportation can be incorporated into benchmarking studies (Lerner, 2011; Audenhove et al., 2014). Efforts were made to evolve benchmarking as a tool for policy makers (Henning et al., 2011a) and to even evaluate sustainable transportation (Henning et al., 2011b). Nevertheless, benchmarking studies always kept the character that the performance and efficiency, which are economic aspects, are the top priorities and other dimensions of sustainable development fall behind.

I regard Newman and Kenworthy's research on automobile dependence in cities around the world with their work 'Cities and Automobile Dependence: An International Sourcebook' in 1989 as the pioneering research of sustainable transport assessment, because they described fundamental challenges of sustainable transportation with a large indicator assessment before the concept of sustainable development gained popularity. Their main argument is that there is a strong correlation between private motorization and urban sprawl, thus spatial planning is important to restrict motorization (Newman and Kenworthy, 1989; Kenworthy and Laube, 1996). Their findings have been later summarized in other publications (Kenworthy and Laube, 1999; Barter et al., 2003) and their database was used for a comparative analysis of Asian cities (Barter, 1999). In difference to sustainable development indices their indicators are divided between transport and land use. Kenworthy contributed to other indicator-based researches where factors of private motorization (Cameron et al., 2003) or urban mobility cultures (Klinger et al., 2013) were examined. Other researches built up on their indicator set and alternate them slightly (e.g. Coevering and Schwanen, 2006; Haghshenas and Vaziri, 2012; Haghshenas et al., 2013). Cervero wrote to similar effects: Travel demand is affected by features of the built environment, namely density, diversity and design, summarized as the 3Ds (Cervero and Kockelmann, 1997). Later, 4 more Ds were added: destination accessibility, distance to public transportation, demand management and demographics (Ewing and Cervero, 2010). These researches, which focused mainly on the urban structure, can be regarded as important parts towards the evolution of sustainable transportation assessment.

In 1992 the ‘United Nations (UN) Conference on Environment and Development’ in Rio de Janeiro was the most important stepping stone for indicators about sustainable development. The UN called all countries to develop sustainable development indicators in chapter 40 of Agenda 21. Indicators for the UN were developed by the ‘Commission on Sustainable Development’ (CSD), which published a first set of 134 indicators in 1995 and later in 2005 they reduced the amount to 50 core indicators and 96 additional indicators. (Dobranskyte-Niskota et al., 2007; Haghshenas and Vaziri, 2012; UN, 2007)

Nowadays, sustainable transportation assessments are widely used and this research identified 52 indicator initiatives (summarized in Appendix 1). The EU developed projects like the ‘SUstainable Mobility, policy Measures and Assessment’ (SUMMA) (Ahvenharju et al., 2004) or the ‘Transport and Environment Reporting Mechanism’ (TERM), which is used for transport policies (EEA, 2013). The CST designed the so-called ‘Sustainable Transportation Performance Indicators’, which have a longitudinal character and they measure wherever transportation becomes less or more sustainable over time (Gilbert et al., 2003). For the United Kingdom, a set of indicators was proposed to measure the sustainability of transportation

(Marsden et al., 2007). The Mineta Transportation Institute published a set of indicators for California (Lee et al., 2003a). Other indicators were developed to evaluate cities like Mumbai (Nathan and Reddy, 2011), Lyon (Nicolas et al., 2003) and Melbourne (Reisi et al., 2014). A very valuable example is the 'Index of Sustainable Urban Mobility', (I_Sum). It was developed for cities in Brazil and it was applied to Curitiba (Miranda and Silva, 2012), Sao Carlos (Silva and Costa, 2010), Itajuba (Lima et al., n.d.) and even to a national comparison of Portugal and Brazil (Costa et al., 2005). The examples show that indicator compilations have no geographical boundary and they are used on all scales. An essential question is how these indicator assessments are developed.

Table 1: Progress of Sustainability Indicators

Steps	Measure
Step 1	Goal-setting
Step 2	Determining scope of research
Step 3	Selection of indicator framework
Step 4	Definition of indicator selection criteria
Step 5	Search for potential indicators
Step 6	Evaluation and determining final indicator set
Step 7	Data collection and analysis
Step 8	Preparation and presentation of result
Step 9	Examine performance of indicators

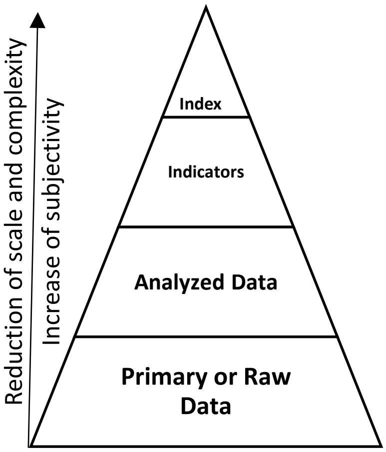
Source: Made by Author, Based on Maclaren, 1996.

A very useful overview about the process of sustaina-bility indicators is shown in table 1. It was developed by Maclaren (1996) for urban sustainability indica-tors. The first 4 steps are outlining the assessment. The fifth to sixth step are preparations before the indicator set is applied to the research area in the seventh step. The presentation of results is seen as very important and after the last step the process begins again from the beginning. In all of these steps the involvement of individuals and stakeholders is emphasized because a discussion about anticipated sustainability goals and possible indicators can lead to better results. She defines indicators as a simplifier of a topic. Indicators just indicate a condition or issue and thus a set of indicators is the best way to show all aspects. (Maclaren, 1996)

Important literature on indicators has Gudmundsson and Höjer (1996), Gudmundsson (2003) and Joumard and Gudmundsson (2010). Achieving sustainable transportation is a difficult task but it will have great impacts (Gudmundsson and Höjer, 1996). Gudmundsson believes that indicators have the ability to induce sustainable transportation. However, it is challenging to build a comprehensive picture through indicators. They result from operationalization. Indicators should help to show causal relationships. At the same time they should also refer to policy targets and identify the influence on decision making. A single indicator adds a particular piece to the big picture. A well-working framework is a requirement, because it connects the information and it ensures that the indicator set is comprehensive as well as that it reflects the purpose and importance of indicators. (Gudmundsson, 2003)

OECD's general sustainability assessment involves 14 environmental issues and it lists a core set of indicators for each issue. They emphasize that there is neither a unique set of indicators nor a unique framework. The OECD selects indicators according to their relevance for policies, analytical soundness and measurability. Their work clarifies the expressions indicator, parameter and index: A parameter is a measured or observed value. An indicator is a parameter that gives information about a state of an area or phenomenon but it has more significance than just a number. An index is a set of weighted indicators. (OECD, 1993)

Figure 3: Hierarchy of Elements

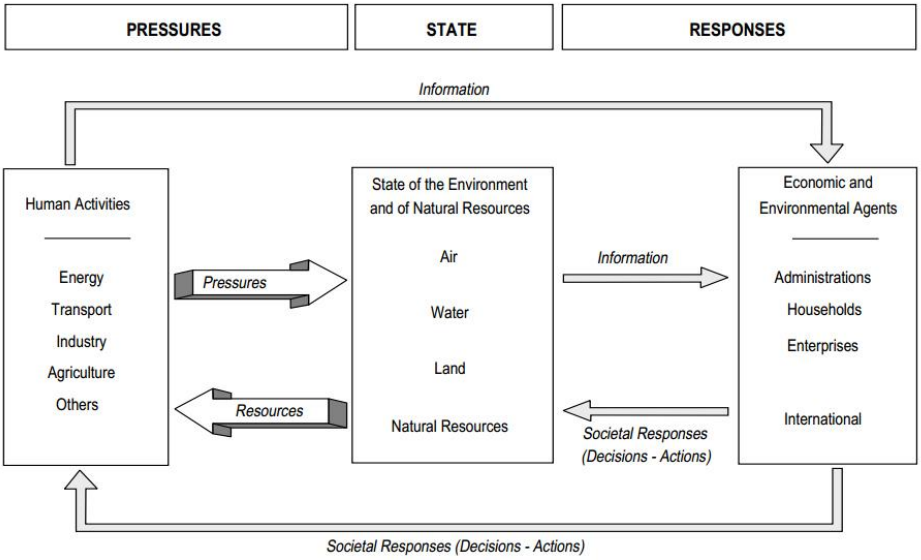


Source: Based on Spreng and Wils, 1996 in: Hall, 2006, 407.

The difference between the elements of an index shows figure (fig.) 3. Hall (2006) sees indices at the top of a hierarchy and raw data on the bottom. In between, there are the analyzed data and the indicators. The fig. also displays the issue of subjectivity: A higher rank means that the data becomes less complex but the subjectivity of information increases (Hall, 2006).

As it was mentioned earlier, frameworks are a very important part of indicator assessments. There are several different kinds of framework. OECD's Pressure-State-Response (PSR) framework is a famous example.

Figure 4: The Pressure-State-Response Framework



Source: OECD, 1993, 10.

The PSR-framework in fig. 4 reflects a basic concept of causality, where humans put pressure on the environment through certain activities, make use of the resources (air, water etc.) and respond to these changes. All these steps can be seen as part of a loop, repeating and adapting to each other. Indicators can belong to any of these 3 types and express pressure, state or response. (OECD, 1993)

Transport is a theme of the pressure area in the model and in a further model indicators for transportation are divided into: (1) trends and patterns with environmental importance of transport; (2) impacts on the environment of transport and (3) influences from economy and policy between transport and environment (OECD, 1999). Similar causal-relationship frameworks are the 'driving forces, pressures, state, impact and responses'-framework, which was used for EU's TERM project (Dobranskyte-Niskota et al., 2007) or the driving force, state and response framework by the CSD (UN, 2007). The PSR-framework is criticized for its simplicity, because in reality the processes are very dynamic and part of a large system with many interconnections (Bossel, 1999). For example, Richardson (2004) shows the sustainability of transport systems is influenced by a complex network of factors. So the CSD changed to an index, where indicators are divided in certain themes, which function as categories, and the advantages are that the themes have a connection to policy fields and adapt well to new priorities (UN, 2007). This dissertation will apply a theme-based framework as well, which will determine the basic outline of the index without explaining a causal relationship between the groups. In this way all indicators are basically equal until the weighting process.

Litman (2008; 2013) adds many points to the discussion of sustainable transportation indicators. For him indicators are a tool to show problems and they reflect issues like the decision-making process, responses from users and economic, physical or social impacts. Reliable and accurate information are basic requirements for policy making. The selection of indicators has to be made carefully, because the same situation may be evaluated differently by another set of indicators. A system, which was evaluated as good by a set of indicators, may score low with another set. Sustainability is about a paradigm shift from growth (quantity) towards development (quality). For transportation it means that there is a shift from mobility to accessibility. Transport planning is no longer about increasing the movement but about increasing the ability for people to get goods or services. He discusses principles and functions of indicators and his study developed to research about livability in sustainable transportation assessments. (Litman, 2008; Litman, 2013)

Regarding the livability aspect, still assessments about transportation and the quality of life are rare, but in the future more indices will combine these two areas. For example, a research identified important quality-of-life indicators and their relationship with sustainable transportation. In order to function well, citizens have to be able to be able to express their preferences for future development, because it depends on their views what a high life quality means. (Steg and Grifford, 2005)

Such assessments have to include subjective indicators, as it was done by Klinger et al. (2013), who measured the urban mobility culture in Germany with a set of 23 indicators. A factor analysis and cluster analysis is carried out and the cities are grouped into, for example, cycling cities, public transit metropolises or auto-oriented cities (Klinger et al., 2013). Their research gave important impulses for this work and a cluster analysis will be also attempted in Ch. 5 of this research.

Attention must be paid to several points: The list of potential indicators is almost endless and it is difficult to select indicators in an objective way. The selection process has to be transparent and reproducible. Indicators have to be clearly-defined, applicable to various scales and comprehensive. Also, they should be understandable and practical, incorporate different stakeholder views and allow comparability with alternative developments. Too often the availability of data determines the selection process. (Bossel, 1999)

A solution for the data-problem is shown in the I_SUM. Indicators are arranged into themes and just one indicator per theme has to be used. The weighting of indicators is flexible and gets adjusted to missing parameters. The I_Sum has the purpose of assisting in mobility management and policy-setting. It was developed through a process of extensive literature research, workshops with experts and selection of indicators, which cover various aspects of mobility, are easily collectable and analyze easily transport systems. As a result, the I_SUM has 87 indicators and obviously such a long list allows more flexibility. (Silva and Costa, 2010)

So how can the subjectivity be limited to a minimum and criteria like the reproducibility of the selection process be guaranteed? The study by Tanguaya et al. (2010), which summarizes 17 assessments about sustainable development on the local scale, uses a “survey-based selection strategy” (Tanguaya et al., 2010, 415). The strategy counts how many times each indicators appears and selects the most often-used. In addition, their research compares how well each category is covered by different thresholds. A weakness of their study is that due to a high threshold, not every category had an indicator and some indicators were added individually. (Tanguaya et al., 2010)

To summarize, transportation indicators evolved from benchmarks of a transit cooperation over measurements of automobile dependence to the assessment of sustainable transportation. Based on the strong presence of sustainability in the field of transportation, Zegras (2005) sees the shift to sustainable transportation indicator as a natural development of performance measurements to a higher, more distinct level of assessment. There is no standard way of developing indicators in the field of sustainability or a universal set of indicators (OECD, 1999; Steg and Grifford, 2005; Tanguaya et al., 2010; TRB, 2008). The indicators are always going to depend on the purpose and the scale (OECD, 1999; Zegras, 2005). Every country or even every city has different transportation issues (Silva and Costa, 2010). The literature review has the following lessons for the KSUTI: Indicators are a very powerful tool. The name implies that they just indicate certain conditions. Therefore, a compilation of many indicators seems to provide a better picture. The research will be done without a complex framework about a causal relationship and instead the indicators will be organized in simple themes or categories. An effective approach is to minimize the subjectivity in the selection process is a literature survey.

2.3 Transport Assessments in Korea

The last subchapter of the literature review will focus on transportation assessments in Korea.

Besides an index about sustainable transportation, there are two major transportation indices in use. The 'Korea Transportation Safety Authority' (TS) examines the traffic rule obedience and road safety through an annual survey. The index is called 'Transport Culture Index' (TCI). It begun in 1998 with a survey of thirteen cities and since 2006 it is a nation-wide survey with around 200 municipalities. Their index consists of 4 categories (driving behavior, road safety, pedestrian behavior and transport disadvantaged) and 13 indicators. The 2013 report shows that there are gradual improvements in the transport culture: In 2011 the average score was 74.79, in 2012 it grew to 75.20 and in 2013 it improved to

76.04. (TS, 2009; TS, 2010; TS, 2011; TS, 2012a; TS, 2013)

Table 2: Weights of the Transport Disadvantaged Index in 2012

Indicator	Weight
Quality of passenger facilities' mobility convenience	0.146
Quality of transport methods' mobility convenience	0.136
Quality of pedestrian amenities near passenger facilities	0.124
Pedestrian deaths	0.109
Supply rate of low-floor buses	0.100
Percentage of special transport methods	0.088
Usage rate of special transport methods	0.069
Accident rate of elderly and children	0.104
Traffic administration	0.123

Source: MOLIT, 2013a.

An index about the mobility of transport disadvantaged is based on the 'Act on Promotion of the Trans-portation Convenience of the Transport Disad-vantaged'. It examines cities in terms of how well certain groups (handicapped, elderly, pregnant women, children and infants) can use the transportation system. The act was established in 2005 and the first report was published in 2006. The indicators and their weights are shown in table 2 on the previous page. In total 9 indicators are used and the most important indicator is the quality of passenger facilities and the quality of transport methods for travel convenience. The scope changes every year, so it is difficult to detect a positive or negative change. Regarding the 7 cities of this research, the report from 2012 evaluated Incheon as the best city, Seoul was second and Gwangju was ranked last. The index about the mobility of transport disadvantaged will be included later in the KSUTI. (MOLIT, 2013a; TS, 2014)

To my best knowledge, Chung et al. (2002) was the first study which transferred the concept of sustainable development to transportation in Korea. An evaluation of public transportation is proposed but an index about sustainable mobility has not yet been developed in that report. In the same year, a report by the Korea Transport Institute (KOTI) proposes the first transportation indicator set with 56 items for Korea (Hong, 2002). It follows the basic characteristics of sustainable development and groups the indicators according to the environmental, economic and social dimension. The indicators can be found in the overview at the end of this subchapter. 5 years later another proposal for sustainable transport indicators is published: Lee (2007)'s research emphasizes the importance of an institutional framework for the promotion of sustainable transportation and a number of necessary legislative changes. A set of 31 indicators as well as their data-availability for Korea is presented. Neither Hong (2002) nor Lee (2007) actually apply their compilation.

In 2008 sustainable development received a major boost in Korea through the green growth paradigm, which will be explained in the next chapter. An assessment of sustainable transportation was carried out through the 'Green Growth Index for Transportation' in 2009. It translates the paradigm of green growth into an index. It was developed by the KOTI, and it was tested on two levels: first, on the national level with 10 OECD countries, and second, on the city-level within Korea. The index is divided into the 3 areas low-carbon eco-friendliness, energy efficiency and economic activity. In total 72 indicators were proposed but for the assessment of Korean cities 15 indicators have been used.

Table 3: Scores of Green Growth Transport Index

Rank	City	Total	Low-Carbon Eco-Friendliness	Energy Efficiency	Economic Activity
1	Daejeon	72	79	89	57
2	Gwangju	61	55	79	49
3	Daegu	61	55	77	50
4	Busan	58	69	43	52
5	Seoul	56	59	60	41
6	Incheon	44	57	10	63
7	Ulsan	22	16	21	40

Source: Choi et al., 2009, 105.

That index ranks Korea as the eighth among 10 OECD countries. The result of Korean cities is shown in table 3. Daejeon scored the best with 72 points in average and the last position has Ulsan with only 22 points (Choi et al., 2009; Choi et al., 2011). The index was not used since then.

In 2009 the 'Sustainable Transport and Logistics Development Act' was passed by the Korean government. The act defines the term sustainability as satisfying the needs of the current generation without decreasing the resources and degrading the conditions of the economic, social and environmental dimension as well as transportation for the needs of future generations and instead a balance has to be found. As I mentioned earlier, it is similar to WCED's definition. Further, sustainable transportation is by law defined as based on sustainability and the focus is on the improvement of mobility and accessibility of people as well as the efficiency of freight. (Korea Law Information Center, 2013)

That act is the legal ground for the assessment of sustainable transportation. Here again, the KOTI has the responsibility to create and perform the evaluation. An assessment about the sustainability of transport systems is applied to 73 cities (all Korean cities over 100,000 inhabitants). The cities are put into 7 classes according to their result for the z-score and on a point-scale with a t-score transformation (average of 70 and standard deviation of 15). (KOTI, 2012; KOTI, 2014a)

Table 4 shows the ranking of the 2012 assessment. Seoul is the best city in terms of sustainable transportation. Only Seoul and Incheon have a score above the average of 70 points and the least sustainable transport systems are in Ulsan and Daegu. The scores of the latest assessment are not disclosed and according to the division by the 7 classes, Seoul and Busan are in the first class, Daegu, Incheon and Daejeon in the second and Gwangju and Ulsan are in the third class (KOTI, 2014b). So Busan improved as well as Daegu by multiple ranks and Gwangju lost some ranks between 2012 and 2013.

Table 4: Index of Sustainability of Transport Systems (2012)

Rank	City	Score
1	Seoul	80.2
2	Incheon	72.2
3	Gwangju	69.4
4	Busan	68.4
5	Daejeon	67.0
6	Ulsan	66.5
7	Daegu	66.4

Source: KOTI, 2012, 31.

The cities were divided into 3 groups: the 7 cities with the status of a metropolis or capital city are in the first group, cities with over 300,000 people are in the second group and cities with less than 300,000 cities are in the third group. (KOTI, 2014c)

An important function of that assessment is to identify how well the sustainability of the transport area in each city is developed in comparison to other peers from their group. The lowest 5 percent for consecutive 3 years (usually one city per group, in the third group 2 cities) are then designated as cities with the need for alternative measures. The first selection of such special cities is planned for December 2014 and the implementation of measures will be from 2016 to 2018. (KOTI, 2014d)

Table 5: Indicators and Weighting of the 2013 Evaluation

Dimension	Weight of Dimen-sion	Indicators	Weight of Each Indicator
Environmental	0.357	Greenhouse gas emissions by transport sector per population	0.095
		Greenhouse gas emissions by private vehicles per population	0.080
		Greenhouse gas emissions by transport sector per area	0.052
		Greenhouse gas emissions by transport sector per GRDP	0.045
		Air pollution emissions per population	0.084
Social	0.336	Traffic deaths per 100.000 people	0.129
		Traffic deaths per 10.000 cars	0.113
		Satisfaction rate of public transport usage	0.094
Economic	0.307	Modal split of public transport	0.165
		Share of green vehicles	0.067
		Congestion fees per population	0.075

Source: KOTI, 2014e.

The index contains 11 indicators, which were divided into environmental, social and economic dimension (KOTI, 2014e). The table 5 shows the structure including the indicators and weights.

The most important dimension is the environment, followed by the social dimension and the economic dimension. Among the indicators the share of public transportation has the highest weight, followed by traffic deaths per 100,000 people. The least important indicator is greenhouse gas emissions per GRDP. The indicator air pollution is on the next level divided into CO, NOx, SOx, PM10 and volatile organic compounds. Their weight is 0.109, 0.357, 0.068, 0.253 and 0.212, respectively. (KOTI, 2014e)

This index is used in other literature with data from 2000 to 2009 in order to forecast the development of sustainable transport. 5 scenarios for the future were developed. Each scenario has a different setting for the development of greenhouse gas emissions. The authors come to the conclusion that it will cost large sums to support an environmentally friendly transport system and many efforts have to be done. Further there will be a huge increase in traffic fatalities and public transportation. (Kim and Han, 2011)

The next table compares the 4 Korean indicator sets. A similar synthesis on sustainable transport indices was done by Jeon (2007) and it gives a preview of how the indicators of the 52 studies were summarized for the KSUTI.

Table 6: Overview of Korean Indices about Sustainable Transport

Indicators	Index of Sustaina-bility of Transport Systems (KOTI, 2012; KOTI, 2014a)	Green Growth Index for Transportation (Choi et al., 2009; Choi et al., 2011)	Framework for Sustainable Transport and Logistics Policies (Lee, 2007)	Strategies for Sustainable Transport (Hong, 2002)
Environmental Dimension:				
Greenhouse gas emissions by				

transport sector				
Air pollution emissions				
Noise pollution				
Water pollution caused by the transport sector				
Recycling of vehicles				
Land take				
Preservation of ecosystem				
Efficiency of resource usage				
Social Dimension:				
National Area				
Road length				
Rail length				
Bicycle path length				
Total number of cars				
Total traffic accidents				
Traffic accident costs				
Total number of injured or dead				
Hazardous materials transport				
Land area occupied by transport facilities				
Satisfaction rate of public transport usage				
Condition of transport for weak users				
Conditions of residential area				
Transport costs				
Ratio of weak users and handicapped				
Conditions for non-motorized transport				
Transport situation of school children				
Social participation				
Economic Dimension:				
Modal split				
Mode split of public transport				
Modal split of green vehicles				
Energy consumption in transport sector				
Efficiency of freight transport				
Total travelers				
Person-km				
Ton-km				
Private vehicle km				
Public transport passenger-km per person				
Vehicle travel distance per person, ton or vehicle				
Average commute time and distance				
Congestion fees per population				
Congestion time per vehicle				
Average travel speed by mode				

Transport expenses per household				
Employment accessibility				
Land use				
Variety of transport methods				
Costs of transport infrastructure				
Transport pricing policy				
Land use policy				
Tax system				
Bicycle ownership				

All of the 4 indices include air pollution and the share of public transportation. In 3 of 4 indicator lists appear greenhouse gas emissions, injured people or deaths due to traffic and the share of green vehicles. These are crucial points for a sustainable transport system. The other indicators vary because of a different purpose or different understanding of sustainable transportation. The official index has 4 indicators which are just different measures of greenhouse gas emissions and two indicators are related to traffic deaths. So the index covers 7 issues and it is to question if it index shows a comprehensive picture. The study by Kim and Han (2011) indirectly expressed that the official index only allows very limited statements for policy-making.

To summarize the chapter, sustainable transportation, as it is defined by the EU, is a complex issue with several impacts on people's lives, the environment and economy. Various indicator compilations exist on different scales and for different cities or countries around the world. The literature review on Korea shows that the Korean government uses assessment indices for transportation. But there is only a small number of indicator initiatives about sustainable transportation in Korea. The green growth index and the official index have around a dozen indicators. They are until now the only 2 assessments of sustainable transportation in Korea, which were applied to a certain number of cities.

This research contributes to the area of sustainable transport assessment by having the probably largest literature analysis about used indicators. Many researches emphasize the data-availability but this aspect will be secondary during the indicator selection process. The priority is to analyze a large number of indicator compilations and to discover the most common indicators. Besides, the field of transport indicator assessment in Korea misses a study with a large indicator set and multiple cities. There is clearly a need for the KSUTI in Korea. It is the first attempt to apply a relatively large indicator set to Korean cities. It does not have to mean that the usage of more puzzle pieces creates a clearer, more realistic picture of the issue but the KSUTI can be regarded as more comprehensive and it will contain more information with more dimensions.

3. A Comprehensive Index for Korea

This chapter will briefly introduce important measures to a greening of transportation in Korea before the new index will be compiled.

3.1 Sustainable Transport in Korea

The history is divided into Korea in general and Seoul because the capital stands out with many effective measures.

3.1.1 Paradigm Shift on the National Level

The urban fabric in Korea is strongly influenced by a measure, which was introduced a half century ago: the so-called restricted development zones, which are greenbelts around cities, shaped Korean cities significantly because they did not permit any construction in the outer-skirts. That measure had the purpose to protect the environment and prevent sprawl. It assisted in managing urban growth, which resulted in a high density. Additionally, it had advantages for national security. The first greenbelt was made around Seoul in 1971 and between 1971 and 1977 greenbelts around other cities were established. Even though they served a good purpose, it led to extreme density gradients, high costs for housing and large travel distances between cities (World Bank, 2002). These days the greenbelts have been getting smaller as more development is approved in such areas. (Kim, 2010)

1988, the year of the Seoul Olympics, can be seen as the beginning of sustainable transportation in Korea because in that year catalysts became mandatory in all motorized vehicles. In the second half of the 1990s, as private motorization continued to grow, the government reacted with travel demand management initiatives. There was a 14.1 percent increase of vehicles per year and the length of trips grew around 5 percent every year during that period (Hong, 2002). In 1998 the government established a voluntary program for citizens to leave their cars at home on specific dates, which corresponded to the last digit of their license plate. Other related efforts included congestion charges, a nation-wide toll system on expressways and promotion of alternative transport methods such as bicycles. After 1999 the first mid and long-term goals for environmentally friendly transport development were established. Among the goals was the reduction of emissions through natural gas as an energy source for city buses and an increase of fuel efficiency of private vehicles. (Chung et al., 2002)

But it was not until 2008 that sustainability became a major policy issue. President Lee Myung-bak, who was previously a mayor of Seoul, introduced the paradigm of ‘Low Carbon, Green Growth’ (UNFCC, 2011). The Ministry of Land, Infrastructure and Transport (MOLIT) is responsible for transportation policy-making on the national level and they compile medium-development plans. The fourth plan covers the period from 2006 to 2020. It was modified in 2011 due to the high magnitude of changes in the transport area. One of the remarks in the plan states that the transport infrastructure of rail and highway will be extended. The national goal is that the highway network should be accessible within 30 minutes from anywhere in Korea (UN, 2009). Another goal is an efficient intermodal transport system. This means that transport users will be able to use public transportation more efficiently through a hub-and-spoke system and transfers between modes will become easier. For freight traffic, the connections between rail, air and water transport will improve. To emphasize walking and cycling as daily transport methods, every year 5 new pedestrian priority zones should be established. As bicycles extend the catchment area of public transportation, bicycle facilities have to be expanded and safe bicycle paths will be built. The first Korean public bicycle sharing system was introduced 2008 in Changwon and 14 cities established similar services by 2012 (Shin et al., 2013). The bike sharing service can assist in achieving low carbon transport together with high-technology transit. Intelligent transport systems can raise the efficiency of Korea's transport environment. Urban development includes transit-oriented development (TOD) and it is even transferred to the regional level referred to as transit-oriented regions. (MOLIT, 2011)

Most importantly for sustainability is the 'Sustainable Transportation Logistics Development Act'. The national government and each local government have to implement strategies of sustainable transportation, which will be published every 10 years. The Act promotes rail and public transportation. Logistic services which use more environmentally friendly modes can receive subsidies by the government. Non-motorized transport will be promoted through comprehensive 5-year plans. The government will provide funds to private organizations for developing environmentally friendly transport technology and give subsidies to buyers of hybrid or electric cars. In addition, various educational programs are planned (e.g. energy-saving driving behavior). Most important, the Act is the basis for the index of sustainable transportation, which evaluates the transportation systems and compares all municipalities with each other. (UN, 2009)

MOLIT realized that a policy shift towards sustainability is necessary. They aim to increase investments in public transport, focus on seamless connection of pedestrians and cyclists with public transportation and promoting pilot projects related to integrated transport systems. Among their main tasks for cities include the development of transit malls, improvement of the environment for bicycles, creating transit-oriented corridors, establishment of complete streets-concept and better legal systems for traffic participants. (MOLIT, 2013b)

The general goals of the green growth paradigm were: minimizing the negative by-products of growth, increasing energy efficiency and maximizing the potential of growth and production (Choi et al., 2009). By 2020 Korea wants to reduce greenhouse gases by 40 percent below the current development and by 2030, greenhouse gases should be reduced 60 percent (Park et al., 2011). Greenhouse gases by cars should be reduced by 30 percent and the fuel efficiency increased by 40 percent (Business Korea, 2014). Regarding cycling, Korea plans to construct a 30,000 kilometers-large bicycle network and the national goal is to achieve a modal share of ten percent for bicycles by 2019 (UN-HABITAT, 2013). However, the number of registered vehicles will grew further and it is estimated that there will be 21.9 million vehicles in 2020 (MOLIT, 2013b). Among that a bigger share of electric cars has to be achieved and the goal for 2020 is to have one million electric cars on the roads (UNFCC, 2011).

Lee Myung-bak's legislature period ended in 2013 and Park Geun-hye, who is from the same party, was elected as the next president of Korea. She named the focus of her administration on creative industries, welfare, creative education, a safe and integrated society, foundation for unification with North Korea and a trustful government as the primary goals. The modernization of transportation (logistics, passenger transport etc.) was emphasized and mobility of transport disadvantaged was to improve. An upgrade of safety standards for all transport methods was included in the plan for her legislature period. (Korean Government, 2013)

The emphasis on sustainable development is not as strong as with the previous president. An upgrade of transport systems may probably include new environmental standards and safety as a very important aspect of life quality. Especially since the Sewol ferry disaster in April 2014, the public and government want to raise safety standards in the transport sector. Sustainable transportation is not directly mentioned by the new government, but the already established measures and planning tools are continued and included in the plan instruments.

3.1.2 The Case of Seoul as a Forerunner

While the government creates the general path of transportation development, Seoul applied several measures related to sustainable transportation.

Park (2010) divides the history of transportation in Seoul into the following eras: tram era (1899-1956), bus era (1957-1985), subway era (1985-2003) and hybrid era (2004 until now). Another researcher (Kim, 2012) recognizes the following milestones: Seoul entered the modern period of transportation as the first Korean city with trams in 1899, public city buses were introduced in 1928 and the first subway line opened in 1974. In the 1980s private motorization began to accelerate and it caused problems including congestion, air pollution and noise.

The rapid urbanization put pressure on Seoul as heavy traffic became a serious problem and the streets became congested (Barter, 1999; Cervero and Kang, 2011). Bicycles and pedestrians had been neglected by policy makers during that time (Hook and Replogle, 1996). 5 years after the 1992 UN conference, the Seoul Agenda 21 was established and for transportation it contained measures like improvements for pedestrians, establishment of transportation etiquette, convenient public transportation, reduction of traffic accidents and more bicycle usage (Choi, 1999). Seoul tried to promote public transport in the 1990s, but the quality of public transport was insufficient and so measures were ineffective (Barter et al., 2003). The heavy investments into the metro system caused a shift from bus and taxi users to subway without a decrease of motorization (Nelson et al., 2001, in: Nakamura and Hayashi, 2013). Successful measures to manage travel demand and restrict car usage in the city were prioritizing buses, congestion charging at inner-city tunnels, TOD and the public transportation reform in 2004. Bus lanes on the outer lane of streets were introduced in 1986 but they had no success due to conflicts with traffic crossing these lanes (Cervero and Kang, 2011). Tolls for the usage of Namsan tunnels no. 1 and no. 3 have to be paid since 1996 and it resulted in a reduction in the number of vehicles as well as an increase of the average travel speed (Hwang, 2010).

TOD was from the beginning a very important part of urban development because motorization levels had been low and public transportation secured the mobility of citizens. Seoul transformed from a mono-centric city in the 1970s to a multi-center city, in which Gangnam became the second center of Seoul. Development in Seoul and in the surrounding towns mainly happened at subway extensions and at transport nodes. A priority for the capital region was always to keep the density high. (Barter, 1999)

Seoul recognized late that the key to an efficient transportation system is to restrict private motorization while improving public transportation at the same time. The 2004 public transportation reform was an integrated approach to solve the most urgent traffic problems. A quasi-public operation system improved the service quality. Since the reform buses are operated by private companies but Seoul manages the fare system, routes and schedules. The reform introduced an integrated fare system, where the fare is based on distance and free transfers to other buses or metro lines is possible (Pan et al., 2013). A part of the reform was the introduction of the intelligent transportation system with real-time information. Innovative technology like the smartcard system and real-time information systems raised convenience of public transportation. Bus exclusive lanes next to curbs were expanded and BRT-like median-lanes were introduced for the first time (Cervero and Kang, 2011). The average speed of buses increased up to twenty percent in Seoul. Since 2004 the modal share of cars did not expand further, while the share of buses grew slightly (KOSIS, 2014a). Citizens were involved in the process through a special committee where they were able to express their opinions and concerns. (Chon and Kim, 2010)

The 2004 reform is regarded as a milestone in Seoul's public transportation history as it was a move towards a more sustainable city. Parallel to the new public transportation system, the Cheonggyecheon restoration project removed an urban expressway and constructed a high-qualitative public space (Suzuki et al., 2013). The Cheonggye overpass was a 16 meter wide and almost 6 km long elevated road through the center of Seoul. It was built in a decade (1970 to 1979), when 28 elevated road structures were constructed in Seoul. These elevated roads were constructed to improve the traffic flow but it was later recognized that they do not fulfill this function and due to maintenance this infrastructure became a burden for the city. 14 overpasses have been removed between 2002 and 2011 and the Cheonggye overpass was removed in 2003. The others removed elevated structures had a length between 300 and 500 meters in average and therefore, the Cheonggye overpass including the stream restoration project was a very unique case. (Kim and Kim, 2011)

Since that there have not been any large reforms in Seoul. Some recent minor measures are a public bike-sharing system, car-free Sundays and pedestrian zones. It was previously mentioned that Korea promotes the usage of bicycles and over a dozen cities currently offer bicycle sharing. In Seoul public bicycle sharing services were established in 2010 at 2 locations: first, the island of Yeouido which hosts a business district, the National Assembly and multiple broadcasting networks, has 220 bicycles at 26 stations and second, Sangam-dong, where Seoul's World Cup Stadium and a large public park are, has 18 stations with a total of 120 bicycles (Seoul, 2013). Another example is the car-free Sunday in downtown Seoul. On September 23 in 2012, the 550m-long road Sejong-ro was closed for traffic during the daytime. It was a first trial to introduce a car-free event and after a couple of test-runs in 2013 it became a regular event on every first and third Sunday between

March and October 2014 (Seoul, 2014a). Another area, Sinchon, was transformed in 2014 to a transit mall, where only buses are allowed to drive during most hours of the day (Seoul, 2014b). The sidewalks were widened and the environment for pedestrians improved. These two measures restrict car travel in certain areas or during certain periods. The concept of transit malls and pedestrian zones are planned to be applied in other areas of Seoul in the near future. The very dynamic changes in society are a challenge for the future, because changes in travel behavior of households in the Seoul Capital Area are greatly influenced by current social trends including a slower economic growth, aging and use of high technology (Choi et al., 2014).

This brief look into the history shows that Korea and especially Seoul reacted with a variety of measures to the increase of private motorization. As the statistics in the next chapter will show, the capital was relatively successful in managing travel demand. Other cities could not limit car usage as much as Seoul did and useful measures have to be identified for them after their situation is assessed.

3.2 Identifying the Potential Indicators

This subchapter will present the results of the indicator-survey, which is actually the backbone of the indicator compilation for the KSUTI. While it is a way to select indicators, it also answers questions like which categories are used the most, how many indicators are used in average and what indicators are popular. In that order these questions will be answered in the subchapter.

All indices or indicator compilations, which contain the keywords ‘sustainability’ and ‘transportation’, ‘sustainable transportation’ and ‘indicators’ or ‘sustainability’, ‘transport’ and ‘assessment’ as well as ‘benchmarking’, ‘indicator’ and ‘public transportation’ were included and there was no geographical restriction. The literature could use indicators either as independent variables in a list or as weighted indicators in a synthesized index. In total, 52 such researches have been included (see Appendix 1). To my best knowledge, it makes this indicator survey to the biggest sustainable transportation assessment-survey.

Table 7: Analysis of Categories

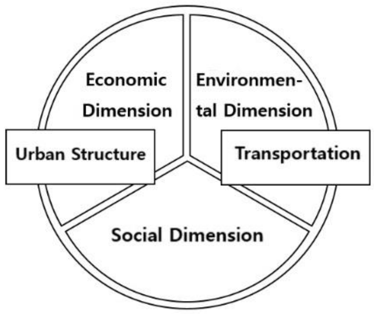
Category	Usage
Economic dimension	20
Environmental dimension	19
Social dimension	17
Public transportation	7
Transportation	6
Mobility	6
Accessibility	6
Socio-economic dimension	5
Performance	5
Safety	5

Source: Made by Author.

At first, the assessments were examined for their categories. The summary of categories is based on the original categories in the indices. 78 individual categories were summarized and the table 7 shows the categories, which were used 5 times or more. The 3 dimensions of sustainable development dominate over transport-related categories. Almost every second indicator set had the economic, environmental and social dimension as a category. These 3 categories clearly dominated in the summary. The KSUTI is going to have the 3 categories as well and 2 more categories, namely the urban structure and transportation, are going to be added.

The urban structure is very important for transportation. These 5 themes suit the indicators well because, as the next subchapter will show, a similar number of indicators will be in each category. The fig. on the right visualizes the 5 themes: The urban structure and transportation are basic settings and the 3 dimensions of sustainability develop inside them.

Figure 5: Themes of Index

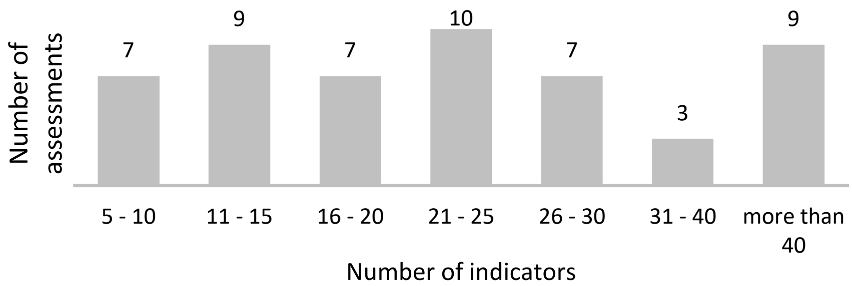


Source: Made by Author.

The survey collected 448 individual indicators. The most popular category was transportation with 126 indicators. The second-highest amount had the environmental dimension with 111 indicators. There were 106 indicators related to social issues, 62 indicators in the economic dimension and 43 indicators about the urban structure. The fact that the biggest proportion of indicators is directly connected to transportation in sustainable transportation assessment is not very surprising. But it can be interpreted that transportation can be measured in more ways than the urban structure. The urban structure has the least number of indicators. Among the 3 dimensions of sustainable development the environmental aspect had the highest amount of indicators, almost twice as much as the economic dimension.

In the 52 assessments 24.9 indicators were used in average. The following fig. shows the distribution of indicators:

Figure 6: Number of Indicators per Research



Source: Made by Author.

The majority of measurements has between 21 and 25 indicators, followed by compilations with 11 to 15 indicators. Other groups are quite similar and there is a couple of indices with a large list of indicators, but it is very dispersed with up to 80 indicators.

Bossel (1999) believes that an indicator set has to be compact and small "but not smaller than necessary" (Bossel, 1999, 7), because it still has to cover all dimensions. Reisi et al. (2014) use as less indicators as possible in their assessment of Melbourne and so there are 9 indicators, ranging from emissions, accessibility, traffic accidents to car ownership costs. The Wuppertal Institute for Climate, Environment and Energy also argues that less than 10 sustainability indicators have to be used and each indicator has to be relevant for policy-making and significant for sustainable development (Spangenberg and Bonniot, 1998). Other approaches select a small set because the indicators function as basic indicators like 12 indicators by the WBCSD (2004). However, the short lists of indicators have the tendency to miss some of 3 dimensions of sustainable development. For example, Black (2002) has 11 indicators but 4 are about emissions. Borken (2003) uses 7 indicators to evaluate sustainable mobility and all of them are only about environmental issues.

On the contrary, some researchers prefer many indicators. A long list of indicators has the I_Sum but not all of them have to be used every time, as it was explained in Ch. 2.2 (Silva and Costa, 2010). The UITP has their own database, which allows them to use large set of indicators (Vivier, 2006). To gain a comprehensive picture of transportation in Asian cities, Barter (1999) uses a large number of indicators. Briassoulis (2001) introduces many indicators, but his indicator set is not only about transportation. Europe's SUMMA project uses 62 indicators in the 3 areas economic, environmental and social theme (Ahvenharju et al., 2004). Although Litman (2013) acknowledges that a compact list offers more convenience in terms of data collection and interpretation, he also favors a long list of indicators because it is more comprehensive and includes more aspects. In summary, there are contrary opinions about the length of indices: To secure an easy overview some lists stay very compact or to be comprehensive a long list of indicators is used. Korea's sustainable transport index has 11 indicators which clearly represents a short set.

Table 8: List of Most Popular Indicators

Indicator	Number of usage	Graphical visualization
Traffic accidents (deaths, injuries)	32	
Modal split	31	
Air pollution emissions	28	
Motorization rate	24	
Transport expenses	22	
CO_2 emissions	21	
Traffic noise	20	
NO_x emissions	19	
Travel time	19	
Road network length	18	
Passengers per kilometer	18	
Vehicle kilometers	17	
Transport energy use	17	
PM10 emissions	15	
Land take by transport	14	
Population density	13	
Investments into transport system	13	
Accessibility to transit	13	
Population size	12	
Fuel usage by transport	12	
GDP/GRDP	11	
Share of zero-emission vehicles	11	
Travel distance	11	
Ton per km freight	11	
Bike network length	10	
Expenses for public transport	10	
Accessibility for mobility impaired	10	
Public transportation fares	10	
Number of trips	10	

Source: Made by Author.

Table 8 contains all indicators, which were used 10 times or more in total. There were 29 indicators, which were that often. If the threshold is lowered to all indicators which were used 5 times or more, the list would include 71 indicators. A higher threshold of 15 times or more would result in 14 indicators. Therefore, the threshold of 10 delivers a sufficient amount of indicators. The maximum was that one indicator was used 32 times. The difficulty in this early stage of the research was to summarize the indicators in an objective way, because the description of indicators is nominal. The most often-used indicator is traffic accidents (number of deaths and injuries), followed closely by the modal split and third is the emissions of air pollutants.

These indicators were extracted from indicator compilations, which were applied on different scales and in different regions. It gives an answer to the discussion of indicator selection for the general assessment of sustainable transportation. I am convinced that these 29 indicators are very effective for the usage in any city or country in the world because they represent very important features and they cover a variety of different topics. The indicator list has to be checked for availability and the weights of each indicator have to be weighted by the participation of locals. The next subchapter will adjust the indicator set to Korea.

3.3 Selection of Final Indicators and Weights

The next step in the process is to check for data availability, to create the final set of indicators for the analysis and to determine the weight of indicators.

In general, the statistical records for the 7 cities in this study are better than for other cities in Korea. They have a special status, e.g. Seoul has the status of the capital city and the other 6 cities are metropolitan cities. I attempted to use the latest data, which was available at the time (October 2014) of data collection.

Statistical data about Korea is accessible through the Korean Statistical Information Service (KOSIS). It is a large portal summarizing all statistics of various public institutions. There are over 900 subjects with statistical data. Under the section transportation and communications 47 subjects are listed, but also many of the required data is in other categories like population and environment. (KOSIS, 2014b)

The second main source is the Korea Transport Data Base (KTDB). The KTDB begun in 1998 as a way to monitor policies and development of transportation in Korea (KTDB, 2014b). This database offers many information and in this study if data was not available at KOSIS, the KTDB usually provided the data, either through their homepage or in the yearbook about transportation statistics (KTDB, 2014c). Additional statistics or data like detailed spatial data of Korea's road network are possible to request through their website.

There have been some issues, which should be discussed, with a couple of indicators. For example, the modal split is a very common indicator for transportation assessments. Some initiatives only include the share of public transportation or the share of private vehicles. It was summarized in the indicator-survey as one indicator 'modal split' except for the share of zero-emission vehicles. The reason was that this type was inquired many times separately. The indicator usually includes electric cars, pedestrians and bicycles as it is the case in the official index of sustainable transportation (KOTI, 2014f). Statistics about electric vehicles are provided only on the national level in Korea and they show that the number of registered electric cars is still very low. In 2011, there have been 335 registered electric cars nationwide and by 2012 the number grew to 849 (KTDB, 2014a). So, currently the modal split of electric vehicles is almost non-existent. The development should be further observed and maybe in the future the share of green vehicles will be significantly higher.

The indicator air pollution emissions in general and each air pollutant (over the threshold of 10 are PM10 and NOx) was counted. Korea records the level of CO, NO_2 and PM10 and so instead of NOx the emissions of NO_2 were used as an indicator and CO was added as indicator, even though it was only used 7 times in total. So CO also represents that air pollution in general was used many times.

Commute time and accessibility measure the same dimension (time) but from two different aspects. They were tested for correlation in order to prevent overlapping of indicators. The test showed that the data does not overlap and so both indicators were kept. The indicator public transportation fares will not be included because the fares are indirectly part of the indicator 'expenses for public transportation' in a way, which is a better parameter for measuring sustainable transportation.

Data for 6 indicators could not have been retrieved: transport expenses, land take by transport facilities, overall transport energy use by transportation, overall travel distance, passenger per kilometer and ton per kilometer freight. How much a person or households spends on transportation is an insightful character but it is not available on the local scale. On the national level a household with 2 persons or more, who lives in an urban area, spent 306,495 Korean Won in average on transportation in 2013 (KOSIS, 2014a). Data about land taken by transportation including transport-related facilities is not available because Korea divides the land use into the categories residential area, commercial area, industrial area, green space and undesignated area. A newspaper calculated the land take for cars in Seoul through multiplying the amount of parking spots with 12 square meters and adding official statistics about the street area and so they came to the result that the space for cars is 128.7 square kilometers (Seoul's total area is 605.2 square kilometers) (Chosun Ilbo, 2014). The energy use of transport covers in comparison to the fuel usage of transportation more areas like energy supply for public transportation and traffic-related infrastructure and it is not only reduced to fuel. The indicator travel distance intends to show what distances people in average take on a daily basis. The travel method could be by foot, public transportation and motorized transport methods. Information about that were unable to retrieve, too. The problem about the indicator passenger per kilometer was that data for subways exists but not for the bus systems. Ton kilometers is measuring freight transport and such data is neither available at KOSIS or KTDB on the city level in Korea and so that indicator was dismissed.

The statistical service and the cities should consider to collect data for the missing indicators because they help in generating a comprehensive picture of transportation. The following table shows the final selection of indicators. After confirming the data, there were 22 indicators.

Table 9: Final List of Indicators

Urban Structure	Environmental Dimension	Economic Dimension	Social Dimension	Transpor-tation
· Population size · Population density · Road network length · Bike network length	· CO_2 emissions · CO emissions · NO_2 emissions · PM10 emissions · Traffic noise · Fuel usage by transport	· Investments to transport system · GRDP · Expenses for public transport	· Traffic injuries · Traffic deaths · Accessibility of public transport · Mobility of transport disadvantaged	· Modal Split · Motorization rate · Vehicle kilometers · Commute time · Number of trips

Source: Made by Author.

There are 4 indicators for urban structure, 6 indicators about the environmental dimension, 3 economic indicators, 4 variables for social dimension and 5 transportation indicators. They seem to suit well the definition of sustainable transport by the EU. As the first point of the definition expresses social issues like accessibility, safety and equity, the KSUTI covers these issues in the social dimension. Economic indicators represent affordability and regional development (GRDP), which are included in the second point of the definition. The last part mentions environmental issues, who connect well to the indicators fuel usage, CO_2, air pollution and noise levels.

Now the next step is the weighting of indicators. It is an important part of the composition of indicators because it significantly influences the final score. Some researchers criticize weighting due to a lack of rational justification for giving indicators different weights and the only justifiable process is public participation (Tanguaya et al., 2010). The weighting can always be questioned and how indicators are weighted depends on the research question or the examined space (Black, 2004). However from another viewpoint, weights express the value of an indicator and they carry a certain level of subjectivity (Waeger et al., 2010). And this subjectivity represents in a positive way the local context. In this case the weights express how important each indicator for the assessment of sustainable transportation in Korea is.

The method to empirically divide the weight was AHP, which was developed by Saaty in 1977. It is the most common method for weighting indicators (Reisi et al., 2014) and generally, it is used as a multi-criteria decision tool. The main principle is that factors undergo a pairwise comparison. In this case the indicators are compared and it identifies the importance of each indicator in relation to each other. (Triantaphyllou and Mann, 1995)

AHP was used for the official index and the green growth index as well. The official Korean index for sustainable transportation collected weights for indicators through a survey but there are no information on the survey participants (KOTI, 2014d). The weights for that index were discussed in Ch. 2.3. The green growth index for transportation conducted an AHP survey of 30 people (5 government officials, 15 researchers or academics and 10 people from the transport industry) to determine the weights of the 3 indices and categories but not directly for the indicators (Choi et al., 2009).

Responses were gathered through an online-survey, provided by Goepel (2014). The indicators were translated into Korean and the primary contact method was through e-mail. The survey was sent out to approximately 90 people. No personal information except the name of the participant were collected, in order to later identify them. The target group of this survey were academics in the field of transportation, researchers of public transportation or sustainable transportation at the KOTI or at local development institutes, government officials or civil servants, who work in the city's transportation divisions or for any other government organization, and citizens with a professional or academic background in sustainable transportation.

In total, 15 people took part in the survey: 4 researchers from local research institutes, 3 researchers from KOTI, 3 citizens with a background in sustainable transportation, 4 civil servants and one academic. 2 researchers work at the Busan Development Institute. One respondent has a Ph.D. in urban engineering with public transportation as his research field and the other respondent has a background in traffic engineering. One respondent is from the Incheon

Development Institute and the person has a Ph.D. in engineering and traffic planning as a major. The Seoul Institute is represented by one respondent, who works in the division of transport system research. The answers from KOTI came from 2 employees from the public transportation-division and one researcher from the transport safety and highway-division. All of them have higher education in transport planning or transport engineering. The academic is a professor with a Ph.D. in transport engineering and currently teaches transport planning. Nobody from the city administrations or transport-related government organizations replied to the survey. But still, in order to include public servants, 4 people from other transport-unrelated ministries were surveyed. They can be regarded as non-experts with a general opinion about sustainable transportation and that makes them closer to the citizens. Among the 3 citizens, which were chosen because of their interest in sustainable transportation, was one non-Korean, who has a professional background in sustainable transportation and received further education in another field in Korea. The other 2 Korean participants work in different fields of sustainable development and whereas one has no background in transportation at all, the third respondent majored in sustainable transportation at a European university. This brief overview emphasizes that the respondents are not representative for the whole population and they represent of a mix of 7 non-experts and 8 mostly highly-educated experts in the field of transportation.

The answers by all participants showed a homogeneity of 63.8 percent. I did not expect to find a very high consent because different groups were involved. The consensus was the highest for the social dimension with 80.3 percent. The second highest consensus has the sub-category traffic accidents with 75, but the chance for a similar answer is high, because there are only two indicators. The sub-category air pollution with 3 indicators has a consensus of 71.5 percent. Transportation had a consensus of 68.2 percent, environmental dimension has 67.5 percent, economic dimension has 67.3 percent, and urban structure has 65.4 percent consensus. The comparison of the 5 themes has the lowest consensus with 60.9 percent.

Table 10: Hierarchy of Indicators

Category	Weight of cate-gories	Indicators	Weight of indicator in category	Indicators – level 2	Weight in group	Total weighting
Urban Structure	0.2474	Population	0.2265			**0.05604**
		Population Density	0.3748			**0.09273**
		Road Network Length	0.2325			**0.05753**
		Bicycle Network Length	0.1661			**0.04109**
Environ-mental Dimension	0.2114	Air Pollution	0.2116	CO	0.3711	**0.01661**
				NO_2	0.2387	**0.01068**
				PM10	0.3902	**0.01746**
		Greenhouse Gas Emissions (CO_2)	0.3515			**0.07432**
		Noise	0.1811			**0.03829**
		Fuel Usage by Transportation	0.2559			**0.05410**
Economic Dimension	0.1769	GRDP	0.3009			**0.05323**
		Investments into Transport Systems	0.3582			**0.06337**
		Expenses for Public Transport	0.3409			**0.06030**
Social Dimension	0.1493	Traffic Accidents	0.1465	Traffic Injuries	0.5127	**0.01122**
				Traffic Fatalities	0.4873	**0.01066**

		Accessibility of Public Transport	0.5956		**0.08894**
		Mobility of Transport Disadvantaged	0.2579		**0.03851**
Transpor-tation	0.215	Modal Split	0.3400		**0.07308**
		Motorization Rate	0.1312		**0.02819**
		Vehicles-KM	0.1880		**0.04041**
		Average Com-mute Time	0.1429		**0.03072**
		Number of Trips	0.1980		**0.04256**

Source: Made by Author.

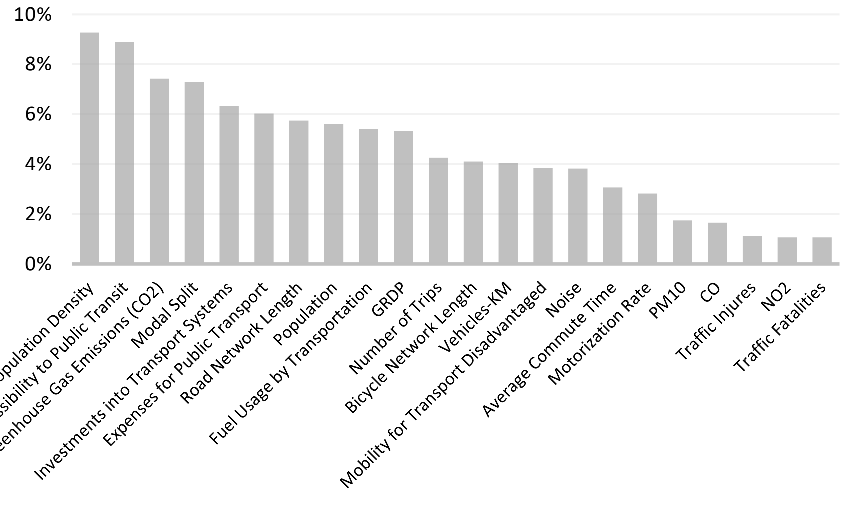
Table 10 on the previous page shows the hierarchy and how the indicators were weighted in 2 areas: first, the fourth column shows the weight of the indicators in each category and second, the last column shows the weight for the total score of the KSUTI. 5 indicators are on a sub-level: CO, NO_2 and PM10 are grouped under air pollution measures. Traffic accidents summarize the rates for traffic injuries and traffic deaths.

Regarding the themes, the highest weight (0.2474) received urban structure. The second-most important category is transportation with 0.215. Transportation is closely followed by the environmental dimension (0.214). The economic dimension got a weight of 0.1769 and social dimension got 0.1493. The 3 dimensions of sustainable development were regarded as less important as the urban structure and transportation. These two categories received almost half of the weight. The reason may be that sustainable transportation is better association with them. The environment is also highly linked to sustainable development and the impact of transportation on the environment is high, whereas the respondents see a rather weak connection to social aspects.

The indicator with the highest weight or, in other words, the highest importance is population density. Second is the accessibility of public transport and third is CO_2.

The fig. 7 shows the weights for the indicators in a chart.

Figure 7: Weighting of Indicators



Source: Made by Author.

The indicator with the lowest weight is traffic fatalities, which is quite surprising because safety is in general regarded as a very important issue in the life quality. NO_2, traffic injuries, CO and PM10 have also low weights. The hierarchy of the AHP model is a major reason for this outcome because these indicators were divided into sub-categories on the lowest hierarchy level.

The survey provides information on how a certain groups of experts and non-experts evaluate the indicators. The group of researchers (KOTI and local research institutes) divides the weight among the 5 themes as follows: urban structure has 26 percent, transportation 25 percent, environmental dimension 18 percent, economic dimension 16 percent and social dimension got 15 percent. The distinction between transportation and urban structure from the other categories is stronger. The 3 dimensions of sustainable development have equal weights. Focusing on the indicators, the researchers regard the population density as the most important aspect with 12.2 percent weight, followed by 8 percent for modal split and 7.1 percent for accessibility of public transportation. The researchers put in average more emphasize on the population density than the total average. Modal split has a higher relevance for assessment than accessibility. On the fourth rank is vehicle kilometers with 6.8 percent, which is lower in the overall result, and then on the fifth position is CO_2 with 6.4 percent. The number of trips was voted as more important from the research group. Another big difference to the overall survey result is the weight for traffic fatalities, which is much higher voted with 2.6 percent. The lowest weight (0.8 percent) received NO_2 from the transportation researchers. In comparison to the researchers the government officials and citizens saw the greenhouse gas emission (CO_2) indicator as the most important variable with 13.66 percent and second comes the population size. It shows that the researchers put a stronger emphasizes on transport-related factors and the underlying issues of transportation, while the other respondents seem to put more concern on environmental aspects of transportation.

The weights were then multiplied with the transformed values of each indicator. Each indicator has a different unit, because it measures a different aspect of sustainable transportation. To allow comparability, the values were transformed in two steps: First, the values were standardized with the z-score (mean of 0 and standard deviation of 1) and second, the t-score transformed the results of the z-score with a mean of 50 and standard deviation of 10.

Now all necessary preparations for the KSUTI are complete. The preparatory steps included design of the framework, indicator selection, data collection and specification of weights. While I chose the categories, the indicators are the result of a summary of 52 indicator assessments and the weights were determined by 15 Korean respondents of an online-survey.

4. Evaluation of Korean Cities

In this chapter the KSUTI will evaluate the cities. The main question of this part is how well the cities score in each category and in the whole index. The score for each dimension in the following subchapters is weighted according to the weight for each indicator in their category (see table 10).

4.1 Urban Structure and Transportation

Table 11: Indicators About Population

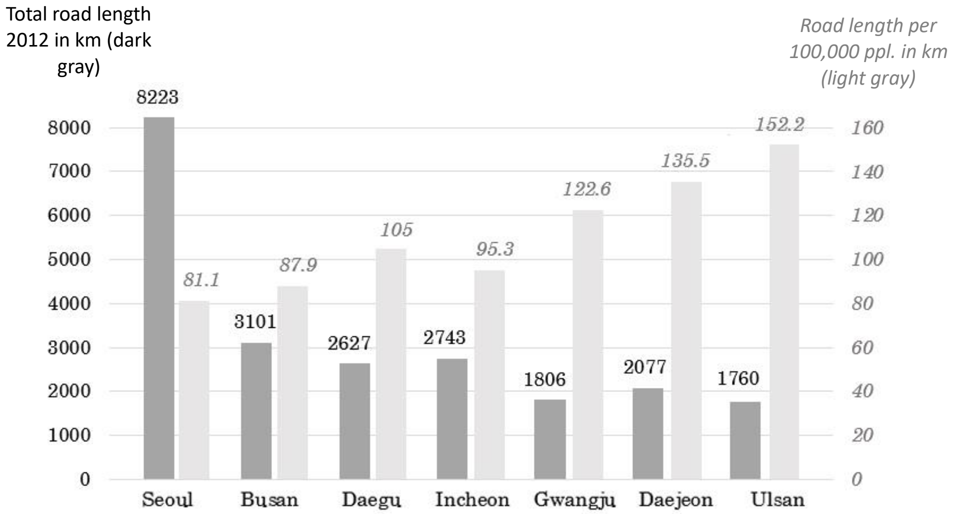
City	Population size (2013)	Pop. density (ppl./㎢)
Seoul	10,143,645	16,760.5
Busan	3,527,635	4,583.3
Daegu	2,501,588	2,830.9
Incheon	2,879,782	2,766.8
Gwangju	1,472,910	2,938.9
Daejeon	1,532,811	2,837.2
Ulsan	1,156,480	1,090.8

Source: KOSIS, 2014a.

The first indicator is the population size. Although research (e.g. Barter, 1999) showed that the population size can have different effects on transport patterns, the KSUTI associates a smaller popu-lation size as a favorable condition for sustainable development be-cause a smaller city has shorter trips and shorter travel time, which also results in lower energy consumption. Seoul is by far the biggest city with over 10 million inhabitants. Busan has 3.5 million citizens and Incheon and Daegu have 2.8 and 2.5 million inhabitants, respectively. Ulsan is the smallest among the examined cities.

Population density is seen as a major influence on mobility and it is the main feature for sustainable urban planning strategies like the compact city (Klinger et al., 2013). A high density represents short travel lengths, high public transport share and a good environment for cycling and walking (Kenworthy and Laube, 1996). Especially if density is combined with a mixed use of land and street designs for non-motorized transport methods, it can lead to large decreases of private cars (Cervero and Kockelmann, 1997). The survey respondents selected population density as the most important indicator for sustainable transport assessment in Korea. Ulsan is not only the smallest city, but it also has the lowest density. Around 1,000 people live in a square kilometer on average in Ulsan. Seoul's density is 16 times higher than Ulsan's. Busan has the second-highest density. Gwangju, Daejeon, Daegu and Incheon have similar densities of around 2,800 people per square kilometer.

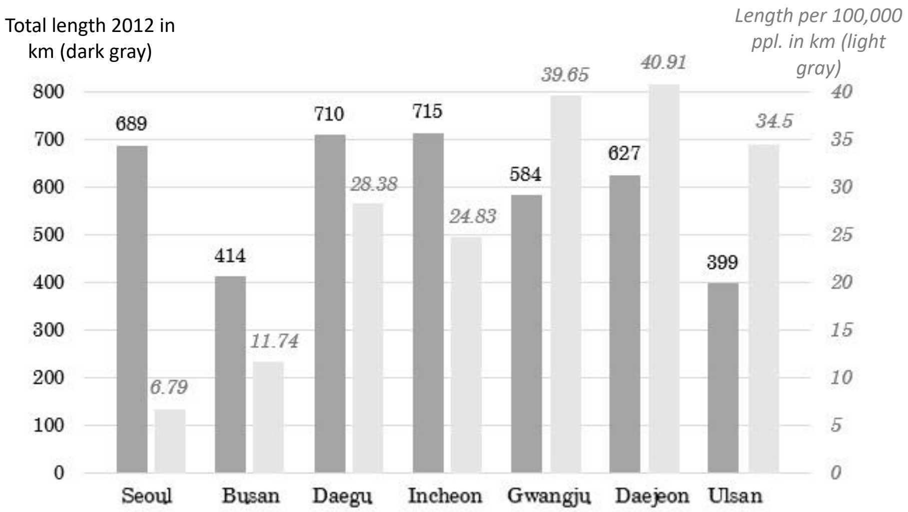
Figure 8: Road Network Length



Source: Made by Author, Based on KOSIS, 2014a.

The third indicator is the road network per 100,000 people. It is assumed that a large road network induces private motorization because it makes driving more convenient and available to more people. Ulsan has with 152.2 km per 100,000 inhabitants the biggest relative road network. Fig. 8 on the previous page shows the road length in total and per capita for every examined city. It is followed by Daejeon, Gwangju and Daegu. Seoul has the smallest road network in relation to inhabitants. In the sample smaller cities have a bigger road network due to a low density.

Figure 9: Bicycle Network Length



Source: Made by Author, Based on KOSIS, 2014a.

The last indicator in the urban structure-theme is the bicycle network length per 100,000 people. A longer bicycle network is preferred. The reasons are similar to the road network: It can be assumed that a provision of bicycle paths will lead to a potentially higher share of cycling. The longest bicycle network has Incheon, but Daejeon has the longest network in relation to citizens. Seoul has again the lowest value. Despite the large network in total numbers, it has by far the lowest share of bicycle paths per population. The examined cities have in average 26.69 kilometer bicycle roads per 100.000 people and so Seoul, Busan and Incheon are under average, while Daegu, Ulsan, Gwangju and Daejeon are above average.

Table 12: Ranking and Score in Urban Structure

City	Rank	Score
Seoul	1	53.59
Gwangju	2	50.63
Incheon	3	50.06
Daegu	4	49.96
Busan	5	49.87
Daejeon	6	49.54
Ulsan	7	46.31

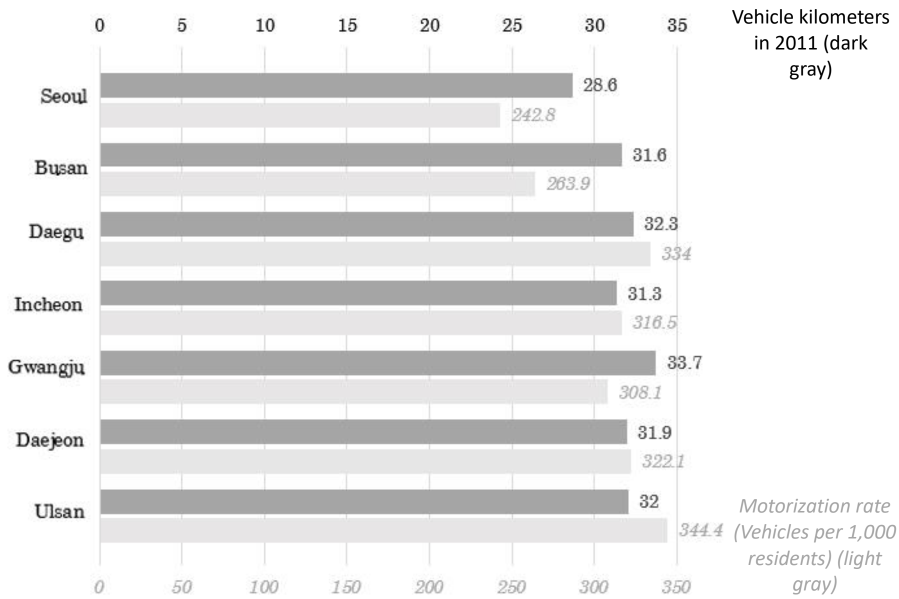
Source: Made by Author.

The result for the category urban structure in table 12 shows that Seoul has the highest score. Despite the large population size, Seoul has a very high population density and low road rate. Ulsan has the lowest score with 46.41 points. The other examined cities have a similar score between 49.5 and 50.6 points.

Now the data for the category transportation will be examined. The motorization rate is calculated by dividing the number of registered cars in each city by the number of citizens (in this case per 1,000 citizens). A higher rate of motorization can be seen as unfavorable for sustainable transportation because it implies that the car is a necessity. The indicator shows that Ulsan has the highest value (344.4 registered vehicles per 1,000 inhabitants). Second is Daegu and third is Daejeon. Seoul and Busan are the only 2 cities with less than 300 vehicles per 1,000 people.

The next fig. shows the indicators motorization rate and vehicle kilometers. While the motorization rate showed how many cars are possessed in each city, the next indicator vehicle-kilometers highlights how much a car is used in average.

Figure 10: Motorization Rate and Vehicle Kilometers



Source: Made by Author, Based on KTDB, 2014a; TS, 2012b.

The length of vehicle kilometers actually shows how much a city dependence on automobiles (Kenworthy and Laube, 1996). The problem here is that more travel by car increases the external costs but only a marginal amount is covered by the user (Litman, 2013). Gwangju has the highest value. Citizens of that city drive 33.7 kilometers in average with their own car on a daily basis. While almost all cities are between 31 and 33 kilometers, Seoul has a distinctive lower value of 28.2 kilometers.

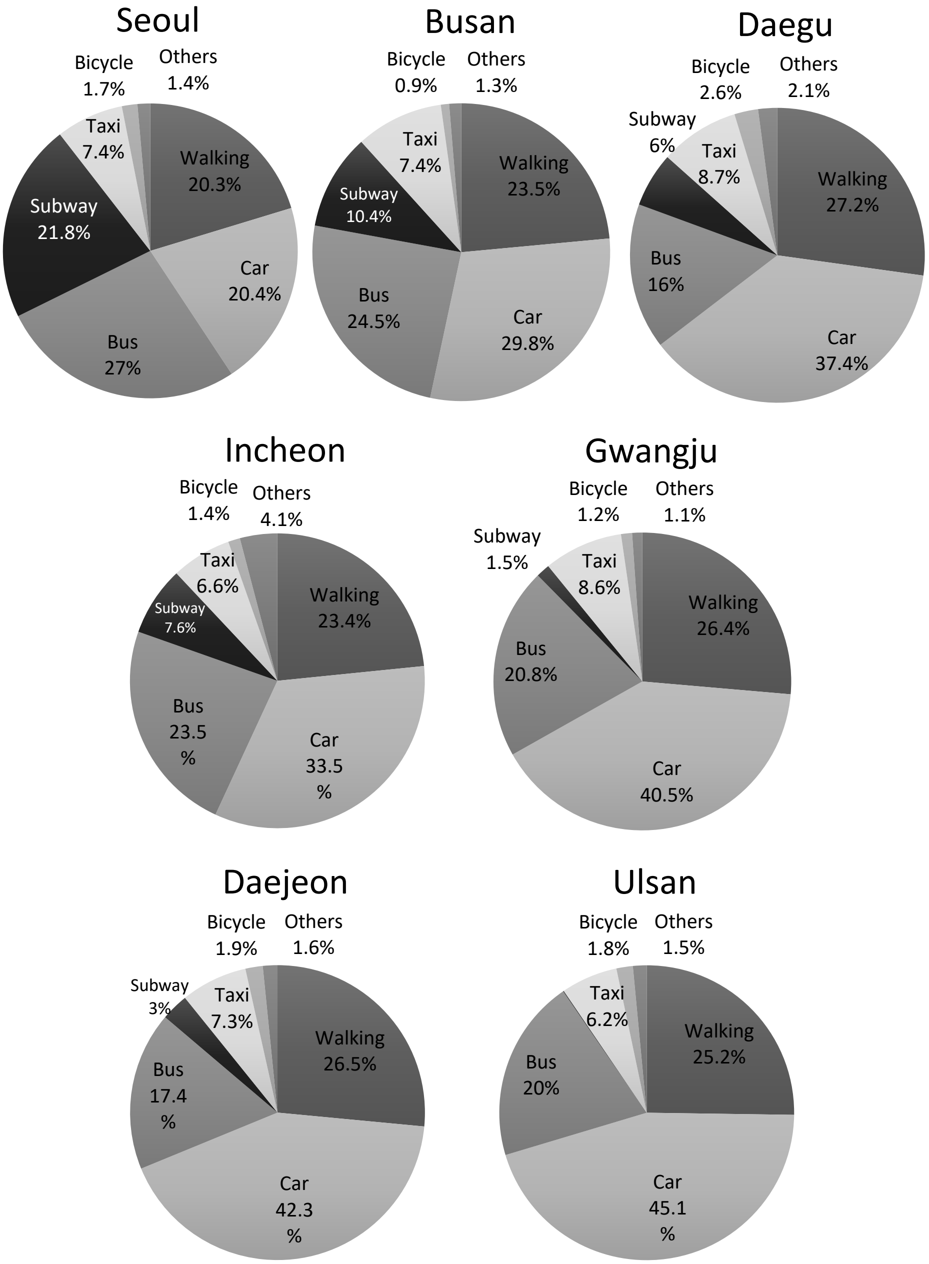
The fourth-most important indicator, according to the online-survey, and the second-most often-used indicator in sustainable transportation assessments is the modal split. In Korea, statistics divide transport methods into foot, car, bus, subway, taxi, bicycle and other methods.

For sustainable transportation the shares of walking, bicycles and public transportation are important. They are regarded as healthy modes and part of active transportation (Banister, 2008). The proportion of car usage is seen as the only unsustainable parameter among them. Seoul has with 48.8 percent the highest share of public transportation. Busan's share of subway and bus is 34.9 percent and Incheon is third, followed by Gwangju, Daegu, Daejeon and Ulsan. Ulsan is the only city without a metro-system. Seoul and Busan are the only 2 cities, where public transportation has a higher share than private cars. Taxis are popular in Busan, Daegu and Gwangju.

Every city has low rates of bicycle usage. In Busan it is even under the one percent rate. All cities show a quite similar modal split with one exception: Seoul. Korea's capital has lower car usage and a higher subway share than the other cities.

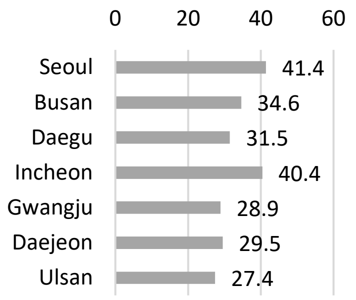
The following fig. visualizes the modal split of each city in a pie chart and it shows how the share of bus or subway decreases with an increase of car usage.

Figure 11: Modal Split of Korean Cities



Source: Made by Author,
Based on KTDB, 2014a.

Figure 12: Average Commute Time (2010 in min.)

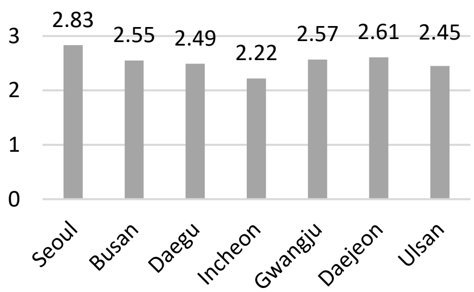


Source: Made by Author, Based on KOSIS, 2014a.

The next indicator compares the average commute time to school or office. Here the weakness is that it does not consider the travel method. A commute by car can be faster but it can be less environmentally friendly as a commute by public transportation. Nonetheless, in general a shorter commute is preferred for urban dwellers and therefore, the KSUTI regards a lower time amount as better. Seoul and Incheon have an average commute time of over forty minutes. Busan and Daegu record over thirty minutes, while the other 3 cities Ulsan, Gwangju and Daejeon are under thirty minutes. Ulsan has the shortest commute.

A sustainable transportation system decreases the need for trips, which may cause emissions or accidents. On a daily basis Seoul has the highest number of trips with 2.83 trips per capita. In total numbers it means that there are 28 million trips in Korea's capital. The second highest amount of trips per person is in Daejeon with 2.61 and the other 4 city range between 2.45 and 2.57. The lowest number of trips (2.22 per person) are undertaken in Incheon. Seoul and Incheon have distinctive trip amounts in

Figure 13: Number of Trips per Capita (2012)



Source: Made by Author, Based on KTDB, 2014a.

comparison to the other cities.

Table 13: Rank and Score for Transportation

City	Rank	Score
Incheon	1	55.05
Seoul	2	55.02
Busan	3	54.33
Daegu	4	53.06
Ulsan	5	51.34
Daejeon	6	51.04
Gwangju	7	50.03

Source: Made by Author.

In summary, Incheon scores the best for the transportation-theme and Seoul is second with only 0.03 points less than Incheon. Gwangju is on the last rank with 50.03 points, caused by high vehicle-kilometers, high number of trips and a low share of bus and subway.

4.2 Environmental Situation of Cities

Now the results of the 4 indicators in the environmental dimension will be discussed. Air pollutants harm the environment but they have even stronger negative impacts on people's health. Air pollution is indirectly connected to leukemia, asthma and lung diseases like bronchitis (Banister, 2008). That issue will be measured through the average levels of CO, NO_2 and PM10. The emission levels were collected on city level and they can be caused by other reasons than transportation. It is estimated that private vehicles cause almost 75 percent of NO_2 emissions in Korean cities (Kamal-Chaoui et al., 2011). A detailed discussion of air pollutants by private vehicles gives Liddle and Moavenzadeh (2002).

The air pollution indicators and noise are summarized in table 14.

Table 14: Air Pollution and Noise Emissions

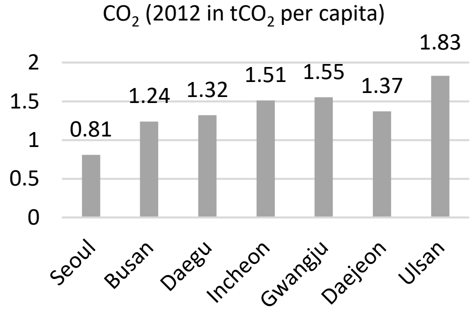
City	CO level (2013 in ppm)	NO_2 levels (2013 in ppm)	PM10 levels (2013 in ㎍/㎥)	Traffic noise (2011 in Leq dB(A))
Seoul	0.53	0.033	44.5	61.0
Busan	0.42	0.021	48.5	60.3
Daegu	0.48	0.023	45.3	59.8
Incheon	0.63	0.028	49.1	58.3
Gwangju	0.54	0.020	42.3	57.0
Daejeon	0.43	0.020	41.7	58.3
Ulsan	0.51	0.024	47.1	61.5

Source: KOSIS, 2014a.

The highest concentration of CO levels has Incheon. That city recorded also the highest levels of PM10. Seoul has the highest NO_2 concentration. The lowest CO levels has Busan, but that city has measured the second-highest PM10. Another problem in urban areas is noise. The city with the biggest noise is Ulsan, second is Seoul and third is Busan. These 3 cities have recorded over 60 decibels in certain areas. Gwangju has the lowest noise with 57 decibels.

Transport is a main cause for CO_2 emissions on the local and global scale (Liddle and Moaven-zadeh, 2002). The next indicator covers the amount of CO_2 per capita emitted by transportation. The lowest amount of CO_2 emissions has Seoul with 0.81 tCO_2 per capita. Incheon and Gwangju have almost twice as much as Seoul and Ulsan has the highest amount with 1.83 tCO_2 emissions per capita.

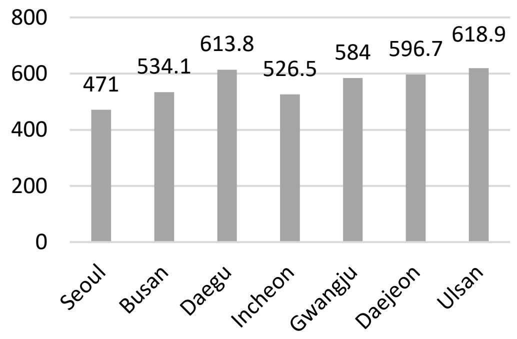
Figure 14: Greenhouse Gas Emissons



Source: Made by Author, Based on KTDB, 2014a.

The next indicator highlights the fossil energy consumption of transportation. The indicator fuel usage by transport per person is led by Ulsan. A citizen of Ulsan uses 618.9 liter fuel in average. Daegu is above 600 liter per capita as well. Citizens from the capital uses 471 liter fuel per year, which is the lowest amount of all cities.

Figure 15: Fuel Usage by Transport (Liter per Person in 2011)



Source: Made by Author, Based on KEEI, 2012.

Fig. 15 visualizes the fuel usage in a chart. The amount of fuel usage per person is lower in Seoul, Busan and Incheon than in the other 4 cities. Daegu and Ulsan are even above 600 liter per person.

Table 15 shows the total score for the environmental dimension. Ulsan is at the far bottom of the ranking. The city received only 38.28 points, 10 points less than the sixth-ranked city Daegu. Gwangju has the fourth rank and it has an average score of 50.79. Seoul leads with 57.94 points. As the indicators showed, Ulsan has a high level of fuel usage, high level of noise and large amounts of CO_2 emissions.

Table 15: Ranking for the Environmental Dimension

City	Rank	Score
Seoul	1	57.94
Busan	2	52.42
Daejeon	3	52.00
Gwangju	4	50.79
Incheon	5	48.80
Daegu	6	48.42
Ulsan	7	38.28

Source: Made by Author.

4.3 Economic and Social

Dimension of KSUTI

The third subchapter examines the economic and social dimension.

Table 16: Financial Aspects of Transportation

City	Investments into transport system (per 100,000 ppl.)	GRDP per capita (2012 in 1,000 KRW)
Seoul	44,476.7	28,454
Busan	54,072.6	18,019
Daegu	49,768.8	15,491
Incheon	43,056.9	21,055
Gwangju	27,042.7	18,175
Daejeon	23,065.6	18,707
Ulsan	33,613.0	61,088

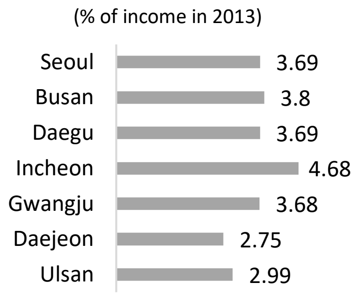
Source: KOSIS, 2014a.

The investments into transport systems by the govern-ment per 100,000 inhabitants is about how much a city spends each year for transportation. A higher amount of expenses is regarded as positive because more investments mean that the transport system is being constantly developed. The largest sum is spent by Busan with over 50,000 Korean Won (KRW) per 100,000 people. Daegu is second and Seoul is third. Gwangju spends half of the amount of Busan. Daejeon has the lowest investments into transportation.

The second indicator is GRDP per capita. A high GRDP means that the region is wealthy and that the living standards are high and the quality of life is assumed to be better. The highest GRDP per capita has Ulsan. It is more than twice as high as Seoul's GRDP. Incheon is third and then Daejeon, Busan and Gwangju follow with a similar GRDP of around 18 million KRW per capita. The lowest GRDP per capita has Daegu.

The indicator expenses for public transportation expresses the affordability of public transport. It is measured by the calculation of how many percent of the monthly income is spent for the usage of buses and subways. Less expenses is, of course, more favorable for the individual. In general, all citizens spent less than 5 percent of their income for public transportation in Korea. The public transport expenses were available for the cities Daegu (41,303 KRW), Gwangju (41,440 KRW) and Daejeon (32,703 KRW) as well as for the agglomerations Seoul and Incheon (51,053 KRW) and Busan and Ulsan (43,438 KRW). Citizens from Daejeon spend the least amount on public transportation (in total numbers as well as relative to their monthly income). The highest portion of the income was spent in Incheon, which means that it is a bigger burden for citizens of Incheon to use public transportation.

Figure 16: Expenses for Public Transport per Person



Source: Made by Author, Based on KOSIS, 2014a.

Table 17: Rank and Score for Economic Indicators

City	Rank	Score
Ulsan	1	58.25
Busan	2	52.06
Seoul	3	51.62
Daegu	4	50.85
Daejeon	5	48.39
Gwangju	6	44.43
Incheon	7	44.39

Source: Made by Author.

In contrast to the other categories, Ulsan has the best score for the economic dimension. It is mainly because of the high GRDP per capita and low percentage of expenses for public transportation. Busan is second, Seoul has the third rank and Incheon records the lowest score. Gwangju has slightly more points than Incheon and a big gap to Daejeon, which is on the fifth rank.

The category social dimension measures the number of traffic accidents, accessibility of transit and mobility of transport disadvantaged.

Safety is one of the most important quality-of-life indicators (Steg and Grifford, 2005). A safe traffic environment increases the convenience of pedestrians and bicycles, who are usually the most vulnerable towards injuries and deaths by traffic accidents. Table 18 shows the total number of fatalities and injuries, while fig. 17 on the next page shows the used indicators: traffic injuries per 100,000 people and the fatalities per 10,000 people.

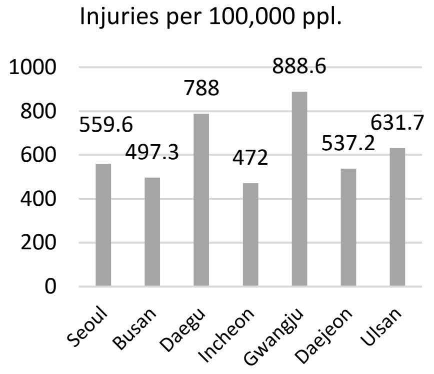
Table 18: Traffic Accidents

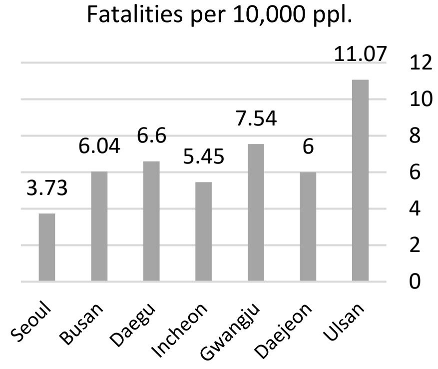
City	Traffic accidents (injuries) in 2013	Traffic accidents (deaths) in 2013
Seoul	56,761	378
Busan	17,542	213
Daegu	19,713	165
Incheon	13,594	157
Gwangju	13,089	111
Daejeon	8,234	92
Ulsan	7,305	128

Source: KOSIS, 2014a.

The safest city regarding injuries is Incheon with 472 injuries per 100,000 inhabitants. The most traffic accidents with injuries happen in Gwangju, almost twice as much as in Incheon. The most fatalities per 10,000 people occur in Ulsan. That city has by far more fatalities than any other city in this study. 11.07 fatalities per 10,000 citizens were recorded in Ulsan. On the sixth rank is Gwangju with 7.24 fatalities per 10,000 citizens. The lowest number of fatalities has Seoul with 3.73 fatalities per 10,000 people.

Figure 17: Injuries and Fatalities

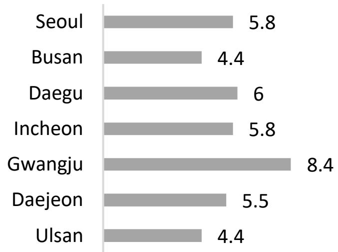




Source: Made by Author, Based on KOSIS, 2014a.

The following indicators is the accessibility. The decision on using public transportation depends mainly on accessibility to such services (Taylor and Clifford, 2005). Thus, it is in general a very important indicator. In this case the accessibility of public transportation is measured by how many minutes it takes to reach a public transportation station on foot. The data is again based on agglomerations. The shortest duration has Ulsan and Busan with 4.4 minutes. In Daegu it takes the longest with 6 minutes. Seoul and Incheon require also long durations with 5.8 minutes.

Figure 18: Accessibility of Public Transport (by foot in min. for 2011)



Source: Made by Author, Based on KOSIS, 2014a.

The last social indicator focuses on the mobility of transport disadvantaged. As previously mentioned, the score of the official Korean index about the mobility of transport disadvantaged is used. The index and indicators were introduced in Ch. 2.3. Incheon scored the best in 2012, Seoul is second and then there is a large gap to the third place Daejeon. Daegu and Ulsan have a very similar score. Gwangju has the last position.

Table 19: Mobility Impaired

City	Mobility of transport disadvantaged (score for 2012)
Seoul	83.1
Busan	61.9
Daegu	59.0
Incheon	84.1
Gwangju	53.2
Daejeon	62.7
Ulsan	59.3

Source: MOLIT, 2013a.

The indicators about the social dimension for sustainable transportation show in the summary that 3 cities are under average. Daegu has the last rank with only 41.71 points due to weak accessibility and bad environment for mobility impaired. Gwangju and Daejeon also score low. Busan has the best score, followed by Ulsan.

Table 20: Ranking and Score of Social Indicators

City	Rank	Score
Busan	1	58.21
Ulsan	2	55.45
Incheon	3	50.64
Seoul	4	50.55
Daejeon	5	48.35
Gwangju	6	45.07
Daegu	7	41.71

Source: Made by Author.

4.4 Overall Result for the KSUTI

Finally, the result for the KSUTI will be presented. Table 21 shows how the cities score if every indicator would have the same weight. Seoul leads the list with a score of 52.33 points. The second rank has Busan with 51.79 points. All other cities have less than 50 points, which means that they score under average. On the last rank is Gwangju with 47.81 points.

Table 21: Overall Ranking and Score With Equal Weights

City	Rank	Score
Seoul	1	52.33
Busan	2	51.79
Daejeon	3	49.96
Incheon	4	49.88
Ulsan	5	48.75
Daegu	6	48.14
Gwangju	7	47.81

Source: Made by Author.

Now, in table 22 the weights are applied to the data. Seoul is still on the first position. Busan is second with 53 points and Daejeon got exactly 50 points, which are 0.05 points more than Incheon. The difference to the equally-weighted scoreboard is that Ulsan is now ranked sixth and Daegu went up a position. Ulsan has less points due to a low population density, a very car-focused modal split and high CO_2 emissions. Gwangju is still last with 48.61 points. Through the weighing the gap of Seoul and Busan with the other cities got bigger.

Table 22: Result of KSUTI

City	Rank	Score
Seoul	1	54.01
Busan	2	53.00
Daejeon	3	50.00
Incheon	4	49.95
Daegu	5	49.22
Ulsan	6	49.17
Gwangju	7	48.61

Source: Made by Author.

To give an overview, here is the score for each category and in total:

Table 23: Overview of KSUTI Scores

City	Urban Structure	Trans-portation	Environ-mental D.	Economic D.	Social D.	KSUTI Total
Seoul	1	2	1	3	4	**1**
Busan	5	3	2	2	1	**2**
Daegu	4	4	6	4	7	**5**
Incheon	3	1	5	7	3	**4**
Gwangju	2	7	4	6	6	**7**
Daejeon	6	6	3	5	5	**3**
Ulsan	7	5	7	1	2	**6**

Source: Made by Author.

Seoul scores high in the first 3 dimensions and Busan is in the upper ranks in all dimensions except for the urban structure. Daegu has the last rank in the social dimension and in 3 categories the fourth rank. Incheon's ranks vary largely. Gwangju was even second in the urban structure-category, but it was ranked low for transportation, social dimension and economic characteristics. Ulsan has two times the last position but in the economic dimension it scores as the best city.

So how does the KSUTI evaluate cities in comparison to the other two Korean indices? Different viewpoints and measurement tools lead obviously to different outcomes. The official index measures greenhouse gases, air pollution, traffic accidents, congestion and public transport-related issues. The green growth index is divided into a low-carbon eco-friendliness, aspects about energy efficiency and the economic activity regarding sustainability. Ulsan has in both

Table 24: Result of Previous Indices

City	Index of Sustainability of Transport Systems – Rank [1)]	Green Growth Transport Index – Rank [2)]
Seoul	1	5
Busan	2	4
Daegu	3	3
Incheon	4	6
Gwangju	6	2
Daejeon	5	1
Ulsan	7	7

Source: 1) KOTI, 2014b; 2) Choi et al., 2009, 105.

indices the last rank, but in the KSUTI it is on the second-last rank. More points for the social and economic dimension gave Ulsan a better rank than Gwangju. Seoul, Busan and Incheon have the same ranks in the KSUTI and the official index. In the green growth index Seoul ranks only fifth, Busan is fourth and Incheon is sixth. Busan scores better than Seoul in low carbon-dimension and for economic activity, because of a lower CO_2 emissions, less traffic accidents and a higher travel speed. In difference to the green growth index, the KSUTI includes the social dimension. A large difference between the KSUTI and the green growth index shows Gwangju, which is ranked second in the KOTI's index but last in the KSUTI. It is influenced by a low CO_2 emissions in total and per capita, low air pollution rates and a low energy usage by transportation. In general, smaller cities score better in the green growth index because of their lower amount of total CO_2 emissions. In addition, the green growth index regards the distance travelled by cars as positive and henceforth, cities like Daegu and Gwangju, which proved to have a higher motorization rate and longer travels by car have a better score. However regarding sustainable transportation, the usage of cars and length of trips should be as low as possible, as the KSUTI is expressing it.

The KSUTI and the official index have the same outcome for 3 of the 7 cities. Gwangju and Ulsan are both at the bottom of the ranking, just in reverse order. Only Daejeon and Daegu show a difference of two ranks. The official index evaluates Daegu as better than Daejeon because lower CO_2 per capita, higher satisfaction of public transportation, less traffic fatalities, a higher share of public transportation and green transport. Congestion is also less severe in Daegu than in Daejeon. In the

KSUTI Daejeon scored better for bicycle network length, fuel usage, the GRDP, expenses for public transportation, accessibility and some other indicators.

The official transportation index has the advantage that it covers even a subjective parameter through the survey of 'satisfaction of public transportation'. The usage of subjective topics is a good addition to objective indicators and it measures an aspect of the quality of life. For this indicator Seoul receives the best score and Incheon has the worst score. Besides the official index was applied to almost all municipalities in Korea. Even though the 7 cities for the KSUTI were chosen because of their easy accessibility of data, it does not mean that data for other indicators may be missing in smaller cities. It is expected that data about registered vehicles, population, land size, accidents and so on exist. So the KSUTI could be extended to all cities.

The comparison of total scores shows that the rankings of the cities in the KSUTI and the currently used index are relatively similar. Nevertheless, the KSUTI uses 5 categories and 22 indicators, which are twice as many indicators as the official index, and so it covers more aspects and more issues. The biggest strength of the KSUTI is that it generates a more comprehensive picture of sustainable transportation. This is an advantage for the formulation of policies, which is the main function of an indicator compilation.

5. Implication for Policies

The purpose of the index was to use it to reflect on policy, therefore this chapter briefly discusses how the findings can be translated into measures. However before that, the subchapter 5.1 will apply an exploratory data analysis technique in order to simplify the formulation of measures.

5.1 Clustering of Indicators and Cities

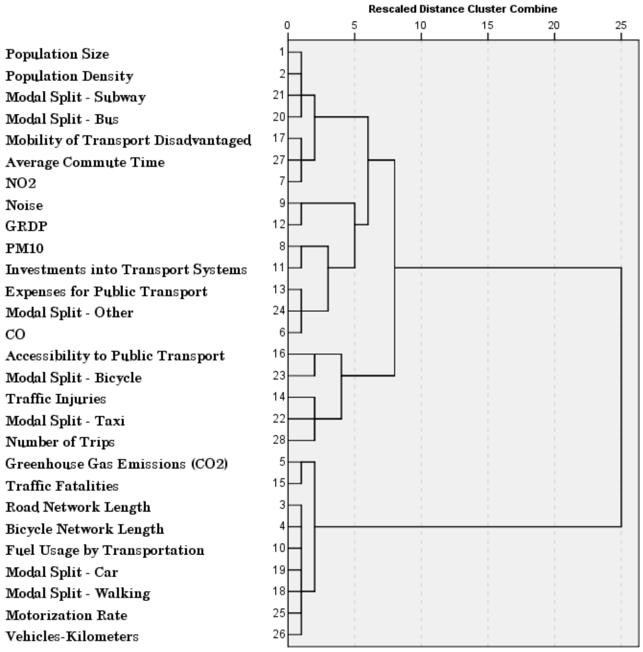
A cluster analysis is carried out in this subchapter. This method identifies groups with a high homogeneity in the data. It is made once with the indicators, which are treated as 28 variables (each modal split separately) and then for the 7 cities.

In both cases a hierarchical cluster analysis with the Ward method and squared Euclidean distance of the standardized values was performed in SPSS as the first step. The Ward method showed the most-structured results and the squared Euclidean interval allowed a better distinction between clusters than the simple Euclidean interval. The dendrogram and testing of different cluster sizes assisted in determining the best number of clusters for the non-hierarchical cluster analysis with k-means, which was done in the next step. This method has the advantage that it provides valuable information about the clusters (cluster membership, cluster centers and distances, ANOVA). Outputs are summarized in Appendix 2.

5.1.1 Analysis of Indicators

This subchapter attempts to answer the following questions: Are there any groups that show a similar variance for the 7 cities, among the indicators? What kind of aspects of sustainable transportation do these groups represent?

Figure 19: Dendrogram of Indicators



Source: Made by Author.

The preliminary hierarchical cluster analysis has 9 initial clusters, which have between 2 and 7 indicators. A cluster-analysis with 2 classes would divide the indicators into measures of pro-sustainable trans-port and indicators contra-sustainability. The coefficients of the agglomeration schedule began to increase greater than before at 5 clusters and the dendrogram indicates also that 5 clusters will be the most detailed separation of indicators that is interpretable. Therefore, the cluster analysis with k-means was done for 5 clusters. The indicators are grouped according to their values for the cities and not by what they measure. It identifies similar patterns of indicators and the same cluster membership does not mean that they are directly influenced by each other but that they have a strong (dis)similarity.

Table 25 on the next page shows the result of the non-hierarchical cluster analysis with 5 clusters. The first cluster consists of CO, PM10, private expenses for public transport, mobility of transport disadvantaged and the modal split of other transport methods. Incheon has high values for all these indicators and its share of other transport methods is 4.1 percent. Seoul also has high values for all of these indicators. CO and PM10 are caused by similar sources but there is no causal connection to public transport or special transport methods of mobility impaired. A causal connection between all 5 indicators is difficult to identify. Yet the first cluster can be labeled as additional features of a sustainable transport system because as the research will show, these aspects have higher values for cities with a good score for the KSUTI.

The second cluster contains population size, population density, NO_2, investments into transport systems, modal splits of bus, subway and taxi, commute time and number of trips. The majority of them represent important positive elements of sustainable transportation.

Table 25: Five Clusters for Indicators

Cluster	Cluster Members
Cluster 1	CO PM10 Expenses for Public Transport Mobility of Transport Disadvantaged Modal Split - Other
Cluster 2	Population Size Population Density NO_2 Investments into Transport Systems Modal Split - Bus Modal Split - Subway Modal Split - Taxi Average Commute Time Number of Trips
Cluster 3	Road Network Length Bicycle Network Length Greenhouse Gas Emissions (CO_2) Fuel Usage by Transportation Traffic Injuries Modal Split - Walking Modal Split - Car Motorization Rate Vehicles-Kilometers
Cluster 4	Accessibility of Public Transport Modal Split - Bicycle
Cluster 5	Traffic Fatalities Noise GRDP

Source: Made by Author.

There is a close relationship between popu-lation size and population density, because the exa-mined cities show that cities with a larger popu-lation have a higher density. Such cities also had a higher share of buses and subways. An efficient public transport system benefits from the high density and there are many potential users in the catchment area. Expenses per capita by the government are higher in the large, highly-dense cities. Possible reasons could be that more transport services are offered, which require funds, or that new transportation projects are initiated by the local government. The number of trips is a part of this cluster and that indicator basically stands for the level of mobility. More trips are recorded in the larger cities. The previous chapter pointed out that cities like Seoul and Busan have longer commute times than cities with lower density and a lower share of public transport. Such factors influence the commute to school or work in a negative way. Seoul did also account for a significantly higher

NO_2 concentration than the other 6 cities. Seoul is the cluster center, which means that of all cities it is the closest to this cluster. The capital leads in many categories, which are part of the cluster. In summary, this cluster can be named the pro-sustainable transport indicator group.

The third cluster shows that there are similar patterns between features like road network length, CO_2, fuel usage, traffic injuries and the 3 car-related indicators (modal split of cars, motorization rate and vehicle-kilometers). The length of the bicycle network is part of this cluster because there is a close relationship to the road network. Usually bike paths follow the roads and the ratio of bike network length to road network length is between 8 and 30 percent. People appear to walk more due to low density and less public transportation. The third cluster has as many members as the second cluster. Seoul has the lowest values for this cluster, while Ulsan and Gwangju have positive correlations to that cluster. The indicators mainly measure the negative aspects of sustainable transportation, which have to be decreased as far as possible. Henceforth, the cluster represents contra-sustainable transport aspects.

The smallest group, with only 2 members, is cluster 4. It contains the accessibility of public transport and the modal split of bicycles. If the time to reach a bus stop or subway station increases, the share of bicycle usage also goes up. In other words, if the accessibility gets worse, the rate of cycling increases. Daegu had the worst accessibility but at the same time the city has the highest percentage of bicycle usage in the KSUTI. Other cities have a comparable pattern. It seems that lower accessibility is compensated for by a higher usage of bicycles. The phenomenon has to be examined further because the sample of 7 cities could be misleading. The fourth cluster describes the potential of bicycle usage.

Noise, GRDP and traffic fatalities are in the fifth cluster. Ulsan, for example, has not only the highest GRDP, but that city has also the highest noise levels and most traffic fatalities. Economic activity may lead to higher average level of noise than in other cities. Noise can be caused by freight vehicles, factories or other economic activities. The bridge to traffic fatalities consists due to a higher rate of accidents in cities like Ulsan, Incheon and Busan, who have a GRDP above average. An exception is Seoul, which has the second-highest GRDP per capita but the lowest number of traffic deaths per 10,000 people. The label for this cluster can be economic aspects of transportation.

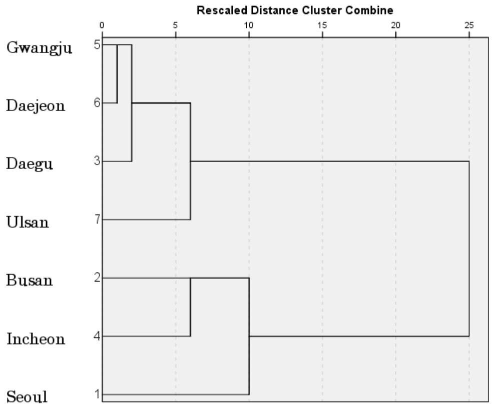
The output of the cluster analysis describes how close these 5 groups are to each other. Cluster 2 is the closest to cluster 1 and cluster 4. These 3 clusters combine mostly positive aspects of transportation and cities, which tend to have high values for the indicators them have a better score in the KSUTI. Cluster 3 has the lowest distance to cluster 5. They represent unfavorable conditions for sustainable development. The largest distance is between cluster 2 and cluster 3. Obviously the second cluster about sustainable transportation and the third cluster about car-related indicators display opposite aspects of the same coin.

In conclusion, the cluster analysis shows that sustainable transportation in Korea consists of the elements in cluster 2: Korean cities require a well-developed public transportation system with a high density and high investment for achieving a sustainable transportation system. Usage of cars and fossil-fuel vehicles has to be limited and the safety of transport users has to be increased. Bicycles are not a substitute for car trips and so far they seem to function as feeders to the public transportation network in Korean cities. Policies have to embrace that and they have to integrate these aspects in a bundle of measures.

5.1.2 Analysis of Cities

Now, a cluster analysis will divide the 7 cities into groups.

Figure 20: Dendrogram of Cities



Source: Made by Author.

The dendrogram of the hierarchical cluster analysis shows that the usage of 3 clusters delivers good, interpretable results. 2 clusters would split the cities in a big group of 5 and another containing just Seoul and Busan. 4 clusters would leave 2 cities as single-members of a group and combine the cities in a totally different way than the initial clusters. Besides, 4 groups would be too many for 7 cities. The non-hierarchical cluster analysis with k-means is applied to the data and the following 3 clusters are identified: Seoul is the single member of the first cluster, Busan and Incheon form the second cluster and Daegu, Daejeon, Gwangju and Ulsan are in the third cluster.

Seoul has distinctive characteristics and so it stands out from the other 6 examined cities. The capital of Korea has the highest values for population size, density, NO_2, noise levels, bus usage, subway share, commute time and number of trips. Seoul has the lowest values for road network length, bicycle paths, fuel usage, traffic deaths, share of walking, car usage, motorization and vehicle-kilometers. The higher concentration of people and activities is probably the reason why NO_2 and other air pollutants are more emitted. Seoul represents a public transportation-dominated city with a well-developed sustainable transport system. The capital has high values for the items of the second indicator cluster, which were regarded as aspects of sustainable transportation.

The second city cluster consists of the two port cities Busan and Incheon. They have similar rates of bicycle paths and road network, which is below the average of the 7 cities. Fuel usage, walking trips, cycling and car usage is also below average. These two cities have the lowest rates of traffic injuries. Both have a relatively high share of subway. Incheon is part of the greater Seoul metropolitan metro network and Busan has a subway network of 5 lines. The motorization rate is above average in Incheon but it is still lower than in the other 4 cities. Busan and Incheon form the group of hybrid cities, which is between a public transport-dominated and car-depended system. In terms of sustainable transportation, their transport system is relatively good but it still has potential to develop. Examining the distance between the cluster, Busan and Incheon are closer to the third cluster than to Seoul.

The other 4 cities make up the third cluster. They have a population size between one and 2.5 million. All cities except Ulsan have a similar population density of around 2,800 people per square kilometers. Common features, which are above average, are fuel usage and share of walking as well as the share of cars. All these cities even have a modal split of cars above average. It is around forty percent in Ulsan, Daejeon and Gwangju. The vehicle-kilometers are above average, too. The commute time in these for cities is lower but the usage of buses and subways is low. Except Daegu and Gwangju all cities show high CO_2 emissions per capita. CO_2 emissions are by far the highest in Ulsan. The third group clearly represents car-dominated cities. In combination with the previous subchapter, indicators from the third cluster are represented very strongly in this group.

The clustering generally confirms the ranking of the KSUTI. Seoul, the public transportation-dominated city, which dominates many of the sustainable transport-related indicators, is on top, followed by Busan in the second rank. Daejeon is in third position ahead of Incheon. The reasons for that rank is that Daejeon received better scores for the environmental and economic dimensions.

The grouping of cities assists in policy-making because similar measures can be applied to cities of the same group. Seoul requires another strategy than the third cluster or Busan and Incheon. For example, Seoul has to lower air pollution while improving sustainable transportation-related indicators.

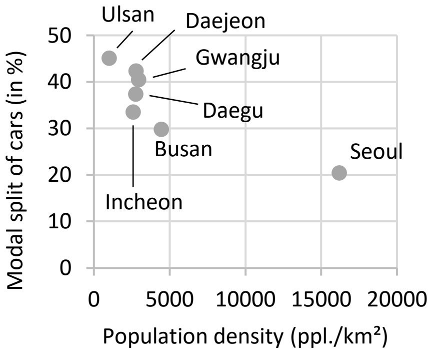
5.2 Application of Findings to Policies

I mentioned several times throughout the dissertation that the KSUTI should help to make policy measures. This subchapter will briefly show, what kind of suggestions can be given with the result of the KSUTI and the clustering.

Regarding the urban structure, the results emphasized the importance of a high population density. A compact city has many advantages and it is fundamental for a sustainable transportation system (Cameron et al., 2003). That's also the case for Korea. Sustainability of transportation systems strongly relies on a high density and a well-developed public transportation. For example, the high population density offers many advantages in Seoul.

The other cities have to increase their population density, or at least they have to prevent sprawl and a decrease of urban density. Fig. 21 implies how the share of cars decreases with an increasing density. So a city should monitor the development of the density and the usage of land. In general, the population density can be increased through an influx of people or through compact planning. Strict regulations should minimize the usage of new land for construction of residential neighborhoods. For Seoul the restricted development zones and the high population pressure are main reasons for the high density. The measure has to be reevaluated and adjusted to the modern settings in areas, where the negative side-

Figure 21: Relationship between Car-Usage and Density



Source: Made by Author.

effects can be kept to a minimum.

In addition to the density, the land use in the urban areas is a crucial factor of a sustainable transport system. Mixed land use was not so often used as an indicator as other measurement tools but still it is very important. As the literature showed, the urban structure has to be diverse, if the demand for motorized private transport has to become low. A variety of services and daily needs should be within walking or cycling distance.

Concerning the environmental dimension, cities have to decrease their dependence on fuel, which is a main cause for air pollution and greenhouse gas emissions. Fuel usage can be decreased to a certain point with a better fuel efficiency of vehicles or smaller cars. As already said, the government works on the improvement of fuel efficiency. Cars have to better fit to the urban environment. Smaller cars, which use less fuel, are quieter and have lest exhaust fumes at the same time. It would have positive impacts on all indicators of the environmental dimension. Another way to reduce energy consumption and emission is through less vehicle-kilometers and more usage of non-motorized transport. Generally, bicycles are an important element of sustainable transportation. They are regarded as the best transport method for short trips (Replogle, 1992). However, all Korean cities show a very low share of cycling. The study could not find a very strong relationship between cycling and pro-sustainable transport indicators. As it was mentioned in the previous subchapter, the highest potential for bicycles is as a supplement to public transportation. If Korea wants to increase their share of cycling, it has to be equal to cars and public transportation, which means that high-qualitative infrastructure and public promotion of cycling is necessary. Bicycles will not replace a commute but through an increase of leisure activities an aging society the bicycle can be used for shopping, recreational and personal businesses.

The economy has to embrace sustainable development. The highest GRDP has Ulsan, which has the second-lowest score in the KSUTI and the cluster analysis showed that the GRDP is associated with negative aspects of transportation. The indicators of the economic dimension, especially GRDP, have to be adjusted better in order to reflect green growth. The investments for transport systems and expenses for public transport should have an adequate level which keeps a balance between financial sustainability and satisfaction of users/tax payers.

For the social dimension, traffic injuries have been a major issue. The cluster analysis showed that the values for that indicator stand in a connection to car-related issues. Conflicts of private motorization and other transport users have to be avoided and the safety of the transport environment has to be raised. To give an example, traffic calming can reduce motorized traffic in neighborhoods. Behind the score for mobility impaired are a couple of measures summarized, which can be directly translated to policy measures: expansion of low-floor buses, more transport services for elderly and handicapped, higher quality of pedestrian amenity and so on. Accessibility was evaluated as the second most important indicator. An efficient network of public transport has to cover the whole city. Sustainable transportation goes beyond technical innovation and demand-oriented policies are essential and most importantly, an improvement of accessibility is the goal (UN-HABITAT, 2013).

Cities have to shift to a public transportation-dominated transportation system. Seoul can function as a vision for the other cities, but Korea's capital has not yet reached an end-state. Especially because Seoul has currently still high NO_2 levels and other pollutants. Private motorization can be decreased through measures like higher costs for driving (fuel tax, parking prices and road tolls), ban of cars in certain areas, reducing the need to drive by relocation of jobs close to residential areas and higher frequency of public transport (Liddle and Moavenzadeh, 2002). The 4 cities of the third cluster have to promote public transportation by making the service more attractive and introduce charges for car usage inside the inner-city or on congested roads. The division of indicator into the two different areas shows that private motorization and sustainable transport is not compatible with each other. All cities should put the priority on pedestrians and evolve the transportation and urban planning from the pedestrian-friendly scale. Then the design of streets would change and more amenities for pedestrians and public transport users will appear. Currently, the official index divides all municipalities into 3 groups (according to their population size) and the city (or 2 cities) with the lowest score receive financial support and special measures will be applied, as Ch. 2.3 mentioned. This research grouped the cities and the ministry of government can develop package of measures for each group and maybe even have special funding for the lower-developed group.

A popular strategy for sustainable transportation is the 'avoid, shift and improve'-approach. It contains the following 3 elements: first, 'avoid' is about the reduction of trips and travel lengths; second, 'shift' implies a change of usage from cars to public transit; and last, 'improve' means that the energy efficiency of cars and other vehicles has to be improved. (ADB, 2009)

This approach was applied to Seoul in an analysis of the past measures: The city 'avoided' a large increase in private motorization through land-use regulations, a 'shift' to public transportation was facilitated by mass transit and 'improvements' were about lower emissions of private vehicles (Nakamura and Hayashi, 2013). This strategy is just an example to emphasize that approaches have to be holistic and integrate various aspects. Similar to the concept of sustainable development, the measures have to cover various areas and be well-integrated. The KSUTI pointed out weaknesses in each of the 7 cities and groups were identified. Every city should examine the issues, explore the reasons and apply measures, which are tailored to their city or their group. Cooperation between members of each group may be helpful. The national government can establish a platform for communication and every group can get a guidance as well as financial support for the promotion of sustainable transport. On that way every city would gain something and not only the least-developed city. The KSUTI showed that every of the 7 cities has weaknesses.

Banister (2008) explains the situation well: The measures to achieve sustainable transportation are already well known, but the citizens are the key because they have to understand the importance of sustainable transportation in order to initiate political change. The citizens are crucial because often policy makers follow the public opinion, so the will for sustainable development has to come from the public (Geels, 2012). Measures may develop from educating people about the need of sustainable transportation and involve them in campaigns over showing the benefits of alternative transport methods to gradual policy implementations (Banister, 2008). In this sense, the KSUTI offers an important function: The score can be easily understood by citizens. The index assists in simplifying the complex issue and makes it comparable. To see a city in the lower ranks expresses the need for action.

5.3 Future Development of KSUTI

This subchapter discusses briefly at what point this research ends and what future research has to explore further.

First of all, I acknowledge that this dissertation has certain limitations in its methodology. The priority of the research was not to have a critical analysis of the theory behind indicator compilations or the concept of sustainable transportation. Instead this dissertation was a practical-orientated research and it tried to show the current state of sustainable development in Korean urban transport systems. It was about the application of a new indicator set to the largest Korean cities.

This dissertation set out to score the cities according to an index compiled of the most-commonly used indicators. The research tried to minimize subjective selection issues but it is unable to overcome them completely. The literature review of existing sustainable transportation assessments has at least two shortcomings: first, even though efforts were made to create a complete list of indicator compilations, there may be still some works missing; and second, it was difficult to summarize the indicators in an objective way. Indicators are nominal and the same issue may be measured under different names. Generalization was attempted as far as possible. However, the literature review contains 278 indicators, which were only used one time, 59 indicators were used in 2 indicator sets and 29 indicators were used 3 times.

An issue in the cluster analysis was that it was difficult to identify a suitable number of clusters due to the small sample size. A sample of bigger cities would result in more distinctive results, which means that there will be more groups among cities and among indicators.

This work focuses only on objective parameters of urban transport systems. However the transport system is widely shaped by the user inside the system. Quality of life may be regarded differently by individuals and such views can be only measured through subjective indicators. Moreover raising the quality of life for everybody means that some people will have difficulties adjusting to that change and feel a short-term fall in life quality (Steg and Grifford, 2005). Certain studies (for example Klinger et al., 2013) have a mix of objective and subjective parameters. As such, a next step to advance this research area could be to include such subjective indicators for the assessment of each city’s transport system. The next version of the KSUTI has also to build an indicator set through the involvement of stakeholders and transport experts. According to Sing et al., (2009), the kind of approach of this dissertation takes can be seen as a top-down method, where a bottom-up approach would include stakeholders in all steps.

Both the index and approach of this dissertation have the potential to be also applied to cities outside of Korea. Using the result of the literature survey and checking for data-availability as well as weighting the indicators for the assessment of the other specific research areas have to be done in advance and then the index can assess other cities. The indicator compilation can be used for cities in emerging countries or even for an international comparison of cities from a comprehensive viewpoint. In addition, the brief history of sustainable development in Korea's transport sector introduced lessons that would be very useful for other cities experiencing a very rapid increase in cars.

In summary, the next version of KSUTI has to improve the literature-based indicator survey and incorporate it with roundtable discussions, which discuss indicators, frameworks and the weights. More subjective parameters, for which in some cases the data has to be collected empirically, have to be included. The findings of the most common indicators can be used on other levels and other countries as well.

6. Conclusion

In 2008 the green growth paradigm introduced a shift to sustainable transportation in Korea and since then an index has evaluated the transportation system through 11 indicators covering greenhouse gas emissions, air pollution, traffic deaths, public transport satisfaction, public transport share, green vehicles share and congestion.

Supported by literature and a summary on indicator assessments, this research suggest that the concept of sustainable transportation is very complex and a wider range of indicators is required to evaluate urban transport systems. The KSUTI was designed with 2 additional categories, namely the urban structure and transportation, and twice as many indicators representing the most often-used indicators from a survey of 52 indicator initiatives. The survey identified traffic accidents, modal split, air pollution emissions, motorization rate and expenses for transportation as the 5 most commonly used indicators. A weighting by mixed group of transport experts and citizens or civil servants chose the population density, accessibility and CO_2 emissions as the most important indicators for the assessment of sustainable transportation in Korea.

After applying the KSUTI, Seoul received the highest score and the second to fourth rank were Busan, Daejeon and Incheon. Fifth was Daegu and Ulsan was sixth. Gwangju had the lowest score due to a bad performance in the economic and social dimension as well as in transportation. Seoul showed a dominance in the urban structure and the environmental dimension. Incheon received the most points for transportation. Ulsan lead the economic dimension, and the social dimension was dominated by Busan.

A cluster analysis analyzed the data of indicators and cities. Indicators of a similar pattern were grouped and it highlighted public transportation, population density and the number of trips as important features of sustainable transport in Korea. Among the cities the research identified 3 groups: Seoul is a high-density, public transportation-dominated cities and Daegu, Daejeon, Gwangju and Ulsan are the group of medium-sized cities with a dependency on private motorization. In between are the 2 cities Busan and Incheon, which show a well-developed system but high numbers of private vehicles. Each group requires different, holistic approaches.

The result of the KSUTI did not differ largely from the official index, but the KSUTI has the advantages that it contained more information and covered a wider variety of aspects that were helpful for understanding the situation of sustainable transportation in cities and assisting in policy formulation. Moreover, the index can be useful for the assessment of sustainable transportation in other countries.

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Appendix 1

	Klinger et al., 2013	Silva and Costa, 2010	Audenhove et al., 2014	Black, 2002	Siemens, 2010	Litman, 2013	Victoria Transport Policy Institute, 2003	Victoria Transport Policy Institute, 2014	Ahvenharju et al., 2004	Nicolas et al., 2003
Population size	■									
Population density	■	■	■							
Road network length		■								
Air pollution emissions						■			■	■
CO emissions		■		■	■					
CO_2 emissions		■	■	■		■				■
NO_X/NO_2 emissions			■	■	■	■				■
PM10 concentration			■		■	■				■
Traffic noise		■				■			■	■
Transport energy use					■	■			■	
Fuel usage by transport						■				
Land take by transport						■			■	■
GDP/GRDP						■				
Expenses for public transport						■			■	
Traffic accidents (deaths and injuries)		■	■	■	■	■	■		■	
Modal split	■		■		■	■	■		■	■
Share of zero-emission vehicle			■			■	■			
Motorization rate	■	■	■	■				■		■

	Georgiadis, 2010	Cameron et al., 2003	OECD, 1999	Kenworthy and Laube, 1996	Zegras, 2005	World Council of Business Solutions for a Sustainable World, 2004	Vivier., 2006	US-EPA, 2011	Taylor and Clifford, 2006	Schipper and NG, 2006
Population size	■	■			■		■		■	■
Population density	■			■	■					
Road network length		■	■	■	■		■	■		■
Air pollution emissions			■			■	■			■
CO emissions										
CO_2 emissions							■	■		■
NO_X/NO_2 emissions							■			
PM10 concentration										
Traffic noise			■							
Transport energy use			■				■			
Fuel usage by transport			■						■	■
Land take by transport										
GDP/GRDP	■	■					■		■	■
Expenses for public transport								■		
Traffic accidents (deaths and injuries)			■				■		■	■
Modal split		■	■	■	■		■	■	■	■
Share of zero-emission vehicle					■		■	■		
Motorization rate		■	■	■	■		■		■	■

	Kumar, 2014	Gilbert et al., 2003	Nathan and Reddy, 2011	Cervero and Kockelman, 1997	EEA, 2013	Jeon, 2007	Barter, 1999	Baltic 21, 1998	Henning et al., 2011a
Population size				■					
Population density	■						■		■
Road network length		■	■				■	■	
Air pollution emissions	■	■	■		■	■			■
CO emissions			■		■				
CO_2 emissions			■		■	■		■	■
NO_X/NO_2 emissions	■		■		■	■		■	■
PM10 concentration			■		■	■			■
Traffic noise	■		■		■	■		■	
Transport energy use		■			■		■		
Fuel usage by transport	■					■			■
Land take by transport						■			
GDP/GRDP									■
Expenses for public transport	■								
Traffic accidents (deaths and injuries)	■	■	■			■		■	■
Modal split	■	■	■		■	■			■
Share of zero-emission vehicle					■				
Motorization rate		■	■				■		

	Zito and Salvo, 2011	Marsden et al., 2007	Haghshenas and Vaziri, 2012	Henning et al., 2011b	Thynell et al., 2009	Arora and Tiwari, 2007	Joumard and Nicolas, 2010	Coevering and Schwanen, 2006	Reisi et al., 2014	TRB, 2008	Briassoulis, 2001
Population size	■			■				■			
Population density								■			■
Road network length	■			■				■			
Air pollution emissions		■	■	■	■		■		■	■	
CO emissions			■						■		
CO_2 emissions	■	■							■	■	
NO_X/NO_2 emissions		■	■						■		
PM10 concentration	■						■		■		
Traffic noise		■					■			■	
Transport energy use		■	■	■							■
Fuel usage by transport											■
Land take by transport			■				■		■		
GDP/GRDP	■	■						■			
Expenses for public transport	■				■					■	
Traffic accidents (deaths and injuries)	■	■	■	■	■				■	■	
Modal split	■			■		■				■	■
Share of zero-emission vehicle											
Motorization rate	■		■			■		■		■	■

	Borken, 2003	Dobranskyte-Niskota et al., 2007	Lee et al., 2003a	Dhingra, 2011	Hale, 2011	May, 2003	OECD, 2002	Lee et al., 2003b	Choi et al., 2011	KOTI, 2014	Hong, 2002	Lee, 2007	**TOTAL**
Population size					■								**12**
Population density					■								**13**
Road network length		■	■								■		**18**
Air pollution emissions			■	■		■		■	■	■	■	■	**28**
CO emissions													**7**
CO_2 emissions	■	■					■				■		**21**
NO_X/NO_2 emissions	■	■					■				■		**19**
PM10 concentration	■	■					■				■		**15**
Traffic noise	■	■	■			■	■				■	■	**20**
Transport energy use		■	■					■	■		■		**17**
Fuel usage by transport		■		■		■			■				**12**
Land take by transport	■	■	■				■		■			■	**14**
GDP/GRDP									■				**11**
Expenses for public transport		■	■						■				**10**
Traffic accidents (deaths and injuries)		■	■	■		■		■	■	■	■		**32**
Modal split			■	■	■			■			■		**31**
Share of zero-emission vehicle									■	■	■	■	**11**
Motorization rate		■			■								**24**

	Klinger et al., 2013	Silva and Costa, 2010	Audenhove et al., 2014	Black, 2002	Siemens, 2010	Litman, 2013	Victoria Transport Policy Institute, 2003	Victoria Transport Policy Institute, 2014	Ahvenharju et al., 2004	Nicolas et al., 2003	Coevering and Schwanen, 2006
Vehicle kilometers				■				■			
Transport expenses		■			■	■			■	■	
Public transportation fares		■							■		
Bike network length		■			■		■				
Travel distance		■					■		■	■	
Travel time		■	■		■						
Number of trips		■						■		■	
Passengers per kilometer		■									
Freight transport (ton per kilometer)											
Accessibility of public transportation		■							■		
Accessibility for mobility impaired		■				■			■		
Investments into transport systems		■				■				■	

	Reisi et al., 2014	TRB, 2008	Briassoulis, 2001	Henning et al., 2011a	Kumar, 2014	Gilbert et al., 2003	Nathan and Reddy, 2011	Cervero and Kockelman, 1997	EEA, 2013	Borken, 2003	Dobranskyte-Niskota et al., 2007
Vehicle kilometers		■		■			■				
Transport expenses		■				■	■				■
Public transportation fares					■						
Bike network length								■			
Travel distance					■						
Travel time					■						■
Number of trips					■						
Passengers per kilometer			■	■	■		■		■		■
Freight transport (ton per kilometer)		■	■			■			■		■
Accessibility of public transportation					■						
Accessibility for mobility impaired		■			■						■
Investments into transport systems		■		■							■

	Georgiadis, 2010	Cameron et al., 2003	OECD, 1999	Kenworthy and Laube, 1996	Zegras, 2005	World Council of Business Solutions for a Sustainable World, 2004	Vivier., 2006	US-EPA, 2011	Taylor and Clifford, 2006	Schipper and NG, 2006
Vehicle kilometers		■		■			■	■		
Transport expenses						■	■			■
Public transportation fares	■		■						■	■
Bike network length									■	
Travel distance		■			■		■			
Travel time						■	■	■		■
Number of trips	■				■		■			■
Passengers per kilometer	■	■					■	■	■	
Freight transport (ton per kilometer)			■							■
Accessibility of public transportation	■							■	■	■
Accessibility for mobility impaired										■
Investments into transport systems		■	■				■		■	

	Zito and Salvo, 2011	Marsden et al., 2007	Haghshenas and Vaziri, 2012	Henning et al., 2011b	Thynell et al., 2009	Arora and Tiwari, 2007	Joumard and Nicolas, 2010	Jeon, 2007	Barter, 1999	Baltic 21, 1998
Vehicle kilometers	■							■	■	
Transport expenses	■	■	■	■		■	■	■		
Public transportation fares					■					
Bike network length	■			■						
Travel distance						■				
Travel time		■	■		■	■		■		
Number of trips						■				
Passengers per kilometer	■		■	■				■	■	
Freight transport (ton per kilometer)								■		
Accessibility of public transportation	■				■	■				
Accessibility for mobility impaired										
Investments into transport systems										

	Lee et al., 2003a	Dhingra, 2011	Hale, 2011	May, 2003	OECD, 2002	Lee et al., 2003b	Choi et al., 2011	KOTI, 2014	Hong, 2002	Lee, 2007	**TOTAL**
Vehicle kilometers											**17**
Transport expenses											**22**
Public transportation fares											**10**
Bike network length											**10**
Travel distance											**11**
Travel time											**19**
Number of trips											**10**
Passengers per kilometer											**18**
Freight transport (ton per kilometer)											**11**
Accessibility of public transportation											**13**
Accessibility for mobility impaired											**10**
Investments into transport systems											**13**

Appendix 2

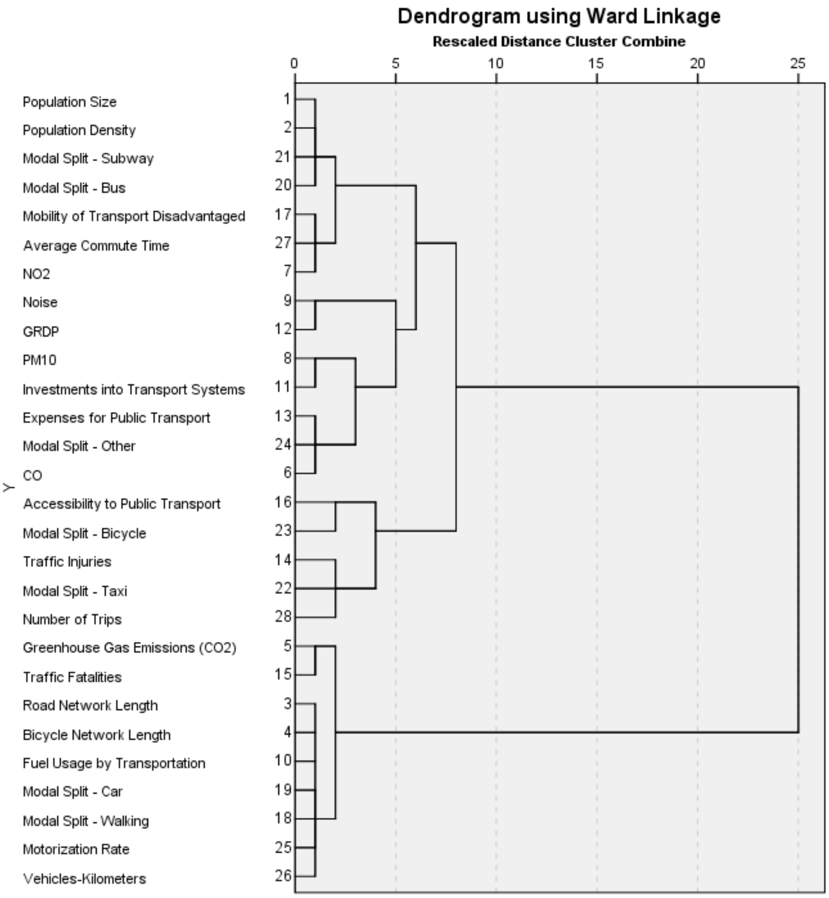
Cluster analysis for the indicators:

1. Hierarchical cluster analysis:

Agglomeration Schedule

Stage	Cluster Combined		Coeffi-cients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	1	2	.091	0	0	2
2	1	21	.443	1	0	16
3	10	19	.845	0	0	5
4	17	27	1.305	0	0	9
5	10	18	1.994	3	0	8
6	5	15	2.776	0	0	18
7	3	4	3.670	0	0	10
8	10	25	4.631	5	0	10
9	7	17	5.672	0	4	19
10	3	10	7.195	7	8	13
11	8	11	8.971	0	0	22
12	13	24	10.807	0	0	14
13	3	26	12.734	10	0	18
14	6	13	14.887	0	12	22
15	9	12	17.144	0	0	24
16	1	20	19.564	2	0	19
17	16	23	22.528	0	0	23
18	3	5	25.620	13	6	27
19	1	7	29.057	16	9	25
20	14	22	33.033	0	0	21
21	14	28	38.086	20	0	23
22	6	8	44.802	14	11	24

23	14	16	53.084	21	17	26
24	6	9	65.295	22	15	25
25	1	6	79.352	19	24	26
26	1	14	99.675	25	23	27
27	1	3	163.316	26	18	0



2. Non-hierarchical cluster analysis:

Iteration History

Iteration	Change in Cluster Centers				
	1	2	3	4	5
1	1.204	.875	1.033	1.217	.815
2	.000	.341	.342	.000	.000
3	.000	.000	.000	.000	.000

The maximum absolute coordinate change for any center is .000. The current iteration is 3. The minimum distance between initial centers is 3.314.

Cluster Membership

Case Number	Indicators	Cluster	Distance
1	Population Size	2	.850
2	Population Density	2	1.024
3	Road Network Length	3	1.283
4	Bicycle Network Length	3	.897
5	Greenhouse Gas Emissions (CO2)	3	1.315
6	CO	1	1.530
7	NO2	2	1.600
8	PM10	1	1.799
9	Noise	5	1.680
10	Fuel Usage by Transportation	3	.778
11	Investments into Transport Systems	2	2.012
12	GRDP	5	.815
13	Expenses for Public Transport	1	1.200
14	Traffic Injuries	3	2.137
15	Traffic Fatalities	5	1.567

16	Accessibility of Public Transport	4	1.217
17	Mobility of Transport Disadvantaged	1	1.537
18	Modal Split - Walking	3	.970
19	Modal Split - Car	3	.602
20	Modal Split - Bus	2	1.531
21	Modal Split - Subway	2	.719
22	Modal Split - Taxi	2	2.731
23	Modal Split - Bicycle	4	1.217
24	Modal Split - Other	1	1.204
25	Motorization Rate	3	1.077
26	Vehicles-Kilometers	3	1.179
27	Average Commute Time	2	1.416
28	Number of Trips	2	2.088

Final Cluster Centers

	Cluster				
	1	2	3	4	5
Seoul	.22	1.44	-1.53	.41	-.06
Busan	-.16	.40	-.67	-1.37	-.08
Daegu	-.15	-.14	.46	1.37	-.15
Incheon	1.65	-.03	-.29	.13	-.51
Gwangju	-.46	-.41	.75	-.35	-.53
Daejeon	-.85	-.58	.47	.36	-.48
Ulsan	-.26	-.68	.81	-.56	1.80

Distances between Final Cluster Centers

Cluster	1	2	3	4	5
1		2.209	3.443	2.774	3.024
2	2.209		3.881	2.730	2.972
3	3.443	3.881		2.887	2.538
4	2.774	2.730	2.887		3.300
5	3.024	2.972	2.538	3.300	

ANOVA

	Cluster		Error		F	Sig.
	Mean Square	df	Mean Square	df		
Seoul	10.055	4	.539	23	18.640	.000
Busan	2.019	4	.355	23	5.695	.002
Daegu	1.339	4	.293	23	4.569	.007
Incheon	3.667	4	.408	23	8.983	.000
Gwangju	2.164	4	.393	23	5.509	.003
Daejeon	2.073	4	.234	23	8.845	.000
Ulsan	5.013	4	.299	23	16.739	.000

Number of Cases in each Cluster

Cluster	1	5.000
	2	9.000
	3	9.000
	4	2.000
	5	3.000
Valid		28.000
Missing		.000

Cluster analysis about cities:

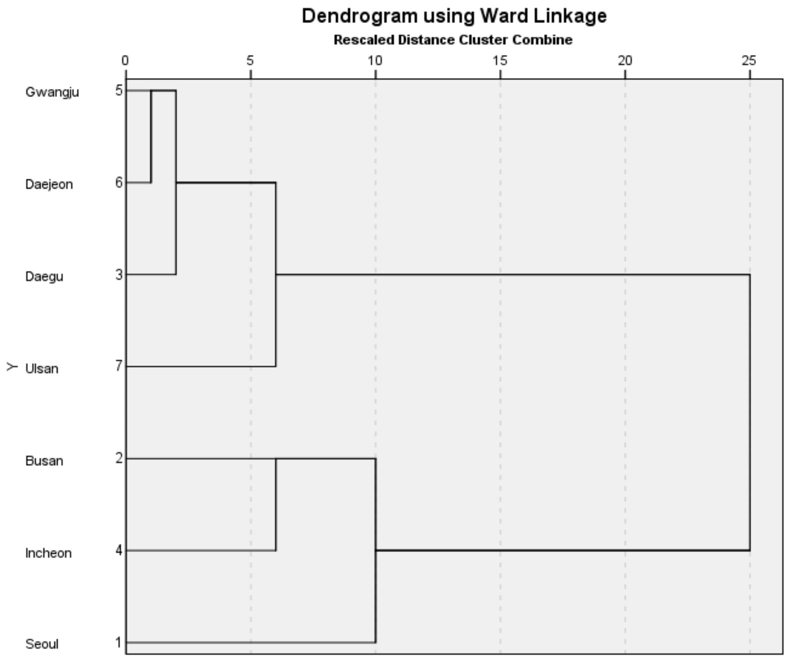
1. Hierarchical cluster analysis:

Case Processing Summary

Cases					
Valid		Missing		Total	
N	Percent	N	Percent	N	Percent
7	100.0	0	.0	7	100.0

Agglomeration Schedule

Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	5	6	8.760	0	0	2
2	3	5	20.784	0	1	3
3	3	7	43.123	2	0	6
4	2	4	65.906	0	0	5
5	1	2	98.123	0	4	6
6	1	3	168.000	5	3	0



2. Non-hierarchical cluster analysis:

Initial Cluster Centers

	Cluster		
	1	2	3
Population Size	2.18171	-.13953	-.69023
Population Density	2.22716	-.38510	-.69797
Road Network Length	-1.15284	-.61309	1.55338
Bicycle Network Length	-1.49881	-.13989	.58893
Greenhouse Gas Emissions (CO2)	-1.79438	.42594	1.44094
CO	.40141	1.68929	.05018
NO2	1.90769	.73507	-.12251
PM10	-.33594	1.24135	.55308
Noise	.94195	-.70646	1.24721
Fuel Usage by Transportation	-1.69447	-.67842	1.01268
Investments into Transport Systems	.44425	.32242	-.48795

GRDP	.16166	-.29867	2.19202
Expenses for Public Transport	.13388	1.71965	-.99861
Traffic Injuries	-.41629	-.97387	.04296
Traffic Fatalities	-1.27622	-.51818	1.94939
Accessibility of Public Transport	.70879	.70879	-1.39610
Mobility of Transport Disadvantaged	1.37707	1.45848	-.56060
Modal Split - Walking	-1.79562	-.51388	.23036
Modal Split - Car	-1.78906	-.24427	1.12364
Modal Split - Bus	1.44566	.55574	-.33417
Modal Split - Subway	1.98210	.05430	-.96390
Modal Split - Taxi	-.29596	-.95891	-1.29039
Modal Split - Bicycle	.10383	-.44130	.28555
Modal Split - Other	-.45738	2.16215	-.36036
Motorization Rate	-1.65262	.31911	1.06564
Vehicles-Kilometers	-1.96628	-.21332	.24115
Average Commute Time	1.43132	1.23951	-1.06906
Number of Trips	1.62193	-1.70741	-.42656

Iteration History

Iteration	Change in Cluster Centers		
	1	2	3
1	.000	3.375	4.093
2	.000	.000	.000

The maximum absolute coordinate change for any center is .000. The current iteration is 2.

The minimum distance between initial centers is 8.130.

Cluster Membership

Case Number	City	Cluster	Distance

1	Seoul	1	.000
2	Busan	2	3.375
3	Daegu	3	3.251
4	Incheon	2	3.375
5	Gwangju	3	3.048
6	Daejeon	3	2.551
7	Ulsan	3	4.093

Number of Cases in each Cluster

Cluster	1	1.000
	2	2.000
	3	4.000
Valid		7.000
Missing		.000

Final Cluster Centers

	Cluster		
	1	2	3
Population Size	2.18171	-.03601	-.52742
Population Density	2.22716	-.21555	-.44901
Road Network Length	-1.15284	-.75282	.66462
Bicycle Network Length	-1.49881	-.63312	.69126
Greenhouse Gas Emissions (CO2)	-1.79438	-.00227	.44973
CO	.40141	.22580	-.21325
NO2	1.90769	.02625	-.49005
PM10	-.33594	1.14098	-.48650
Noise	.94195	-.09594	-.18752
Fuel Usage by Transportation	-1.69447	-.60870	.72797
Investments into Transport Systems	.44425	.79504	-.50858
GRDP	.16166	-.39312	.15614
Expenses for Public Transport	.13388	1.00826	-.53760
Traffic Injuries	-.41629	-.89352	.55083
Traffic Fatalities	-1.27622	-.38939	.51375
Accessibility of Public Transport	.70879	-.34366	-.00537
Mobility of Transport Disadvantaged	1.37707	.55478	-.62166
Modal Split - Walking	-1.79562	-.49321	.69551
Modal Split - Car	-1.78906	-.46243	.67848
Modal Split - Bus	1.44566	.68288	-.70285

Modal Split - Subway	1.98210	.24437	-.61771
Modal Split - Taxi	-.29596	.24269	-.04735
Modal Split - Bicycle	.10383	-.89558	.42183
Modal Split - Other	-.45738	.80388	-.28759
Motorization Rate	-1.65262	-.38350	.60491
Vehicles-Kilometers	-1.96628	-.11594	.54954
Average Commute Time	1.43132	.72858	-.72212
Number of Trips	1.62193	-.79716	-.00690

Distances between Final Cluster Centers

Cluster	1	2	3
1		6.952	9.670
2	6.952		5.522
3	9.670	5.522	

ANOVA

	Cluster		Error		F	Sig.
	Mean Square	df	Mean Square	df		
Population Size	2.938	2	.031	4	94.108	.000
Population Density	2.930	2	.035	4	83.480	.001
Road Network Length	2.115	2	.443	4	4.777	.087
Bicycle Network Length	2.480	2	.260	4	9.533	.030
Greenhouse Gas Emissions (CO2)	2.014	2	.493	4	4.088	.108
CO	.223	2	1.389	4	.160	.857
NO2	2.301	2	.350	4	6.579	.054
PM10	1.832	2	.584	4	3.135	.152
Noise	.523	2	1.238	4	.422	.682
Fuel Usage by Transportation	2.866	2	.067	4	42.784	.002

Investments into Transport Systems	1.248	2	.876	4	1.425	.341
GRDP	.216	2	1.392	4	.155	.861
Expenses for Public Transport	1.604	2	.698	4	2.297	.217
Traffic Injuries	1.492	2	.754	4	1.978	.253
Traffic Fatalities	1.494	2	.753	4	1.984	.252
Accessibility of Public Transport	.369	2	1.315	4	.281	.769
Mobility of Transport Disadvantaged	2.029	2	.486	4	4.178	.105
Modal Split - Walking	2.823	2	.089	4	31.869	.003
Modal Split - Car	2.735	2	.133	4	20.630	.008
Modal Split - Bus	2.499	2	.250	4	9.983	.028
Modal Split - Subway	2.787	2	.106	4	26.197	.005
Modal Split - Taxi	.107	2	1.446	4	.074	.930
Modal Split - Bicycle	1.163	2	.918	4	1.267	.375
Modal Split - Other	.916	2	1.042	4	.879	.482
Motorization Rate	2.244	2	.378	4	5.942	.063
Vehicles-Kilometers	2.551	2	.225	4	11.350	.022
Average Commute Time	2.598	2	.201	4	12.929	.018
Number of Trips	1.951	2	.525	4	3.719	.122

국문 초록

지속가능한 교통 지표에 의한 한국 도시 평가

2014년 한국 자동차등록대수가 2천만을 넘어섰다. 1980년대부터 자동차 보유대수와 사용량의 증가로 대기오염, 교통혼잡, 소음과 같은 문제들이 발생했고 지속가능한 개발이 그 해결책으로 제시되고 있다. 이 논문은 지속가능한 교통 상황을 종합적으로 파악하기 위해서 가장 자주 이용되는 지속가능한 교통 지표로 한국 7개의 대도시를 살펴봤다.

최근 몇 년 동안 한국에서는 도시 내 교통을 개선하기 위한 정책을 시도하고 있다. 2004년 서울의 대중교통 개편은 한국 도시들의 정책 중에서 가장 앞서가는 예다. 국가는 2008년에 녹색성장의 일환으로 친환경 발전을 주목했다. 이를 계기로 지속가능한 교통에 대한 평가를 시행했으나, 사용되는 지표의 수가 적어 다양한 측면을 반영하지 못하고 정책 입안에 한계를 지닌다.

총 52개 지속가능한 교통 관련 지수 평가에서 교통사고, 교통수단 분담률, 대기오염, 자동차 등록률 등이 가장 자주 사용되는 지표로 발견되었다. 이 중에서 대도시의 통계 데이터에 접근할 수 있는 지표가 22개였으며, 5개의 카테고리(도시구조, 교통, 환경적, 경제적, 사회적 지표군)로 나누어진《Korean Sustainable Urban Transportation Index》를 제시했다. 지속가능한 교통과 관련된 전문가와 일반인, 공무원을 대상으로 실시한

설문조사로 각 지표의 가중치를 구했으며 인구밀도, 대중교통의 접근성, 온실가스(CO_2)가 높은 비중을 차지했다.

각 도시에 지수를 적용한 결과 서울이 가장 높은 값을 가졌으며 부산이 두 번째 대전이 세 번째로 그 뒤를 이었다. 그 다음 순서는 인천, 대구, 울산, 광주 순으로 나타났다. 서울은 도시구조와 환경적 지표군에서 가장 높은 점수를 받았으며, 인천은 교통 카테고리의 결과가 가장 높았고 부산은 사회적 지표군, 울산은 경제적 지표군에서 가장 높은 순위를 보였다.

정책을 제시하기 위해 지표와 도시에 대한 클러스터 분석을 실시했다. 지표들은 총 5개의 그룹으로 나누어졌으며, 이 중에서 2개는 지속가능한 교통의 특징을 보여 주고, 다른 2개는 자동차와 관련된 측면을 설명하며, 나머지는 자전거와 대중교통의 접근성에 대한 클러스터를 나타냈다. 도시의 클러스터 분석 결과 서울은 지속가능성이 가장 높은 대중교통도시이며, 광주, 대구, 대전, 울산은 자동차에 의존도가 높은 도시로 나타났다. 부산과 인천은 이 두 그룹 사이에 위치했다.

이 논문에서 제시하는 지수는 지속가능한 교통에 대한 다양한 측면을 포함하여 종합적으로 평가할 수 있는 방안으로 생각한다.

주요어 : 지속가능한 교통, 한국 도시, 지표 평가, 대중교통, 자동차 의존성

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