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Sustainable Transportation Assessment:
A Case Study of Jakarta, Indonesia

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Abstract

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The term "sustainable development" was defined 35 years ago as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'. In the context of megacities such as Jakarta, the rapid growth rates of urbanization means that it will be more important than ever to get the urban areas built in a sustainable way. Therefore, a more sustainable transportation is needed to increase the quality of the citizens' life.

In order to plan sustainable urban transportation policies, the extent of sustainability in transportation itself needs to be assessed. This research discovers various ways to assess sustainable transportation in city-level supported by range of literatures in which most of them are using indicators and scoring weight to indicate the importance level of each indicator. In this research a total number of 20 sustainable transportation indicators were being selected, which then being categorized into 10 factors.

Analytical Hierarchical Process (AHP) survey was then being conducted to formulate the importance level for these sustainable transportation factors and domains. Two groups of respondents were created for this survey, which are the transport 'users' group and transport 'experts' group. The result shows that there are noticeable differences and similarities in both groups. In the domains level, the users are slightly leaning towards social domain as the most important domain, whereas the experts consider the economical domain instead. However, both group's consensus is that the factor of 'urban spaces' and 'road traffic quality' are more important than other factor to obtain the sustainable transportation goal in Jakarta.

With these results, the performance of sustainability transportation in Jakarta can be assessed. In 'urban spaces' factor, the indicators' performance is not desirable as it shows by the dominance of vehicle-based infrastructure in the urban areas rather than green spaces or non-motorized infrastructure. However, the factor of 'road traffic quality' is performing relatively better than the former.

Furthermore, Jakarta's transportation still needs a marginal increase of efforts in order to be as sustainable as it should be. Even though there is a lot of ways and policies that relates to transport sustainability, in Jakarta's case, improving the aspects of urban spaces and road traffic quality is being discovered in this research to be more helpful for achieving that purpose.

Keywords: sustainable transportation assessment, sustainable transportation indicators selection, Analytical Hierarchical Process (AHP), weighting process, transportation policy

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Abbreviations and Acronyms

AHP	-	Analytical Hierarchical Process
AHP-OS	-	Analytical Hierarchical Process-Operating System
BPS	-	*Badan Pusat Statistik* (Statistics Indonesia)
CO	-	Carbon Monoxide
CO2	-	Carbon Dioxide
CR	-	Consistency Ratio
CSTI	-	Composite Sustainable Transport Index
ECMT	-	European Conference of Ministers of Transport
EV	-	Electric Vehicle(s)
GDP	-	Growth Domestic Product
GDRP	-	Growth Domestic Regional Product
ITDP	-	Institute for Transportation Development Policy
I_SUM	-	Indicator of Sustainable Urban Mobility
INGO	-	International Non-Governmental Organization
PM2.5	-	Particulate Matter of 2.5 microns or smaller
PM10	-	Particulate Matter of 10 microns or smaller
NOx	-	Nitrogen Oxide or Dioxide
OECD	-	The Organization for Economic Cooperation and Development
SDGs	-	Sustainable Development Goals
STI	-	Sustainable Transport Indicators
UN	-	United Nations
UMI	-	Urban Mobility Index
WBSCD	-	World Business Council For Sustainable Development

Chapter 1. Introduction

1.1. Background

High rates of urbanization are happening in the urban areas all around the world. According to the UN (2015), by 2030 the global population will grow to over 8.5 billion people and it is forecasted that around 60% of the world population will be living in urban areas and 1 in 3 people will live in a city with more than 500,000 inhabitants. This trend means that it will be more important than ever to get the urban areas built in a sustainable way.

What does it mean by sustainability? Sustainability is inherently adjacent to the term "sustainable development". Brundtland Report, also entitled "Our Common Future", a critical guideline book of sustainability that published in 1987 by World Commission on Environment and Development (WCED) has a definition of sustainable development that is widely used among scholars and academicians around the world until this day:

> 'Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs'. (Brundtland Report, WCED 1987: 43)

Furthermore, according to Du Pisani (2006), sustainable development is a concept that emerged in the context of a growing awareness of an imminent ecological crisis, seems to have been one of the driving forces of world history in the period around the end of the 20th century.

Urban areas in Southeast Asia countries such as Indonesia have been expanding rapidly. The bigger the population it has, the urban challenges and problems will be worse and more severe. Many examples of these wide range of challenges are increasing traffic congestion, air pollution, and traffic accidents. Most of the challenges are created within the transportation[1] sector in the urban area. Reddy and Balachandra (2012) argue that urbanization is the single most important factor in the study of linkages between development and transportation. Transportation for an individual depends on adequacy, affordability, effectiveness, efficiency, and the comfort of a transport system.

Consensus among authors, academicians, and international institutions agree that transportation enhances the quality of life by providing transport and physical access to resources, goods, markets and other amenities. (Sdoukopoulos et al. 2019, World Bank, 1996; OECD, 1999; WBCSD, 2009). However, transportation is also considered as a major contributor to climate change as well as other intense environmental pollution problems both at regional and global level such as air pollution, acidification etc. (OECD, 1999).

Simply stated, there are two types of transportation modes that are used in urban areas: private transportation or public transportation. The former means that a transportation mode that is used in personal or individual manner (such as private cars and motorbikes), and intentionally unavailable for public use. While the latter, as suggested by its name, is provided by the government or authorities for the broader scale of the public. Regardless of the type, one should consider that private and public transportation coexist within a city and balancing the share between those two

[1] *In this thesis, references that are related or synonyms to transportation such as 'mobility' or 'urban mobility' will be referred to as 'transportation' or simply, 'transport'.*

are needed.

Furthermore, the raising of sustainability issue in transportation sector is not a recent phenomenon. Few transport experts have different approach on defining transport sustainability. However, there seems to be a conclusive similarity and nuances that as an economic mean, transportation should also adhere to another aspects of sustainability which are social aspect and environmental aspect. For example, the rise of road infrastructure network must also increase the level of road pollution (which is an environmental issue). Another one is the growing ownership and usage of personal vehicles might increase the probability of road accidents (which is a social issue). Those examples are some of many that can be accumulated to more coherent definitions of sustainability transportation.

In the year 2021, the number of motorized vehicles in Indonesia passed the 143 million mark, with the dominant portion of motorized 2-wheeler bikes (more than 120 million) and 4-wheeler cars more than 15 million units. The ownerships of motorized vehicles in Indonesia are growing every year and most of these are based in big cities. Particularly in Jakarta, there are more than 16 million registered motorized bikes and more than 3.5 million motorized cars. This growing, private motorization has been growing in Indonesia’s major cities since decades ago and will likely cause more serious issues such as traffic congestion, high energy consumption, traffic accidents, CO_2 emission, noise pollution, and many more.

To tackle these issues, in recent years, efforts have been made to improve city transportation through public transportation networks and transportation policies. Most notable examples of these efforts were Jakarta’s attempt to reduce city traffic by dramatically increasing the bus transit network and building the first subway train transit in Indonesia called MRT Jakarta that has been fully operating since 2019. Another remarkable example is the city of Palembang, the capital of Southern Sumatera. Which has procured the first elevated train transit option in Indonesia, built for the citizens of Palembang which is one of the most populated cities in Indonesia and the second most in Sumatra Island.

Many transport researchers agree that to reduce the pace of private motorization and increase the quality of public transportation, efforts are needed. In a transportation study of selected Indian cities, Reddy and Balachandra (2012) suggest that the issues highly related to transportation are as follows: rapid pace of motorization, lack of road infrastructure, shifting focus from public to private transport, and so on. For example, they find that lack of a proper public transportation system is the single-most important cause that hampers transportation and accessibility in urban regions.

However, the lack of monitoring and evaluating systems in the transportation sector, especially its sustainability, hampers the effort of policy makers in Indonesia to create a more sustainable transportation system. Therefore, there is a need for an evaluation approach which will help to analyze the 'macro-level' system to give a 'micro-level' analysis of the transport system (Zope et al, 2019).

In order to assess and evaluate the achievement of transportation sector, we should select the most relatable indicators and track their historical progress whether it is going in a positive direction or not. However, since there presumably numerous indicators that are related to sustainability in transportation, the indicators should be given weight or importance score to help policymakers focus on which aspects inside the transportation itself should be paid more attention in order to achieve the sustainability objective. In this research, Analytical Hierarchical Process (AHP) will be used as the assessment method for sustainable transport.

AHP is created in 1980 by Thomas L. Saaty as a multi-criteria qualitative method for measurement through pairwise comparisons and relies on the judgments of experts to derive priority scales. Few sustainable transport researches such as Ngossaha et al. (2017) and Shiau and Liu (2013) use AHP methodology. In Chapter 2, AHP will be further explained.

1.2. Research Question

This research aims to answer the following main question: “How sustainable is the transportation sector in Jakarta?”. Furthermore, in order to answer that question, we also have to know how to assess the sustainability in transportation itself. Therefore, there have to be another additional question that also need to be addressed, which is: “What factors are associated with sustainable transportation in Jakarta?”.

1.3. Purpose of Research

To answer those questions, we need to look at previous research on transport sustainability. There are many research examples around the world that explore the assessment of transport sustainability in city areas. Bachok et al. (2015) did preliminary research to characterize the current public transportation system and services provided in Klang Valley, Malaysia according to sustainability definitions, and also to identify and select the most suited indicators of public transport sustainability in Klang Valley. Reddy and Balachandra (2012) explore the underlying relationship among urban characteristics (such as income, area, and population) and transportation attributes. There are many more examples that will be explained more in Chapter 2.

For this master's thesis, I hope to discover the degree of transportation sustainability in Indonesian cities (using the capital city of Jakarta) by identifying most suited indicators of transport sustainability. Furthermore, I also hope that this thesis will be beneficial to transport policy makers in Indonesia (both in central and local government) as well as academics, as a material for future studies that focuses on sustainable development and sustainable transportation topics.

1.4. Significance of the Study

To this date, there is no study yet regarding sustainable transportation assessment, specifically in any of Indonesian cities. I hope that this master's thesis will be beneficial to the government of Indonesia, especially transportation policy makers, transportation authorities, and transportation academics.

1. As an input to future policy formulation in Indonesia, and national/local-scale transportation plans.
2. As a research input for future studies in transportation sector.

Chapter 2. Literature Review

In this chapter, I will explore and review relatively numerous literature that are relevant to the research question asked in the previous chapter. To better construct the understanding about sustainable transportation assessment, I divide this chapter into three parts: Sustainable Transportation Definition, Previous Research on Sustainable Transportation Assessment, and Indicators for Sustainable Transportation Assessment.

2.1. Sustainable Transportation Definition

The Brundtland Commission stressed the importance of links between the economy, society, and environment in the definition of sustainable development: "sustainable development is a process of change in which the exploitation of resources, the direction of investment, the orientation of technological development, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations" (WCED, 1987).

According to OECD in Vancouver Conference (1996), sustainable transportation is the expression of sustainable development within the transportation sector. As we can see in Figure 1, referring to Gudmundsson, et al. (2009) citation on World Bank, there are three components of comprehensive sustainable development: 1) Economic Sustainability; 2) Environment Sustainability; and 3) Social Sustainability.

In other words, it is generally accepted that sustainable development, and more specifically, sustainable transport, implies finding a proper balance between (current and future) environmental, social and economic qualities (e.g., OECD, 1996; Litman, 2008; WCED, 1987). However, it is less clear which environmental, social and economic qualities should be guaranteed and balanced (Steg and Gifford, 2005).

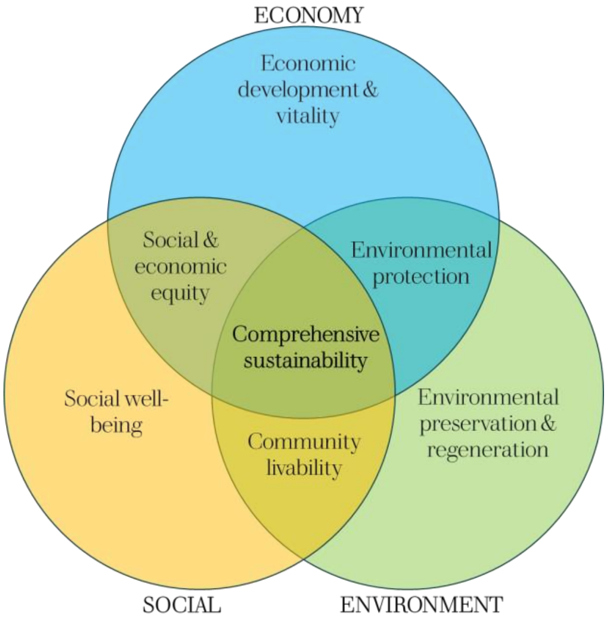

Figure 1 Comprehensive sustainable development cited from Gudmundsson (2009), chart by author

In another perspective, sustainability is one of three key elements (sustainability, safety and smartness) of a modern transportation system and has become a fundamental component of transport planning and policy implications (Moeinaddini et al., 2015).

Reddy and Balachandra (2012) argue that the sustainability aspect of transportation is measured using energy intensity and carbon intensity of transportation. Martins, et al (2019) argued that the means of sustainable transportation may be defined as the means by which transportation takes place in line with the principles of sustainability, which, for instance, entails as little CO_2 emission as possible in transportation and process management in organizations.

Ramanathan and O'Brien (2014) referred to sustainable transportation as any travel mode that has a low impact on the environment by minimizing use of fossil fuels and harmful emissions. Examples include collective passenger transport (e.g., public transit, trains, and carpooling), use of public shared vehicles, as well as active transport (e.g., walking, cycling).

Sustainable transportation is linked with health and well-being through its relationships with people-friendly land-use planning, economic sustainability, potential for interaction with nature, and physical and psychosocial health benefits. Sted and Gilford (2006) elaborated that sustainable transportation might be considered by examining the sustainability of the transport system itself, focusing on externalities of traffic and transport systems (negative and positive externalities) as they are apparent now or in the near future.

Another argument is that we should view city transportation from an individual perspective. Transportation for an individual depends on adequacy, affordability, effectiveness, efficiency and comfort of a transport system. Proximity to an expressway without access for people living in its neighborhood serves no purpose. Similarly, having a vehicle but being forced to drive on a road in poor condition is highly inefficient (Reddy and Balachandra, 2012).

2.2. Previous Research on Sustainable Transportation Assessment

The attempt on assessing sustainable transport in cities has started since the turn of the century, and is particularly growing in recent years after the UN announced its SDGs agenda in 2015.

Reddy and Balachandra (2012) explore the underlying relationship among three variables—energy intensity, mode of transport and passenger kilometers traveled. They use a total of eight indicators to assess the temporal dynamics of transportation and compare them with similar indicators for India as a whole.

1. Passenger-carrying capacity per 1000 persons;
2. Public–Private-carrying capacity ratio;
3. Vehicle density by area (as a proxy for congestion level);
4. Vehicle density by population (as a proxy for vehicle domination);
5. Energy intensity of travel (per PKM) (as a proxy for efficiency of travel);
6. Energy intensity of transport (per capita) (as a proxy for efficiency of transport system);
7. Carbon intensity of travel (per PKM) (as a proxy for efficiency of travel); and
8. Carbon intensity of transport (per capita) (as a proxy for efficiency of transport system.

Tafidis, P. et al. (2016) suggests that the achievement of sustainable transportation should consist of the vision of every urban area yet comprise a challenging issue in which indicators are able to play a key role. In other words, city planning that is related to transportation should be addressed in the assessment. It needs to be noted that this article is using “indicators” as its main assessment to examine the transport condition in the Greek urban areas.

Another approach by Jain, D. and Tiwari, G. (2017) is to select sustainable transport indicators for Indian cities by combining – criteria based, causal chain and causal network frameworks. The methodology involves both subjective judgments for evaluation of indicators against a set of criteria and objectivity during development and assessment of causal networks.

De Freitas Miranda and da Silva (2012), and da Silva et al. (2015) applied the Index of Sustainable Urban Mobility (I_SUM) for assessing the current mobility or transportation conditions of the city of Curitiba, Brazil. The result shows some consistency with I_SUM value and the successful urban and transportation planning in Curitiba. In other words, I_SUM is one of the methods to assess the transportation conditions in any city by taking into consideration the inherent complexity of the urban space. More applications of I_SUM are also used for comparative evaluation of transportation in Brazilian cities (da Silva et al., 2015).

There are some notable established methods among transport researchers such as: Haghshenas and Vaziri (2012), that used sustainable transport indicators (STI) to compare sustainability among various world cities and Moeinaddini et al. (2015), who introduced an urban mobility index (UMI) for evaluating transportation in cities at the macro-level. They argued that the proposed UMI is universally applicable, and that the model is useful for the maintenance and future growth of cities.

Santos and Ribeiro (2013) selected a set of 20 indicators and used them as an example to evaluate their applicability to monitoring the lines of action regarding transportation in Rio de Janeiro, Brazil.

In the 2019 study by Zope et al., seven Indian metro cities were selected. These cities were selected because of their rapid growth of motorized vehicles and its impact on the performance of their transport system. All seven cities are also compared with two international cities namely, New York and Singapore, based on their geographical area and population density. In the same study, a multi-criteria-based value, Composite Sustainable Transport Index (CSTI) is calculated for evaluating transport systems of selected cities. It helps to quantify the overall performance of the transport system and also helps to rank cities as per their index value.

Gerlach et al. (2016) describes the methodological approach to review sustainable indicator suitability that has been used for 10 years in Germany, with a special consideration given to the commonly used modal split and transport intensity indicators. In contrast to these previous systems, the German national SD indicator system does not intend to present all sustainability impacts of the transport sector in a detailed manner. The included indicators should therefore be chosen with the aim to primarily spotlight the most important SD issues in the transport sector.

Lastly, Karjalainen and Juhola (2021) has done a systematic literature review to construct a synthesized and critical overview of how urban transportation sustainability is in fact assessed, consisting of 99 peer-reviewed articles retrieved via three scientific search engines. One of the most particular findings is the mismatch between a conceptually comprehensive sustainability assessment framework and its implementation into practice.

2.3. Indicators for Sustainable Transportation Assessment

International and intergovernmental organizations such as the UN and OECD have explored the role of indicators in government. Agenda 21 emphasizes the role of sustainable development indicators to help decision-making process (United Nations, 1992). OECD defined sustainable transportation indicators as statistical measures that give an indication of the sustainability of social, environmental and economical development (Joumard and Gudmundsson, 2010).

Indicators are simplifications of complex phenomena and they often provide only an indication of the condition or state of a given element (Maclaren, 1996). An indicator is a variable based on some measurements, representing as accurately as possible a phenomenon of interest (Joumard and Gudmundsson, 2010). Indicators are variables selected and defined to measure progress towards an objective (Litman, 2008).

Indicators help in evaluating, simplifying, studying trends, communicating issues and comparing across places and situations. A set of appropriate indicators allow decision makers to monitor status and understand consequences of the actions and inactions (Jain and Tiwari, 2017; Boyko et al., 2012; Toth-Szabo and Várhelyi, 2012). Moreover, the number of indicators should be kept to the minimum necessary to enable an understanding of the overall transport performance (Henning et al., 2010).

Indicators are measurable variables which can be used for quantification of interaction between transport system, human activities, and their impact on economic, social and environmental aspects (Zope et al., 2019). Joumard and Gudmundsson (2010) introduce 10 criteria for indicator selection which were categorized in 3 main groups:

1. Representation: validity, reliability, sensitivity
2. Operation: measurability, data availability, ethical concerns
3. Policy application: transparency, interpretability, target relevance, action ability

Santos and Ribeiro (2013) argue that transportation is an important sector that has significant economical, social, and environmental impacts. In this context, indicators can be used to evaluate sustainable transportation and to guide decision making processes. They also emphasize that it is important to have a set of simple, effective, feasible and modular indicators to assess the sustainability of urban passenger transport.

Following the research of Joumard and Gudmundsson (2010), Haghshenas and Vaziri (2012) collected 9 sustainable transportation indicators from the comprehensive literature review. To define indicators to quantify urban sustainable transportation, this study lists 17 studies that list urban sustainable transportation indicators or STI. Then, the indicators from were collected, summarized, and categorized in 3 main groups: transportation environmental impact indicator (TEII), transportation economical impact indicator (TCII), and transportation social impact indicator (TSII)

Furthermore, Haghshenas and Vaziri (2012) suggested 7 criteria that can be used for comparative assessment of sustainable transportation evaluation between world cities:

1. Target relevance: Each indicator must show one aspect of sustainable transportation
2. Data availability and measurability: Indicators must be measurable and available within the database
3. Validity: Indicators must measure the issue it is supposed to measure
4. Sensitivity: Indicators must be able to reveal cities sustainable transport changes
5. Transparency: Indicators should be feasible to understand and possible to reproduce for intended users

6. Independent: Indicator should be independent of each other
7. Standardized: Indicator should be standardized by city size for cities comparison

To identify sustainable transport indicators for Indian cities, Jain and Tiwari (2017) systematically provide a list of criteria that provide essential qualities an indicator should have to evaluate sustainable transportation: 1) achievable/controllable; 2) data availability; 3) measurable; 4) relevant to context, policy targets and transport; and 5) specific/interpretability.

This following table helps to summarize the criteria of a sustainable transportation indicator should have, based on the previous literatures:

Table 1 Table of indicator criterias (created by author, from various sources)

No	Indicators	Description	References
1	Data availability	Data to measure indicators should be easily available at reasonable cost from reliable sources.	Jain and Tiwari (2017); Joumard and Gudmundsson (2010); Haghshenas and Vaziri (2012)
2	Measurability	Indicator can be measured in theoretically sound and easily understood manner.	Jain and Tiwari (2017); Zope et al. (2019); Joumard and Gudmundsson (2010); Haghshenas and Vaziri (2012)
3	Sensitivity	The selected indicators should be sensitive to the stresses on the system under study. A sensitive indicator must be able to reveal important changes in the factor of interest	Joumard and Gudmundsson (2010); Joumard et al. (2011); Haghshenas and Vaziri (2012)
4	Transparency	A transparent indicator is one that is understandable and possible to reproduce for intended users	Joumard and Gudmundsson (2010); Haghshenas and Vaziri (2012)
5	Interpretability	Indicator should be easily understood by intended users and useful for decision makers.	Jain and Tiwari (2017); Joumard and Gudmundsson (2010)
6	Validity	A valid indicator must actually measure the issue or factor it is supposed to measure	Joumard and Gudmundsson (2010); Joumard et al. (2011); Haghshenas and Vaziri (2012)
7	Reliability	A reliable indicator must give the same value if its measurement were repeated in the same way on the same population and at almost the same time	Joumard and Gudmundsson (2010); Joumard et al. (2011)
8	Target relevance	Provide relevant information to decision makers for changing policies to attain the desired goals. Each indicator must show one aspect of sustainable transportation	Jain and Tiwari (2017); Joumard and Gudmundsson (2010); Haghshenas and Vaziri (2012)
9	Actionability	An actionable indicator is one that measures factors that can be changed or influenced directly by management or policy action	Joumard and Gudmundsson (2010); Joumard et al. (2011)

No	Indicators	Description	References
10	Independent	Indicator should be independent of each other	Haghshenas and Vaziri (2012)
11	Standardized	Indicator should be standardized by city size for cities comparison	Haghshenas and Vaziri (2012)
12	Achievable	Represent issues that can be controlled through policy and strategic actions.	Jain and Tiwari (2017); Joumard et al. (2011)

Sdoukopoulos et al. (2019) elaborate the sequential process of indicator selection is as follows:

1. Setup of an initial list of potential indicators
2. Selection of long list of potential indicators with specific features of the examined area or domain
3. Shortlisting potential indicators with quality selection criteria
4. Selection of an indicator through consultation process
5. Final selection of the indicator if the necessary data is available

As a result, Sdoukopoulos et al. (2019) has selected a considerable number of 78 sustainable transport indicators divided into three pillars: 1) economic pillar such as modal split, fuel prices, and ratio of public transport revenues; 2) environment pillar such as air pollutant per capita, greenhouse emissions per capita, and traffic noise level; 3) social pillar such as accessibility (share of population living within 300-500 m from public transport), and road fatalities. However, not all of the indicators are segregated into those three pillars. There are some indicators that are intersected into 2 pillars or even all three of them. Transport affordability, GDP per capita, and population density are some of them.

In a more specific context, Gerlach et al. (2016) explain how Germany uses a combined top-down/bottom-up approach for the identification of the most relevant sustainability issues in transport since its application in 2002. This following picture shows the sustainable transportation indicator selection process in Germany:

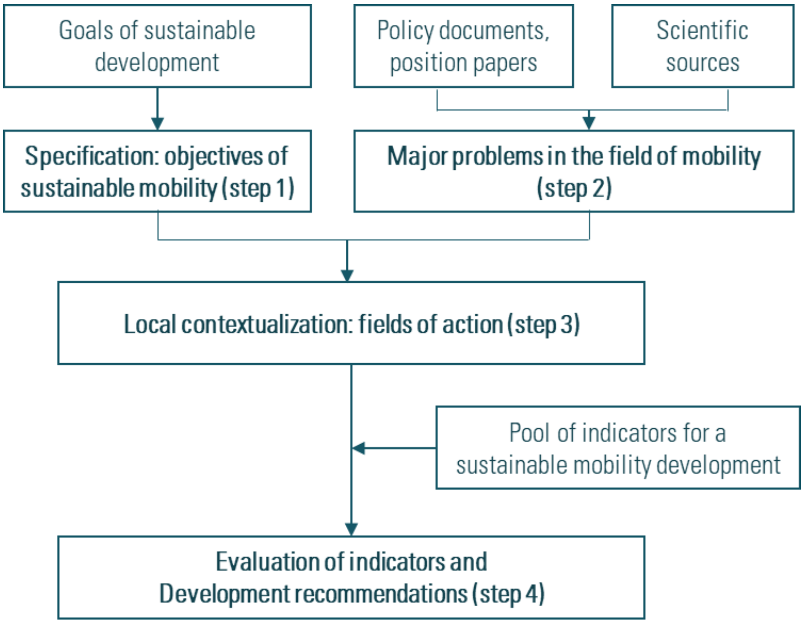

Figure 2 An example of schematic description of indicator selection process (Source: Gerlach et al. (2016), chart by author)

Shiau and Liu (2013) proposes an indicator system for measuring and monitoring transport sustainability at the county or city level. Composed by a committee and groups of government officials and experts from Taipei City and New Taipei City, twenty-one indicators were grouped into economy, environment, society, and energy aspects.

However, we must be cautious when selecting sustainable transportation indicators. Ngossaha et al. (2017) showed that mutual conflict between indicators which may occur could be mitigated using such a model which is based on a holistic view of the transportation system.

Ideally, theory-based conceptions and operationalization of sustainable transport indicators should be developed, first by defining sustainable transport, and then by deriving significant performance indicators that enable us to measure sustainable transport. Valid sustainability indicators are needed to examine the extent to which possible future transport systems affect sustainable development (Steg and Gifford, 2005).

2.4. Conceptual Framework

There are various ways of means regarding conceptualization of sustainable transportation assessment. As has been stated in the previous subchapter, to assess the sustainability of transportation, we have to create a framework of how the indicators (i.e., the assessment tool) is selected.

De Freitas Miranda and da Silva (2012) created the indicators of Index of Sustainable Urban Mobility (I_SUM) by classifying the 'themes' and 'domains' of the indicators, before giving the indicators their weight. The weights of the 'themes' and 'domains' of the sustainability dimensions (environment, social, and economy) for each 'themes' were obtained directly from the average of the values given by the experts.

Haghshenas and Vaziri (2012) has established their method of collecting the sustainable transport indicators (STI) in three steps:

1. Firstly, sustainable transportation indicators were selected by reviewing past researches. Some indicators are edited or redefined. Consequently 9 STI were developed, 3 indicators in each 3 groups of environmental, economical and social.
2. Then, composite index was also suggested by combination of 9 standardized indicators. According to the composite index, various cities were compared.
3. Finally, some important factors affecting urban transportation sustainability

were determined by using correlation analysis between composite index and cities characteristics.

Furthermore, the method used by Haghshenas and Vaziri (2012) for building composite index is simply additive weighted method.

1. In the first step, the Z-score of all indicators are calculated. Z-score is popular to normalize the indicator (Joumard and Gudmundsson, 2010).
2. Then for each group, a composite index is built by adding normalized indicators by regarding equal importance weight. This is one of approaches for multi-criteria decision analysis, MCDA, in which the weights of objects assumed are the same (Joumard and Gudmundsson, 2010).
3. Overall sustainable transport composite index, I-OST, was built by adding the result of the normalized composite index.

Another approach is used by Jain and Tiwari (2017), as they combine three methods of selecting sustainable transportation indicators: criteria based, causal chain and causal network frameworks. Firstly, the causal chain frameworks account for linear relations between indicators of interest. Pressure, State and Response (PSR) framework developed by OECD in 1994 are some of the examples. Second, they argue that there is a need to account for complex, multi trajectory and nonlinear inter-relations between indicators. That requires developing multiple causal chains. Here each indicator shall form part of more than one causal chain resulting in inter linkages between causal chains (Niemeijer and de Groot, 2008). Lastly, relationships between indicators can be quantified using mathematical models like Analytical Hierarchy Process (AHP) and Bayesian network models (Niemeijer and de Groot, 2008). AHP is "a theory of measurement through pairwise comparisons and relies on the judgments of experts to derive priority scales" (Saaty, 2008).

In a more systematic way, Zheng et al. (2013) provides guidance into the issues of selecting an appropriate index by creating a systematic tool for assessing sustainable transportation called the Transportation Index for Sustainable Places (TISP). TISP framework consists of a hierarchy structure that begins from three Domains (environment, social, and economy), expanding into Elements (such as 'Minimize consumption of renewable & nonrenewable resources for transportation'), Indicators (such as 'Energy Consumption', and Variables (such as 'Vehicle mass per capita').

Chapter 3. Methodology

3.1. Study Design and Method

This study will use a quantitative research method with an explorative approach. This approach is to explain, summarize the various conditions, situations, or variables that are the object of research (Bungin, 2014).

Firstly, I will select the indicators based on literature review and data availability of indicators in selected Indonesian cities. The selection has to be based on indicators related to public transport measures and factors that influence the success of a sustainable transport such as the number of ridership, infrastructure, mode share, and more (Bachok et al., 2015). After the selection of indicators, I will conduct survey data and collect hard data. Survey data is useful for weighting indicators that I have selected from literature review. Surveys (and interviews if necessary) will be conducted to researchers, academics, government officials, and citizens.

While collecting survey data, I will also collect hard data parallelly. This hard data is useful to calculate the "score" of every indicator. After that, survey and hard data will be combined to create sustainable transportation indicators. After collecting and combining data, the next step is assessing transport sustainability in Indonesian cities. Methods of statistical analysis will be employed to identify indicators and cities with similar characteristics. This assessment will answer the main research question: "How sustainable is the transportation sector among Indonesian cities?".

As transportation is an important sector that has significant economic, social and environmental impacts. In this context, indicators can be used to evaluate sustainable transportation and to guide decision making processes (Santos and Ribeiro, 2013). In that regard, the next analysis is to further and deeply examine and evaluate Indonesian cities through policy evaluation and potential policy implication to suggest that better scores of sustainability in the transportation sector can be achieved.

The flowchart of this research method can be shown below.

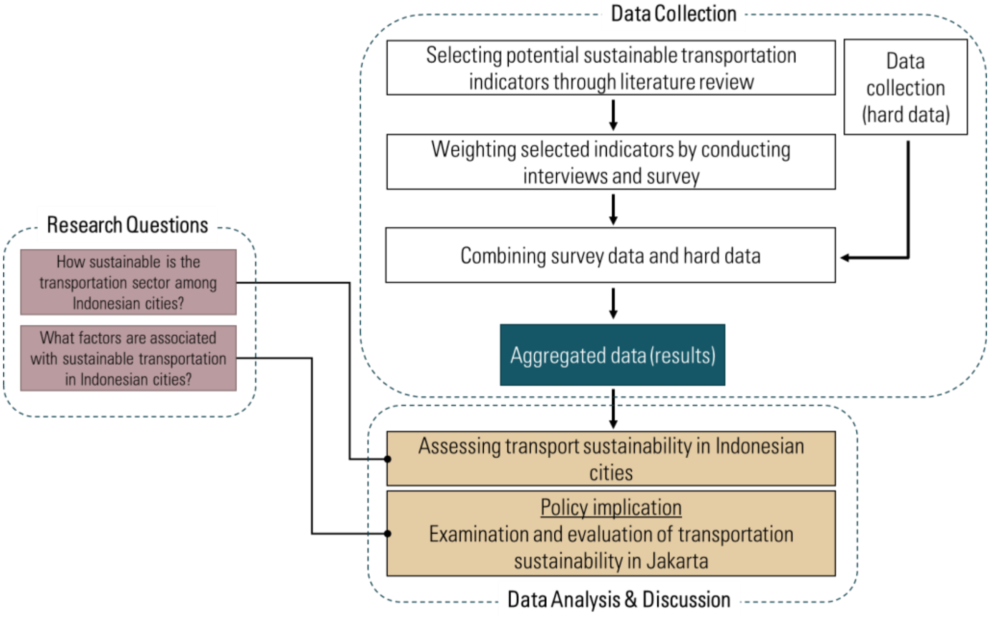

Figure 3 Research method
(Source: author)

3.2. Data Sources

To gather transport sustainability survey data, Bachok et al. (2015) applied the snowball internet survey method, face-to-face, snail-mail, and electronic questionnaire or survey to collect samples from a list of various professionals relevant to the field of transportation. They include transport planners, traffic engineers, public transport operators and managers, transportation economists, environmentalists, academicians and researchers, as well as urban and regional planners. The survey form contained three sections: A) respondents' background; B) possible sustainable public transport indicators for Klang Valley; C) factors of developing sustainable public transport indicators.

However, it is necessary to be careful to produce the data related to sustainable transportation. Karjalainen and Juhola (2021) have shown that most of the sustainable transportation studies show similar conclusions, as a quarter of the studies in their sample did not apply all of the indicators identified as relevant in their assessments. They explicitly stated that data availability is commonly stated as a challenge for diverse indicator use.

In this research I will conduct a survey for transport professionals, academicians, policy makers, government officials, and transport users in Indonesia. That survey will consist of sustainable transport indicators that will be selected based on its availability, relevancy, measurability, and validity.

Beside the survey data, I will also collect hard data parallelly. This hard data is useful to collect the weight value of the indicators from survey data. After that, the result will be analyzed.

3.3. Analytical Method

Analytical Hierarchical Process or AHP is "a theory of measurement through pairwise comparisons and relies on the judgments of experts to derive priority scales" (Saaty, 2008). Moreover, AHP is a non-statistical method that encourages respondents to make subtle trade-offs in nonquantifiable attributes, while conjoint analysis better enables respondents to make trade-offs over quantifiable levels and cost (Duke and Aull-Hyde, 2002).

In this master's thesis, AHP will be used as the analysis tools to calculate the weight of each indicator to rank the indicators for their respective importance level.

Ngossaha et al. (2017) adopted AHP to validate the proposed sustainability indicators system. They argue that AHP has been successfully used in various real-world applications close to the context of our work (e.g., performance-type problem, resource management, corporate strategy, public policy, political strategy, transport development, etc.) and due to its ease of use. They also further elaborate that in reference to the analysis tools, the following were identified: the usage of the AHP method, cost management techniques, definition and analysis of the usage of the performance indicators, the concept and definition of eco-efficiency, the usage of the concept of trade-off, and the development of an ecological transportation model by the generic algorithm.

Another transport researchers, Shiau and Liu (2013) use Fuzzy Cognitive Maps (FCMs) and the Analytic Hierarchy Process (AHP) to construct the cause–effect relationships between key transport indicators and to evaluate sustainable transportation strategies.

Duke and Aull-Hyde (2002) indicated in their study that AHP is not a statistically based methodology. In that regard, there are no requirements for a sample size (respondents) to implement the AHP methodology. However, Melillo and Pecchia (2016) suggested that the effective standard of sample size is around 19 respondents.

The detailed application of AHP for this particular research will be further explained in the next chapter.

In conclusion, my research framework can be seen in figure below.

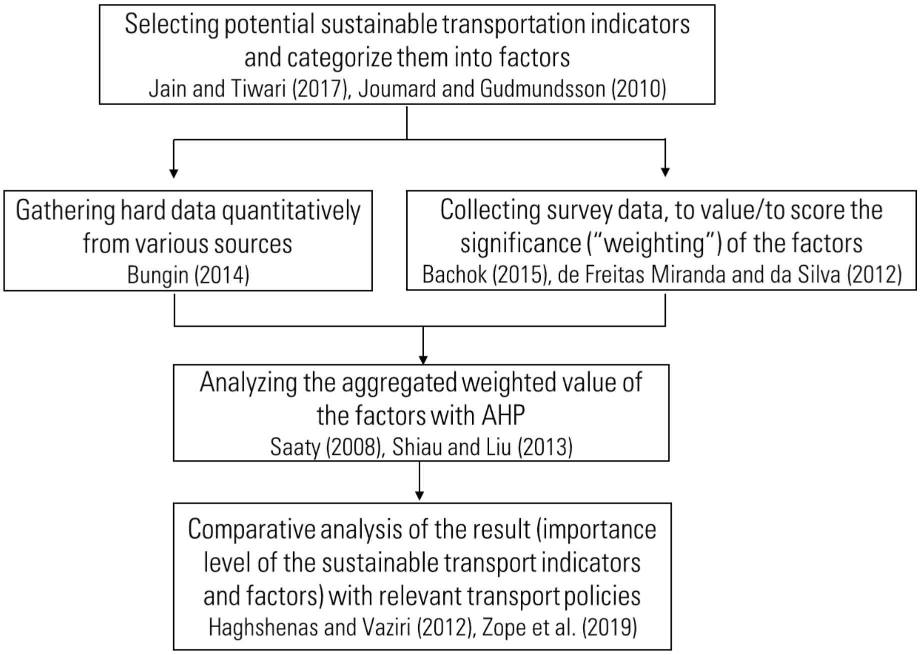

Figure 4 Research framework
(Source: author)

Chapter 4. Sustainable Transportation Indicators Selection

4.1. Background of Sustainable Transportation in Jakarta

4.1.1. Public Transportation in Jakarta

Jakarta as the capital city of Indonesia, is one of the few megacities[2] in the world, with 10.651 million inhabitants living inside the city border. Also, with a densely populated cities of 16.927 people per sq km and population growth of 0.45% (BPS, 2021), the need of a sustainable transportation in Jakarta is ever growing.

Currently, Jakarta relies heavily with public bus transportation called TransJakarta or TJ. In 2019, the total passenger of TJ is 264.032 million people. After the pandemic, the number reduces significantly to 126.845 million and 98.882 million for the year 2020 and 2021 respectively (BPS, 2022). Nevertheless, those number shows how big of a role TJ has to accommodate the mobility of millions of people yearly.

The other possible option of public transportation in Jakarta is rail-based transit which are: KRL Commuter Line, MRT Jakarta, and LRT Jakarta. However, the first one is not exclusively Jakarta-based transport because it is owned by a state-owned railway company that operates the route through multiple cities around Jakarta area. Meanwhile MRT and LRT are operating inside the Jakarta boundaries since 2019 until now, but have only one route for each. In that case, it is difficult to say that the citizen of Jakarta is as heavily reliant on these rail-based transit as TransJakarta.

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[2] *Megacities are defined as cities that has more than 10 million population (Kraas & Mertins, 2014)*

4.1.2. Sustainable Transportation in Jakarta

Sustainable Development Goals or SDGs is relatively well-known in Indonesia, especially around policymakers. However, the term 'Sustainable Transportation' or 'Sustainable Urban Mobility' is considerably less known. Currently, there are lack of planning or implementation regarding infrastructure/mobility policy that accommodate the essence of 'Sustainable Transportation' either on national-level or local-level.

However, ITDP or Institute of Transportation and Development Policy, the international non-governmental organization (I-NGO) that operates in transportation policy has given Sustainable Transportation Awards to Jakarta in 2020 due to its progressive transportation policy and expansion of public transportation network. This means that sustainability in transportation sector is becoming achievable especially in Indonesia. Moreover, in order to make sure that the achievement and goals are being planned and targeted correctly, a set of indicators is needed in the context of transportation sustainability.

4.2. Identifying Potential Sustainable Transportation Indicators

In finding the suitable indicators, 415 indicators from 12 researches related to sustainable transportation indicators were used as the initial list of indicators.

Next step is sorting and categorization of the indicators. Sorting is needed because some of those 415 indicators may have been similar to each other or closely related. Meanwhile categorization helps on finding which indicator is suitable to the three categories or components of Sustainable Development: Economical category, Environmental category, or Social category (Gudmundsson, 2009).

Last step is finding which of those selected indicators that are available in terms of data collection. Data availability is one of the most important criteria for indicator selection that is mentioned in Jain and Tiwari (2017), Joumard and Gudmundsson (2010), and Haghshenas and Vaziri (2012). From this list of selected indicators, I reviewed them one by one with such consideration whether those indicators are feasible to be attained in the context of Jakarta. Figure 5 shows the process of sustainable transportation indicators selection.

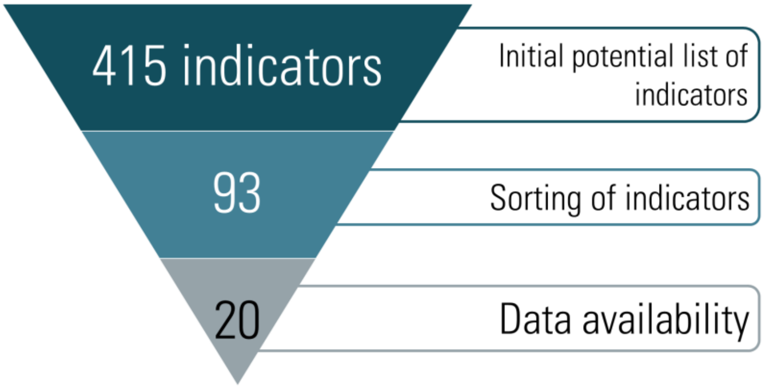

Figure 5 Selection process for the indicators

After going through the process, it has been determined that 20 indicators will be used in this research. However, for the ease of collecting primary survey data, those 20 indicators will be categorized into relevant categories or factors of respective sustainability domains.

In Table 2, we can see how the last 20 indicators are categorized into respective domains. In economical domain, there are 8 indicators which are: vehicle density, population density, tax burden (for private vehicle), public transport fare, GDRP (Gross Domestic Regional Product) per capita, and share of transport to GDRP. Those 8 indicators are being put into 4 categories: 1) inhabitants' density, 2) users' expenditure, 3) regional economic growth, and 4) road traffic quality.

Meanwhile, social domain has fewer categories: 1) transport inclusivity, 2) transport diversity, and 3) impact to health. These social categories have various indicators such as: accessibility, transport for disadvantages, public participation, modal split, fatalities, injuries, and illness due to traffic.

Lastly, environmental domain has two categories: 1) traffic pollution, and 2) urban spaces. In those categories, there are five indicators such as: air pollution, noise pollution, density of infrastructure, share of non-motorized transport infrastructure share, and area of green spaces or parks.

Table 2 References and definitions of finalized indicators

Domains	Categories/ Factors	No	Indicators	Definition	References
Economical	Inhabitants' density	1	Vehicle density	Vehicle ownership divided by total city population.	Reddy and Balachandra (2012); Miranda and da Silva (2012); Haghshenas and Vaziri (2012); Sdoukopoulos et al. (2014)
		2	Population density	Total population divided by land area.	Miranda and da Silva (2012); Jain and Tiwari (2017); Moeinaddini et al. (2014); Sdoukopoulos et al. (2014)
	Users' expenditure	3	Tax burden (private vehicle)	Amount of tax money spent by transport users yearly for their private vehicle(s).	Miranda and da Silva (2012); Haghshenas and Vaziri (2012); Jain and Tiwari (2017); Moeinaddini et al. (2014)
		4	Public transport fare	Average price of transit per 1 kilometer.	Miranda and da Silva (2012); Sdoukopoulos et al. (2014); Moeinaddini et al. (2014)
	Regional Economic Growth	5	GDRP per capita	GDRP divided by population (at regional/provincial level).	Haghshenas and Vaziri (2012)
		6	Share of transport to GDRP	Transportation sector's contribution to GDRP.	Miranda and da Silva (2012); Jain and Tiwari (2017); Moeinaddini et al. (2014)
	Road Traffic Quality	7	Peak hour journey speed	Average speed in peak hour.	Miranda and da Silva (2012); Sdoukopoulos et al. (2014)
		8	Congestion index	Rate or index of traffic congestion.	Miranda and da Silva (2012); Sdoukopoulos et al. (2014)
Social	Transport Inclusivity	1	Accessibility	Access to public transport (population served by public transit near around a train station, subway, bus stop).	Zheng et al. (2013); Zope et al. (2019); Gerlach et al. (2016); Karjalainen and Juhola (2021)
		2	Transport for special needs, disadvantaged	Quality and accessibility of transportation for disadvantaged groups.	Zheng et al. (2013); Zope et al. (2019); Karjalainen and Juhola (2021)
		3	Public participation in decision making	Degree to which public is involved in transport planning process.	Zope et al. (2019); Karjalainen and Juhola (2021)

Domains	Categories/ Factors	No	Indicators	Definition	References
	Impact to Health	4	Fatalities, injuries, and accidents	Number of fatalities, injuries, and accidents caused by transit activities.	Zope et al. (2019); Gerlach et al. (2016); Karjalainen and Juhola (2021)
		5	Illness due to air pollution	Number of chronic respiratory illnesses, asthma attacks, respiratory restricted activity days and premature deaths due to air pollution.	Karjalainen and Juhola (2021)
	Transport Diversity	6	Modal split	Number of transport modes available.	Haghshenas and Vaziri (2012); Jain and Tiwari (2017); Moeinaddini et al. (2014); Sdoukopoulos et al. (2014)
		7	Transit ridership	Share of transit by public transportation.	Jain and Tiwari (2017); Moeinaddini et al. (2014)
Environ-mental	Traffic Pollution	1	Air pollution (CO, CO2, NOx emissions)	Emissions of local air pollutants (CO, VOC, NOx, etc.) per capita.	Sdoukopoulos et al. (2014); Santos and Ribeiro (2013); Bachok et al. (2014); Zheng et al. (2013)
		2	Noise pollution	Traffic noise levels/Share of population exposed to noise levels above the statutory threshold.	Sdoukopoulos et al. (2014); Bachok et al. (2014); Zheng et al. (2013)
	Urban Spaces	3	Density of infrastructure	Density of transportation infrastructure (km of infrastructure per 1000 km² of surface area).	Bachok et al. (2014)
		4	Non-motorized transport infrastructure share	Pedestrian & bicycle mode share.	Karjalainen and Juhola (2021)
		5	Area of green spaces or parks	Total area of green spaces and parks per capita/Green areas as a share of the total urban area.	Sdoukopoulos et al. (2014); Bachok et al. (2014)

After the indicators and the categories/factors are determined, the next step is weighting. The weighting is used for determining the importance level for each factor and domain. As AHP is used for the method of weighting process, those categorizations will be referred as "factors" under the "domains" of sustainable transportation (economical, social, and environment). Figure 6 explains the hierarchy of Goals-Domains-Factors of sustainable transportation.

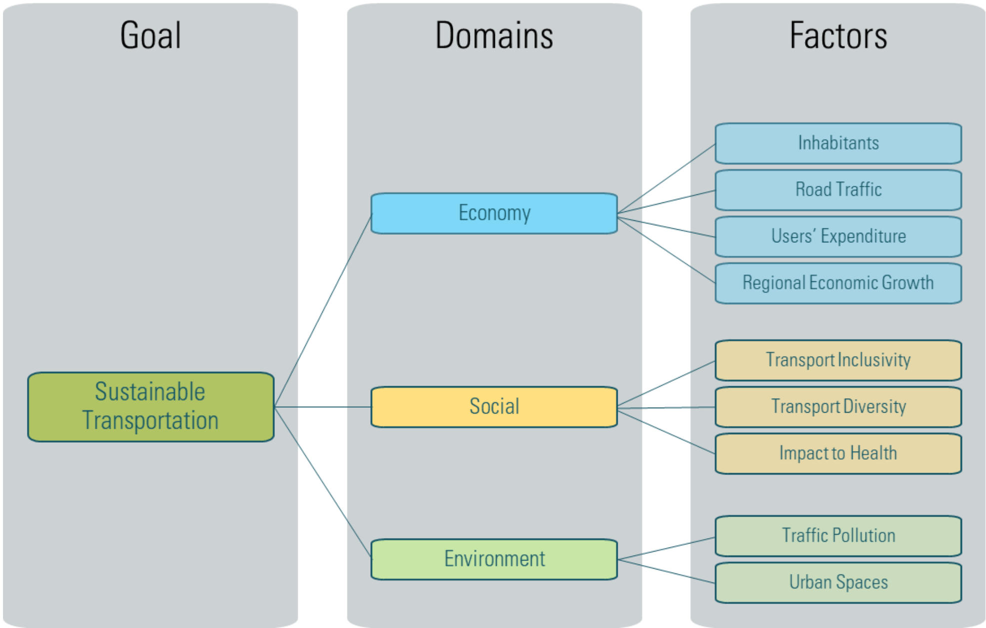

Figure 6 Hierarchy of sustainable transportation
(source: author, combined from various sources)

However, it is important to notice that because of time and resource constraint of this research, the extent of the sustainable transportation is only as far as the 'factors' level. In other words, the level beneath the 'factors' which can be referred to as 'indicators' is not being highlighted further in this thesis.

4.3. Weighting Sustainable Transportation Factors

This subchapter will further elaborate about weighting process for Sustainable Transportation factors. In previous chapter, I have explained about the usage of Analytical Hierarchical Process (AHP) as the method.

AHP survey is used for primary data collection. It was conducted in online manner, with google form, considering its familiarity, accessibility, and ease to use. The survey takes 20 to 30 minutes to fill out which is considerably much longer than the average survey. Moreover, in order to ensure the validity of the AHP result, the limit of Consistency Ratio (CR) must be upheld. No more than 10% or 0.1 score of CR is allowed. If somehow the survey result of one respondent is more than the allowable limit, that I need to reach out to the same respondent to point out his/her inconsistencies and ask them to retake the same survey.

Goepel (2018) provided a web-based online software tool for AHP called AHP-OS which allowed users for detailed analysis and determining importance level through weighting process. This concept is using "pairwise comparison" which is done through the previously mentioned online survey. For example, in domain section, Economy and Social are being compared to one another with 9-scale of importance level. Ranging from 1 which is 'similar importance to 9 which is 'extreme importance'. The respondents' task is to pick which domains and factors are more important and score them. As I mentioned before, after the tasks is completed by the respondent, I check the CR of the result before that result is being put to the AHP-OS.

In this survey, every domain and factor that needs to be scored are being explained clearly and written in Indonesian. In the introduction part of the survey, I point out what sustainable means and how it relates to transportation. I also mentioned the hierarchical definitions of the domains that relate to the factors, as well as the definitions of the factors that relate to the indicators.

The respondents for this survey are divided into two groups: 1) users' group and 2) experts' group.

The former group is called 'users', because it consists of transport users in Jakarta metropolitan area. In this particular group, there are 20 respondents. Most of them have lived and worked in Jakarta for 3-8 years. They are relatively educated individuals with 50 percent of them have a Master's degree (or equivalent to), and the rest have a Bachelor's degree (45%) and a Diploma degree (5%). Moreover, a majority portion of them (80%) are working at government or public sectors. However, it needs to be known that every respondent in 'users' category has a familiarity of sustainability concept to some extent.

The latter group, or the 'experts' group is filled with people with extensive knowledge in relevant branch of sustainable transportation. It consists of academics in the field of transportation, researchers, government officials, professionals with a background in transportation studies, and transport operators or authorities. In summary, 16 respondents from this group took part of this survey: 1 manager in the National Secretariat of SDGs, 1 transport academic/lecturer currently doing transportation research at an UK university, 1 transport/civil engineering lecturer, 2 infrastructure consultants, 2 urban studies graduates, 2 infrastructure engineering graduates, 2 economic analysts, 2 transport planners, 2 highway owner/operators, and 1 railway operator.

Chapter 5. Results and Discussion

5.1. Result from Users' Group

The received answers from 'users' participants showed a 59.9% percent of homogeneity and a very low average AHP group consensus of 48.4%. This result is quite surprising, considering they do not have significant difference regarding their knowledge background. Nevertheless, the result shows that in environment factors, they have moderate level of group consensus with 64.2%, which means a better portion of them agrees with one particular factor (which is Urban Spaces) is more important than the other.

Regarding the weight of the three domains, there is only marginal difference between them. Economy has the weight of 0.351, Social with 0.336, and Environment with 0.313.

In Economy factors, Road Traffic Quality has the biggest portion of the weight of 0.463, followed with Users' Expenditure, Regional Economic Growth, and Inhabitants Density with the weight value of 0.278, 0.138, and 0.121 respectively. In Social factors, Transport Inclusivity has the biggest weight value with 0.455, followed with Transport Diversity with 0.274 and Impact to Health with 0.271. The last factor, Environment, consists of Urban Spaces and Traffic Pollution has the respective weight value of 0.752 and 0.248. The full result is shown in Table 3.

In global value or total weighting, it is shown that Urban Spaces is the factor with the biggest weight value of 0.235, followed with Road Traffic Quality and Transport Inclusivity with 0.162 and 0.153 respectively. Those three factors are relatively more important than the other factors, with the closest one being Users'

Expenditure with 0.098.

Table 3 Hierarchy value from users' group (source: author)

Domain	Weight of domains	Factors	Weight of factors in category	Total weighting
Economy	0.351	Inhabitants Density	0.121	0.042
		Road Traffic Quality	0.463	0.162
		Users' Expenditure	0.278	0.098
		Regional Economic Growth	0.138	0.048
Social	0.336	Transport Inclusivity	0.455	0.153
		Transport Diversity	0.274	0.092
		Impact to Health	0.271	0.091
Environment	0.313	Urban Spaces	0.752	0.235
		Traffic Pollution	0.248	0.077

The factor with the lowest score/value is Inhabitants Density, followed with Regional Economic Growth, which is quite surprising because both of the factors are within the same Economic domain which has the biggest weight compared to others.

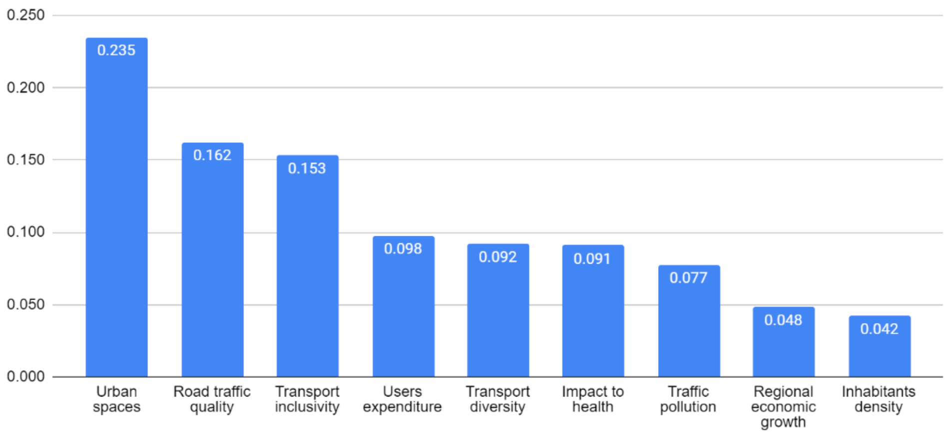

Figure 7 Weight value of sustainable transportation factors from users' group (Source: made by author)

This result shows us that the transport users in Jakarta might feel that there should not be any significant difference in importance between the aspects of Environment, Economy, and Social. However, if there should be some factors that needs to be addressed more in order for Jakarta's city transportation to be more sustainable, they are: Urban Spaces, Road Traffic Quality, and Transport Inclusivity. Keep in mind that if we combined the value of those three factors, the value is 0.550 which is higher than the rest of the factors combined. In that regard, it should be justifiable to focus more on the indicators on those factors to create or even formulate a more sustainability-based transport policy.

5.2. Results from Experts' Group

Similar to the users' group, the experts' group also has a low level of homogeneity with 60.2%. Furthermore, the result shows that the AHP group consensus is also at a very low level with only 47.6%. It fairly suggests that from the diverse background of transportation (whether it is as academics, planners, or owners), they have their own perspective regarding the fulfillment of transportation sustainability.

At the domain level, Economy has the biggest value—with relatively significant difference with Social and Environment—of 0.436. It may suggest that the Economy, both as a domain with underlying factors, is arguably more important than Social and Environment. The factor of 'Road Traffic Quality' has a global weighting value of 0.172, only slightly lower than the biggest factor of Urban Spaces by 0.016.

However, we should not ignore the fact that, from the Table 4, the score difference between the factors is not as apparent as the one from users' group. We can see that the third biggest factor, Users' Expenditure (0.109), is only marginally bigger than the rest of the factors such as Transport Diversity, Traffic Pollution and

Transport Inclusivity with 0.100, 0.095, and 0.090 respectively.

Table 4 Hierarchy value from experts' group (source: author)

Domain	Weight of domains	Factors	Weight of factors in category	Total weighting
Economy	0.436	Inhabitants Density	0.172	0.075
		Road Traffic Quality	0.394	0.172
		Users' Expenditure	0.250	0.109
		Regional Economic Growth	0.185	0.081
Social	0.281	Transport Inclusivity	0.318	0.090
		Transport Diversity	0.354	0.100
		Impact to Health	0.328	0.092
Environment	0.283	Urban Spaces	0.663	0.188
		Traffic Pollution	0.337	0.095

The factor which has the lowest score, which is Inhabitants Density, has the score of 0.075. Interestingly, it is also the factor with the lowest score in the previous group, but with much lower score of 0.042. Even though it is not as significant as the others, it could also mean that the experts value the density of inhabitants or population in higher regard, which can also be one of the prolific factors that stimulate the Economy Domain.

Nevertheless, the difference between Inhabitants Density and Regional Economic Growth is not that much with only 0.006. Those two factors are also within the least scored values in the previous group. Although the different in the scores is considerably high, with 0.033 for both Regional Economic Growth and Inhabitants Density. This may further prove that the experts' group is giving more regard to the economical factors than the users' group.

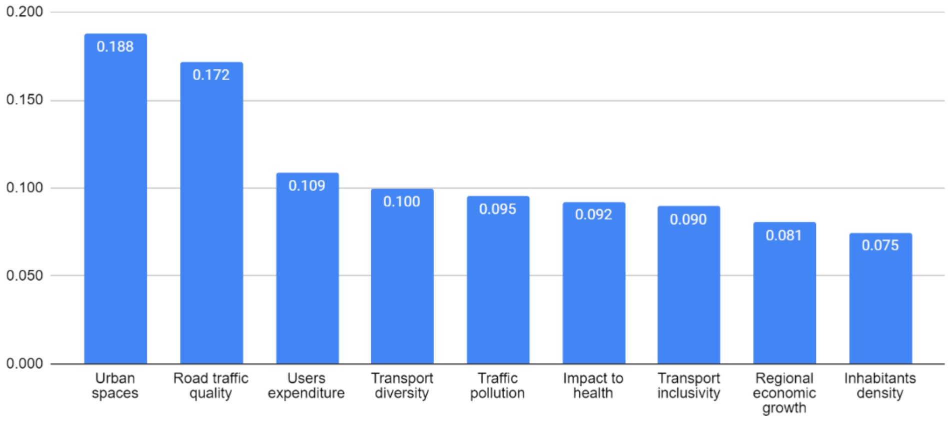

Figure 8 Weight value of sustainable transportation factors from experts' group (Source: made by author)

5.3. Sustainable Transportation Indicators Evaluation

In this subchapter, the sustainable transportation indicators from the factors that we have learned from previous subchapter will be reviewed according to their progress and whether they show positive or negative trend.

5.3.1. Economic Domain

Inhabitants Density

The city of Jakarta is densely populated, both in citizens and motorized vehicles. As a megacity with the population of 10.610 million in 2021, the number of motorized vehicles in Jakarta is surpassing its own citizens with roughly 1.94 vehicles per 1 person. In Table 5 it is shown that two-wheeled vehicles or motorbikes is more dominant than four-wheelers or cars. Moreover, as the population in Jakarta grows, the vehicle population grows too. This creates multiple issues that could have hindered Jakarta's progress on sustainability.

Zhang et al. (2020) suggest that population density positively and significantly influences transport's CO2 emissions. In other words, population density could worsen environmental quality by increasing the demand for energy and transport's sector expansion.

Contrary to the result of this particular factor being the lowest score of all, one interviewee from the experts' group strongly believes that inhabitants' density is one of the most defining factors from the economic domain. The reason behind that argument is that the citizens i.e., the inhabitants themselves are the ones who are behind the economic activities. In transportation context, as the inhabitants grow bigger, the demand for transportation means (public and private) will inevitably rise.

Table 5 Population characteristics in Jakarta (Source: BPS)

Indicators	**Years**						
	2013	**2015**	**2017**	**2018**	**2019**	**2020**	**2021**
Number (in million)	9.951	10.178	10.374	10.468	10.558	10.562	10.610
Density (people/km^2)	14986	15328	15624	15764	15900	15907	15978
Two-wheeled	1200.8	1374.5	1362.8	1436.6	1503.0	1528.2	1557.0
Four-wheeled	302.5	340.8	272.5	294.5	313.6	318.6	387.5
Total	1503.3	1715.3	1635.3	1731.1	1816.5	1846.9	1944.5
Population	1.12	1.16	0.95	0.90	0.86	0.04	0.45
Vehicles	10.38	6.92	6.21	6.37	5.53	1.72	2.34

Road Traffic Quality

Reed (2019) states that traffic congestion is an extensive global phenomenon resulting from high population density, growth of motor vehicles and their infrastructure, and proliferation of rideshare and delivery services. In other words, poor quality of road traffic is a negative externality that may be created by various root causes. However, a study by Abdelfatah et al. (2015) indicates that the traffic growth is mainly due to increases in the private cars motorcycles, while the rate of increase for buses is very small.

Table 6 shows the relative improvement of the road traffic attributes in Jakarta. While it cannot be ignored that the 2020-2021 Covid-19 pandemic may contribute in reducing the traffic congestion level, several transport initiatives has been introduced by Government of Jakarta such as the bike lines, and plate number restrictions in several corridors.

Table 6 Road Traffic Quality indicators (2019-2021)

Indicators	**Years**		
	2019	**2020**	**2021**
Peak Hour Journey Speed[3] (kph)	25.82	24.33	24.90
Traffic Congestion Index[4]	0.53	0.36	0.34

Users' Expenditure

Study by Ahmad and de Oliveira (2019) finds that in developing countries, transport users' income is the most important determinant of the amount of transport and the use of motorized and private transport. In that sense, reducing the cost of public transportation and increasing the cost of private transportation seem to be the trend that any city in developing countries have to take in order to accelerate its transport sustainability.

Since 2015, the private car ownership tax in Jakarta city is 2.0% for first car ownership, and 0.5% progressively for the next ownerships. Comparing to the previous regulation (before 2015) of 1.5% for the first car. However, that increment does not hinder the Jakarta citizens to own their car, as the number of private vehicle

[3] *In selected main road corridors*
[4] *Traffic congestion index gathered from TomTom International BV (www.tomtom.com/traffic-index/jakarta-traffic/)*

ownership is increasing.

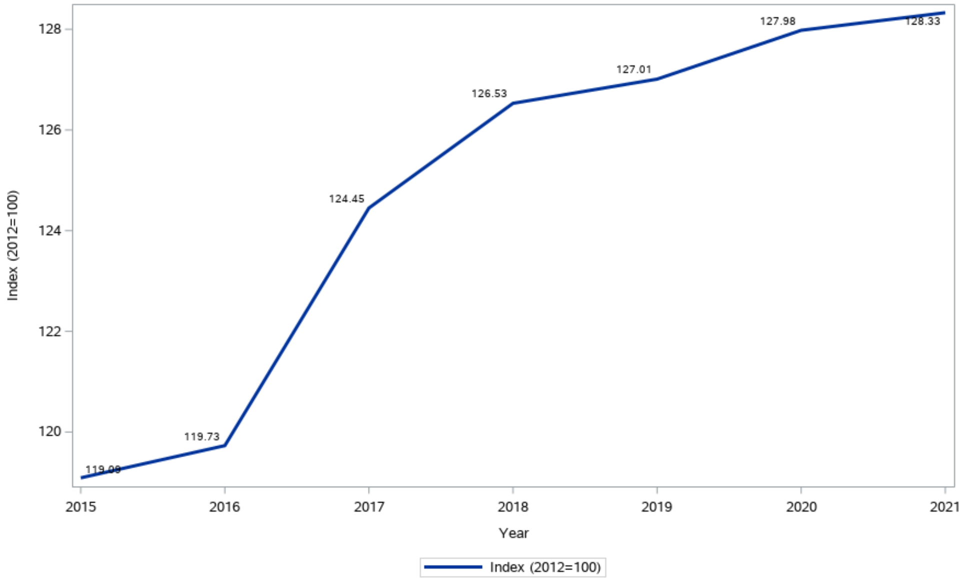

Figure 9 Consumer Price Index (CPI) of Transportation in Jakarta
(Source: BPS)

On the other hand, the price of public transportation has been generally increased since 2012. However, as we can see in Figure 9, it has slowed since 2018. Potentially making the public transportation more affordable thus increasing the number of public transport users in Jakarta to slowly shift the private-based transport to public-based transport.

Regional Economic Growth

Jakarta is not only the biggest city in Indonesia in terms of its population, but also economically. As the central economical hub, Jakarta contributes about 10.14% of Indonesia's GDP[5] in the second quarter of 2022 (Q2-2022). Furthermore, Jakarta's GDRP has been constantly improving. From 2017 to 2019 its GDRP

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[5] *In Q2-2022, Indonesia GDP is 4,919.9 trillion IDR while Jakarta GDRP is 485,414.740 million IDR (BPS, 2022)*

growth is roughly 6 percent which was considerably higher than national growth which is around 5 percent. After the Covid-19 pandemic, Jakarta's economy is slowly recovering with last year's growth at 3.56 percent.

Furthermore, we can see on table 7 that the transport sector in Jakarta has constantly growing too. With the growth rate of 8 to 9 percent from 2017 to 2019 and 12.77 percent on 2021. Closely related, is the share of transport sector itself to Jakarta's economy growth. Railway transport only accumulates with 0.03 percent until 2018. But with the addition of new rail-based transit such as MRT and LRT in 2019, the railway transport share is slowly increasing with 0.05% contribution in 2021.

However, policymakers in Jakarta should be cautious with this achievement. Because one study from Zhang et al. (2020) shows that real income (GDP) has a significant impact on CO_2 emissions, as increasing real income increases the rate of transport's CO_2 emissions.

Table 7 Attributes of Jakarta's economic growth

Indicators	**Years**				
	2017	**2018**	**2019**	**2020**	**2021**
GDRP in Jakarta					
per capita in USD[6]	14,644	15,909	17,216	16,872	17,643
growth (%)	6.2	6.11	5.82	(2.39)	3.56
Transport sector growth (%)	8.91	9.01	8.41	(7.63)	12.77
Share of Transport sector to GDRP in Jakarta (%)					
Railway transport	0.03	0.03	0.04	0.04	0.05
Land Transport	1.63	1.63	1.68	1.65	1.87

[6] *1 USD = 15570 IDR (constant)*

5.3.2. Social Domain

Transport Inclusivity

As one of the factors of sustainability transportation in social domain, transport inclusivity includes accessibility, transport for disability, and public participation in decision making. Tyler (2017) describes accessibility as ability of a person to reach and undertake the activities they desire and need, such that accessibility is available in an equitable manner to the whole of society.

Table 8 TransJakarta coverage and bus stops features

Indicators		Years		
		2019	**2020**	**2021**
TransJakarta land coverage (%)		80%	82.4%	86%
Number of TransJakarta Bus Stops	1) Bus stops	256	256	273
	2) Bus stops for people with disabilities	4	76	68
	3) Percentage	1.56%	29.69%	24.91%

In this yearly trend shown in Table 8, TransJakarta as the main choice of public transportation in Jakarta has been constantly increasing its accessibility in terms of land coverage to 86% of Jakarta city area, also adding its bus stops by 17 bus stops in 2021. However, not every bus stop is equipped with disability facilities such as ramp entrance. In 2019, there were only 4 out of 256 bus stops that have those facilities. In response to this issue, in previous years, there has been collective programs from TJ to install their bus stops with such provisions to make their bus stops more accessible to people with disabilities.

Transport Diversity

Nakase et al. (2021) argues that improving diversity would increase the modal share of public transport, which is considered crucial for developing sustainable transport. In other words, transport mode variety in cities must be utilized and developed to ensure and improve transport sustainability.

TransJakarta and KRL have been the frontrunner of choice in regard of public transportation for almost two decades. However, in 2019, the Government of Jakarta has introduced two rail-based transit modes in MRT and LRT. This creates a higher sense of diverseness regarding the transport choice for the citizen of Jakarta. Nevertheless, it is too soon to evaluate whether the new transit modes will help Jakarta reach its sustainability because from 2020 and 2021, the social restriction of Covid-19 pandemic hindered the progress of both newcomers.

Reflecting on the TransJakarta, which on 2019 marked their total passengers record up to 264 million, which roughly calculates to 723.000 passenger each day. However, as it shown at the other indicators, the Covid-19 pandemic has been a thorn for all transport sectors and the yearly passengers count for the next years has halved onto 126 million and 123 million for 2020 and 2021 respectively.

Nevertheless, that issue seems to not slow down the government and TJ’s effort to increase their reach to the transport users in Jakarta. It is shown on Figure 10 that, even though the number of passengers has been slowing down since 2020, the number of bus fleets is still increasing. Additionally, looking back on Table 8, the number of bus stops has increased too.

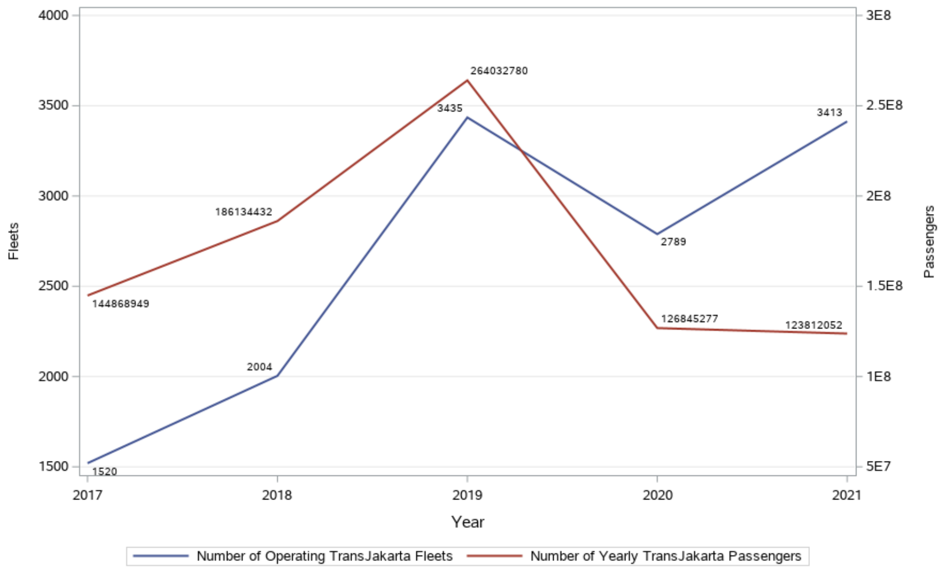

Figure 10 Number of Yearly TJ Passengers and Operating TJ Fleets
(Source: TransJakarta Yearly Report)

Moreover, one thing that must not be overlooked is the diversity in terms of transportation mode. From the interviews, two experts firmly argue how in Indonesia's context, having diverse transportation modes while giving a freedom of choice to the customers i.e., the citizens, are important. That means having an extensive range of options for transit is as important as being affordable.

Impact to Health

The expansion of road networks and surges in personal vehicle ownership are having profound effects on public health. Road traffic injuries and fatalities have increased alongside increased use of motorized transport (Jiang et al., 2017). It should be considered that city transportation should be as safe as possible for its citizen and the externalities of morbidity and mortality should be at the minimum level.

Since the last decade, the number of accident victims has been evidently dropping from 1.016 victims per 1000 people in 2012 to 0.524 victims per 1000 people in 2020.

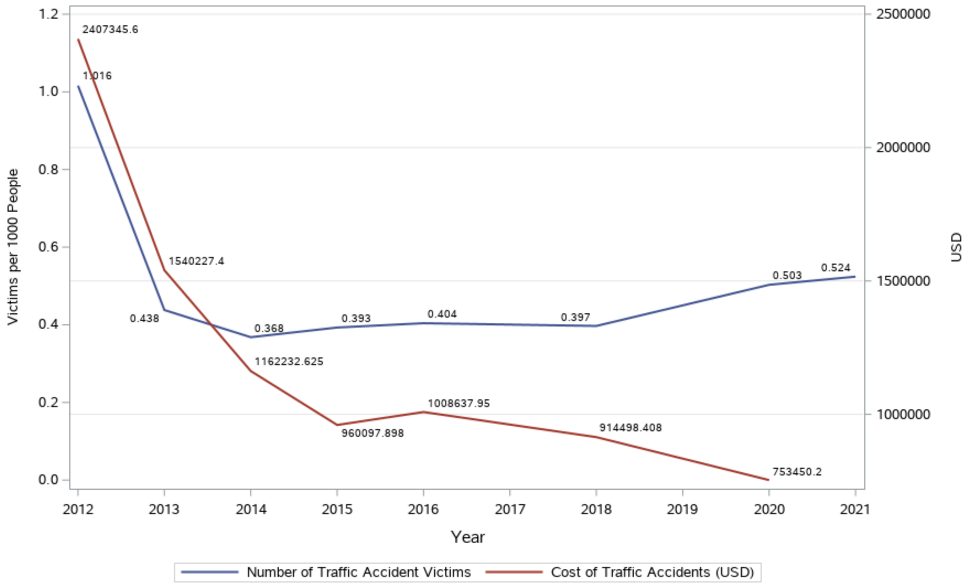

Figure 11 Cost of Traffic Accidents in Jakarta (2012-2020)
(Source: Statistic Indonesia (BPS))

5.3.3. Environment Domain

Urban Spaces

First factor in Environment domain is Urban Spaces, which predominantly consists of these selected indicators: 1) density of infrastructure; 2) non-motorized transport infrastructure share; and 3) area of green spaces or parks. In other words, the density of infrastructure in a city should be considered in ways that whether it supports the motorized vehicles, non-motorized, or pedestrians.

Furthermore, the density of the infrastructure can affect the city's livability on various ways. One of the examples in the city temperature. Lam (2009) suggested that a city with high level of infrastructure density can lead to higher temperatures. Non-motorized infrastructure and city park can help reduce the level of rising temperatures with less carbon-induced transport activities and more greeneries to capture the carbon emission of the city.

In Jakarta, the difference between the motorized and non-motorized infrastructure density is staggeringly high. In Table 9, we can see that in every 11.91 km length of motorized vehicle-based infrastructure, there are only 1 km of non-motorized infrastructure. In other words, the length of road in Jakarta that is equipped with proper infrastructure for bicycles and pedestrians is less than 10 percent. This adhere to the fact from earlier that motorized vehicles are growing and dominating in the city of Jakarta, and the alternative of non-motorized transport mode is stunningly lower that the dominant other. In other hand, there is also need to compare that infrastructure with the one that is specifically built or assigned for TJ buses.

Another aspect of the usage of urban spaces as the sustainable transport factor is area of green spaces and parks. In 2019, share of green spaces in Jakarta city is 4.24 percent, lower than share of road infrastructure of 6.82 percent. Gössling et al. (2016) suggest that the ratio of higher road infrastructure might lead to disadvantage for more sustainable transport mode, such as bicycles.

Table 9 Comparison between motorized and non-motorized transport infrastructure in Jakarta (source: BPS, 2020)

Indicators	**Type of Infrastructure**		**Ratio**
	Motorized	**Non-motorized**	
Length (km)	6492.00	545.07	11.91 : 1
Area (Ha)	4530.52	99.49	-
Density (km per 1000 km^2 area)	0.00978	0.00082	-
Share to city area	6.82%	0.15%	

Table 10 Indicators of areas of green spaces and parks in Jakarta (sources: SDGs Report of Jakarta 2020, Statistics Indonesia)

Indicators	Year							
	2012	2013	2014	2015	2016	2017	2018	2019
Share of Green Spaces in Urban Area (%)	-	-	-	-	-	-	4.01	4.24
Total Area of Forest in Urban Area (Ha)	-	-	-	-	182.54	182.54	182.54	182.54
Total Area of Parks (Ha)	2725.74	2734.93	2748.81	-	-	-	2477.28	-

Almost all of the interviewed experts believe that 'urban spaces' is the most important factor when we are talking in environmental context. They all are aware of how poorly Jakarta's urban space is designed and planned. Many of Jakarta's problems such as flooding, slum areas, urban sprawl, are originated from poor urban planning and governance.

Traffic Pollution

One of the most prominent externalities of transport activities is the pollution. Motorized vehicles emit pollution gas, mainly consists of carbon matter, directly onto the atmosphere. In a densely populated city like Jakarta, the level of traffic pollution is inherently high. From 2011 to 2018, the GHG emissions caused by transportation in Jakarta has increased 56.77% from 8,477 tons of CO_2e to 13,271. Another indicator also shows there are increasing average number of unhealthy air quality days in Jakarta in the span of three years which is 16 days in 2015 and 80 days in 2018. However, with the missing GHG emissions data and the decreasing trend of unhealthy air quality days since 2018, more extensive data collection is needed to further validate this positive trend.

Table 11 GHG emissions in Jakarta and days of unhealthy air quality (source: Government of Jakarta, data.jakarta.go.id)

Indicators	**Year**							
	2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Greenhouse Gases Emissions in Jakarta (x1000 ton CO2e)								
Total	40.937	45.114	54.684	46.041	52.215	53.802	55.580	57.554
Energy sector	19.976	21.262	24.239	20.379	24.669	24.387	25.344	27.195
Transport sector	8.477	11.041	12.807	9.813	13.263	12.968	13.527	13.271
Days of unhealthy air quality in air monitoring stations								
Location of monitoring station	**Year**							
	2015	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	
Center Jakarta	0	2	28	6	14	2	14	
North Jakarta	15	50	42	117	45	28	41	
South Jakarta	33	47	64	81	103	30	43	
East Jakarta	25	14	21	11	54	23	125	
West Jakarta	7	43	43	185	129	67	49	
Average	16	31	40	80	69	30	54	

Beaudoin, et al (2015) summarized in their study that when a city is densely populated, the traffic congestion is increased, and traffic speed is decreased, thus the rising level traffic pollution is inevitable. However, the same study also implies that there is no clear relationship between traffic pollution and the rising of public transportation services. In other words, while there is a clear relation with private motorized cars ownership with traffic pollution, there is no evidence that public transportation modes should lead to that particular externality.

5.4. Policy Implication

In this particular subchapter, we will synthesize the survey result and the evaluation of indicators to find out the best possible plan to carry out transport sustainability policy in the city of Jakarta, Indonesia.

However, from the last two subchapters we have learned two important findings: first, which sustainable transportation factors and indicators are more important than others in the form of weight score (importance level), and secondly which sustainable transportation factors and indicators have been performing relatively worse than others. Even though we can assume that there are linkages between factors and indicators of sustainable transportation, it is still unclear how much significance those might be in the case of Jakarta city. Nevertheless, in the next subchapters we will allude to the two factors of sustainable transportation that are more important than others: Urban Spaces and Road Traffic Quality.

5.4.1. Range of Policy Instruments

May and Crass (2007) suggest that there are few policy instruments for sustainable transportation goals which have been considered for the European Conference of Ministers of Transport (2006) which arguably still could be relevant in our context: infrastructure provision and management; technological improvements (of vehicles, fuels, information provision, and infrastructure); regulation (of manufacturers, providers, and users); pricing and taxation; and information, awareness, and education (including voluntary agreements).

Infrastructure provision and management is closely related to 'Urban Spaces' which there are infrastructure-based indicators such as density of infrastructure and motorized infrastructure. We have learned form Table 9 that there is a massive gap between transport infrastructure made for motorized vehicle (private cars, motorbikes) and non-motorized (bicycles, pedestrians). Inherently, there are more demand for private cars and bikes in Jakarta. As we can see on Table 5, there are about 2.34 private motorized vehicles for every citizen of Jakarta. In Jakarta's case, there is lack of uncertainty of whether non-motorized road infrastructure should be pursued. However, study from ITDP in 2017 shows that it is recommendable for the Government of Jakarta to revitalize 712 km of roads with pedestrians which are connected with mass transport system like BRT or MRT which can increase the likeability of Jakarta citizen to use pedestrian lanes more.

Technological improvements for transportation sector can adhere to how it can improve 'Road Traffic Quality' in Jakarta. The usage of technology in both private and public transportation can reduce the traffic congestion. Wachs (2002) emphasized the importance of integrating information technology (IT) with the transportation network to manage congestion growth. Megacities in developed countries such as Seoul, South Korea has reformed its public transportation system and IT. With Seoul Transport Reform (STR) in 2006, the Seoul Government has introduced the integration of public transport network by unified fare system (with smart card system), feeder system (classification of bus types by colors), and transport facilities (integrated with metro lines).

Evidently, one of the easier tools that the government of Jakarta can use is with transport-related regulation. Whether it is about manufacturers, providers, cars, users, to pricing and taxes. It has been explained in last subchapter that the increasing tax rate of private vehicle ownership has not hindered the growth of motorized vehicle population in Jakarta. Even though there are lack of evidence regarding how taxes can help increase the transport sustainability, a model-based study by Hennessy and Tol in 2011 shows there are link between vehicle tax and energy efficiency since the users tend to use which are less costly (especially in the long-term). However, the study also shows the potential of reducing the carbon emission while still catering to the transport users' demand by introducing the EV (electric vehicle) tax which are less costly for the users and less harmful for the environment. In other words, by implementing regulation that based on transport sustainability, not only factors of 'Urban Spaces' and 'Road Traffic Quality', but every factor and indicator of sustainable transportation can be improved.

Lastly, the policy instrument that the government of Jakarta can utilize is by spreading information, awareness, and education about city transportation and the need for it to be as sustainable as possible.

5.4.2. Sustainable Transport Policies

In this subchapter, a few selected potential sustainable transport policies that can be used in Jakarta will be pointed out. Those policies are of those who has been either successfully implemented or emerged from sustainable transport studies.

A study by Go and Lee in 2012 simulated the land use and transportation policies in Namyangju City, South Korea until 2031 and the result shows that it is possible that the CO2 emissions reduction effect is available from the policy scenarios of the integrated land use and transportation within the existing policies. Furthermore, Hennessy and Tol (2011) also suggested the effect of integrated or mixed land use to make streets more accessible and walkable, in the end, more sustainable. In other words, these policies that related to land use in urban spaces should be highly considered by the city authorities and planners in Jakarta. However, it is slightly unclear in how should it be integrated because every city has their own character and local attributes that needs to be considered before an integration of urban spaces is to be implemented.

Jiang et al. (2017) recommended the use of emerging transportation-related innovations such as autonomous vehicles and connected vehicle technologies, as the study suggests that they have the capacity to improve the traffic flow.

Moreover, Go and Lee (2012) strongly suggest that a long-term evaluation is needed to better evaluate the policies since the effect of those policies will only take account in the extensively long period of time. May and Crass (2007) suggest that some of these policies need to be pursued at a supranational level, especially regarding the regulations to achieve the standards of safety, carbon emissions, and efficiency.

Chapter 6. Conclusion

6.1. Conclusion

The rapid growth of urbanization creates demand for more sustainable way of living in megacities such as Jakarta. A more sustainable transportation is needed to increase the quality of life of the citizen. Naturally, the need to assess the sustainability of transportation is also becoming as important as planning the sustainable transport policy.

Supported by a range of literatures and sustainable transport-related studies, this research shows there are various ways to assess sustainable transportation in city-level. Those ways share similarities which they are using indicators and scoring weight to indicate the importance level of each indicator.

In this research, the sustainable transportation indicators were selected according to its availability and measurability. From initial number of 415 indicators, the final number of 20 indicators were being selected, which then being categorized into 10 factors.

The next step is creating the importance level for these sustainable transportation factors by doing Analytical Hierarchical Process (AHP) survey. Two groups of respondents were created, being the group of 'users' and 'experts'. In both groups, they are noticeable differences and similarities. In users' group, the social domain is more important whereas in experts' group, economy domain is considered to be more important. However, both group's consensus is that the factor of 'urban spaces' and 'road traffic quality' are more important than other factor in regards to obtaining the sustainable transportation goal in Jakarta.

With the result of the most important factors of sustainable transportation in Jakarta, we can assess its sustainability by evaluating the performance of these indicators that are within the factors. In ‘urban spaces’ factor, the indicators’ performance is not desirable as it shows by the dominance of vehicle-based infrastructure in the urban areas rather than green spaces or non-motorized infrastructure. Nevertheless, the factor of ‘road traffic quality’ is performing relatively better than the former. It is shown by the decrease of traffic congestion index from 0.53 to 0.34 in a span of 2 years. However, the number should be cautioned because it could be the result of the Covid-19 pandemic restrictions.

For more than 2 years, the Covid-19 pandemic has impacted Jakarta’s transportation in various ways. Economically, the transportation sector was declining. In Table 7 we are able to see how the transportation experience negative growth of -7.63% in 2020.

However, a new social phenomenon is surprisingly emerging. A study by ITDP has shown an astronomical rising of road cyclist in few road segments in Jakarta by 1000%[7]. This happens because of Jakarta’s government decision to restrict mobility by limiting motorized vehicles (both private and public vehicles) since June 2020. With next-to-nothing mode of transportation left, working people of Jakarta were forced to use bicycles until the government starts to ease the restriction.

Second example comes from the environmental aspect. On September 2020, Jakarta government, alongside with international research groups has done environmental research on air condition in Jakarta. The result is that the air quality,

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[7] *https://www.cnnindonesia.com/nasional/20200615010417-20-513263/itdp-jumlah-pengguna-sepeda-di-jakarta-meningkat-saat-psbb (accessed on 6 December 2022)*

which is indicated by PM2.5 concentration, is decreasing up to 50 percent compared to year 2019[8].

Conclusively, there are still a lot journey for Jakarta's transportation to be as sustainable as it should be. Although there is a lot of ways and policies that relates to transport sustainability, in Jakarta's case, improving the aspects of urban spaces and road traffic quality is considered to be more helpful to accelerating that purpose.

6.2. Recommendation

From this study, few recommendations have been made from both the result of the AHP survey and the key indicators' performance. Policymakers in Jakarta should utilize the tools that they have efficiently and specifically. For instance, the options that would be sufficient are through regulations, provisions, subsidizes, and technological improvements.

Through sound and clear regulations that support sustainable transportation, the effort for achieving sustainable transportation goal can be accelerated. Promoting the use of EV in public transport and private transport by a low-rate of ownership tax would reduce the traffic pollution and quality of road traffic.

Procuring non-motorized infrastructures in urban areas, especially from residential to commercial area, would increase the non-motorized transport share as well as reducing growth rate of private and motorized vehicle ownership.

Lastly, by maximizing the use of technological advancements that related to urban transit, the traffic flow would be less congested and transit ridership would be increased. Integrating transport networks and facilities has been done by cities in

[8] *https://news.detik.com/berita/d-5184489/pemprov-dki-klaim-kualitas-udara-jakarta-membaik-50-persen-saat-pandemi-covid-19 (accessed on 6 December 2022)*

developed countries such as in Seoul, South Korea, since 2006.

6.2.1. Theoretical Implication

It is an undisputable fact that the transportation system is planned, developed, managed, and operated by various governmental entities, agencies, or authorities. In some cases, there are administration boundaries that transcend local, regional, even national level. In doing so, the need for extensive and fruitful collaboration between those entities must be made sure.

Gudmundsson (2016) suggests that the principles of sustainable development must be considered in every level of transportation decision-making. In other words, the coordination between politics, institutions, and the use of information to inform and influence decisions must be reflected. Two common, but broad stages on transportation policy are “planning” and “delivery”. By distinctively reflect both roles and use necessary tools to apply in both stages, a more coherent transportation policy can be meticulously planned and successfully delivered.

In this study we have learned that two most important sustainability factors in Jakarta that can help us on planning the sustainable transport policies in a more precise and focused way.

In improving urban spaces, the government and city planners must shift the collective policy-making mindset from car-based to people-centered cities. The well-being of citizens may be significantly improved by introducing more people-centered transportation policies such as: converting car lanes into bike lanes, opening open public places, and constructing disabled-friendly pedestrian walkways. A study by Blais and El-Genaidy (2014) shows that people with disabilities who have access to public transit have a higher sense of well-being and more so if they cannot afford personal transportation such as private car.

As an economic factor, achieving a better road traffic quality is an economic task. There will always be a cost between congestion costs (which are caused by private car-dominance traffic congestion) and public transport costs. However, regarding transportation in most underdeveloped cities, the cost of congestion is always far higher than the cost for public transportation service. While a study by Proost and Van Dender (2008) provides an alternative to find a balance in those costs, for a city in developing countries such as Jakarta, the trade-off between private and public transportation has to be won by the latter.

6.2.2. Practical Implication

In order for successfully apply the theoretical frameworks and findings from this particular research, we need to look at Jakarta's contexts whether they are historical or cultural context.

If we look back to Jakarta's transport policies of the past, they are progressing slowly in regard of sustainability aspects. For example, it took more than two decades for Jakarta's first subway transit system, MRT, to be fully operated. The exploding increase of vehicle ownerships that lead to traffic congestion is also one of the issues that can be avoided by implementing stricter rules or tax on private motorized vehicle ownership.

As we have learned on chapter 5.3.1, the private car ownership tax has not change since 2015 with 2%, it is marginally much lower than the neighboring country, Singapore, which has 10 times of the amount (20% excise tax). In addition, it is relatively easy to buy and own a vehicle in Indonesia. Especially two-wheelers or motorbikes, because they are cheap, and the down payment of these goes as low as 1 million IDR (around 63.94 USD[9]).

With those reasons, it is likely that private vehicle is still going to be number one transportation choice of Jakarta's citizen. Unless there are drastic measures by the authorities to reduce that reliance on motorized two-wheelers or four-wheelers, we are going to see further dominance of those private vehicles on the street of Jakarta.

Another related aspect is regarding the usage of Jakarta's urban space. With the increasing demand for private transportation, it would lead to the increasing of road infrastructure. In 2014, agreement was made between national government and Jakarta government to build 69.77 kilometers long of elevated highway[10] in the heart of Jakarta's urban scape. While urban transport activists have been showing their criticisms[11], the authorities argues that they are going to include public transportation facilities alongside the elevated highway[12].

In any case, it is strongly commendable that the policymakers should prioritize the aspects (or indicators, in this research context) of urban spaces such as lowering the density of road infrastructure, increasing non-motorized infrastructure, and sprawling more green areas and public parks.

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[9] *1 USD equals 15,634.05 IDR (8 December 2022)*

[10] *https://pu.go.id/berita/perjanjian-pembangunan-6-ruas-jalan-tol-dalam-kota-diteken (accessed on 8 December 2022)*

[11] *https://properti.kompas.com/read/2014/08/21/160741921/.Enam.Ruas.Tol.Dalam.Kota.Tak.Ada.Manfaatnya.Sedikit.Pun.?page=all (accessed on 8 December 2022)*

[12] *https://pu.go.id/berita/enam-ruas-tol-dalam-kota-akan-fasilitasi-transportasi-publik*

6.3. Limitation

As it is apparent from previous chapter, there are some noticeable gaps in secondary data collection primarily due to unclear duty of which agency responsible of collecting the data. In the domains of sustainable transportation, there are numerous and various branch of agencies that is responsible to collect the data, and some of them are unfortunately either missing or discontinued. There is also an issue whether the data should be collected by central or local government. However, the central government seems to acknowledge these issues and have been starting 'Satu Data Indonesia' initiative which means to create one single platform to collect, gather, and publish relevant development data of Indonesia, whether in national, regional, or city level.

The other limitation is regarding time constraint. As the author would like to explore more about these findings (especially regarding the AHP result), the limited time simply would not allow. Few studies have pointed out the assessment by creating 'normalized' score with AHP that could make this particular study about sustainable transport assessment be much clearer and easy to understand. However, the assessment in this study only limited by looking at historical trend, comparing to relevant studies, and the significance of the indicators from the AHP result.

As study by Shiau and Liu (2013) points out the relationships between sustainable indicators by using Fuzzy-AHP method, a method that is arguably more appropriate for this study since the indicators are inescapably related in one way or another.

Another implication caused by the limited time is that data collection, whether it is for primary data (survey and interview data) or secondary data. As we have learned from subchapter 4.3, 36 people has conducted the AHP survey. However, only a few of them (mostly from experts' group) were being interviewed. This creates a lack of depth in analysis part, especially to figure out the reason or meaning behind their given score on each domain and factor of sustainable transport.

Furthermore, time constraint might have been another reason behind the gap in secondary data regarding the sustainable transport indicators. The data that are being used in subchapter 5.3 are mainly from open-source data. Since it is likely that most of the data are not being updated consistently, it is useful to gather the relevant data directly by requesting to the institutions. However, doing this will take a longer time. Months of inquiries, meetings, and red tapes may be necessary for one to receive a more proper, reliable data.

Lastly, even though the topic of sustainable transport has been developing around the world, there has not been particular research about sustainable transport in Indonesia, especially Jakarta. As Gudmundsson (2016) argues that there are no such thing as 'global' sustainable indicators, every measurement in regard of sustainability of transportation must be put in local context. That is another reason why this typical study of transport sustainability in Jakarta, or any other Indonesian cities must be continued to increase its relevancy and reliability.

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Appendices

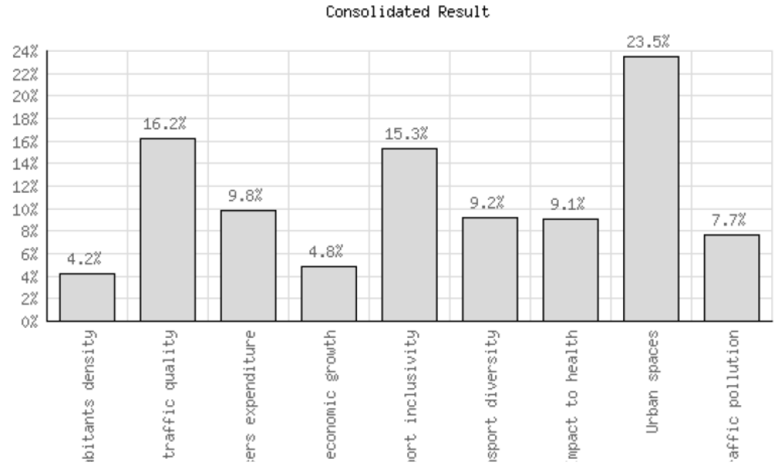
Appendix A - AHP Result (Users' Group)

Hierarchy with Consolidated Priorities

Decision Hierarchy

Level 0	Level 1	Level 2	Glb Prio.
Sustainable Transportation Indo-JKT	Economy 0.351	Inhabitants density 0.121	4.2%
		Road traffic quality 0.463	16.2%
		Users expenditure 0.278	9.8%
		Regional economic growth 0.138	4.8%
	Social 0.336	Transport inclusivity 0.455	15.3%
		Transport diversity 0.274	9.2%
		Impact to health 0.271	9.1%
	Environment 0.313	Urban spaces 0.752	23.5%
		Traffic pollution 0.248	7.7%

Consolidated Global Priorities



https://bpmsg.com/ahp/ahp-group.php

Breakdown by Nodes

Details Node: Sustainable Transportation Indo-JKT - CR: 0.1% - AHP group consensus: 43.8% very low

Details Node: Economy - CR: 0.4% - AHP group consensus: 54.2% low

Details Node: Social - CR: 0.5% - AHP group consensus: 41.1% very low

Details Node: Environment - CR: 0% - AHP group consensus: 64.2% moderate

Appendix B - AHP Result (Experts' Group)

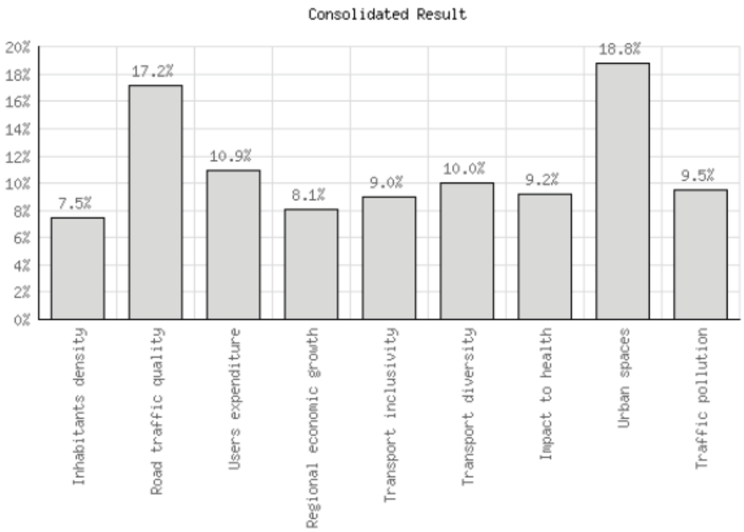
Hierarchy with Consolidated Priorities

Decision Hierarchy

Level 0	Level 1	Level 2	Glb Prio.
Sus-Transport Indo-JKT Experts	Economy 0.436	Inhabitants density 0.172	7.5%
		Road traffic quality 0.394	17.2%
		Users expenditure 0.250	10.9%
		Regional economic growth 0.185	8.1%
	Social 0.281	Transport inclusivity 0.318	9.0%
		Transport diversity 0.354	10.0%
		Impact to health 0.328	9.2%
	Environment 0.283	Urban spaces 0.663	18.8%
		Traffic pollution 0.337	9.5%

Consolidated Global Priorities

https://bpmsg.com/ahp/ahp-group.php



Breakdown by Nodes

Details Node: Sus-Transport Indo-JKT Experts - CR: 0.5% - AHP group consensus: 46.1% very low

Details Node: Economy - CR: 0.1% - AHP group consensus: 50.1% low

Details Node: Social - CR: 0.3% - AHP group consensus: 46.8% very low

Details Node: Environment - CR: 0% - AHP group consensus: 50.1% low

국문초록

지속가능한 도시교통수단 평가:
인도네시아 자카르타의 사례

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35 년 전 '지속 가능한 발전'이란 용어는 '미래 세대가 자신의 필요를 충족시킬 수 있는 능력을 훼손하지 않고 현재의 필요를 충족시키는 발전'으로 정의됐다. 자카르타와 같은 거대 도시의 맥락에서 도시화의 빠른 성장률은 도시 지역을 지속 가능한 방식으로 건설하는 것이 그 어느 때보다 중요할 것이라는 것을 의미한다. 따라서 시민들의 삶의 질을 높이기 위해서는 보다 지속 가능한 교통수단이 필요하다.

지속가능한 도시교통 정책을 계획하기 위해서는 교통 자체의 지속가능성 정도를 평가할 필요가 있다. 본 연구는 각 지표의 중요도를 나타내기 위해 지표를 사용하고 가중치를 채점하고 있는 문헌의 범위가 뒷받침하는 도시 수준의 지속가능한 교통수단을 평가하는 다양한 방법을 발견한다. 본 연구에서는 총 20 개의 지속가능한 교통지표를 선정하여 10 가지 요소로 분류하였다.

이후 이러한 지속 가능한 운송 요인과 영역에 대한 중요도 수준을 공식화하기

위해 분석적 계층적 프로세스(AHP) 조사가 수행되었다. 이 설문조사를 위해 두 개의 응답 그룹이 작성되었는데, 바로 운송 '사용자' 그룹과 운송 '전문가' 그룹이다. 결과는 두 그룹 모두에서 눈에 띄는 차이와 유사성이 있음을 보여준다. 도메인 수준에서, 사용자들은 사회적 영역을 가장 중요한 수준으로 기울고 있는 반면, 전문가들은 경제적 영역을 대신 고려하고 있다. 다만 자카르타의 지속가능한 교통목표를 달성하기 위해서는 '도시공간'과 '도로교통질'이라는 요소가 다른 요소보다 중요하다는 것이 두 그룹의 공통된 의견이다.

이러한 결과로 자카르타의 지속가능성 교통수단의 성과를 평가할 수 있다. '도시공간' 요소에서 지표의 성과는 녹지공간이나 비동기화 인프라보다는 도심지역의 차량기반 인프라 우위성을 보여줘 바람직하지 않다. 다만 '도로교통 질'이라는 요소는 전자보다 상대적으로 좋은 성과를 내고 있다.

게다가, 자카르타의 교통은 그것이 지속 가능해야 하는 만큼 되기 위해 여전히 약간의 노력이 필요하다. 본 연구에서는 교통지속성과 관련된 여러 가지 방법과 정책들이 있지만, 자카르타의 경우 도시공간과 도로교통의 질적 측면의 개선이 그 목적 달성에 보다 도움이 될 것으로 보고 있다.

주요어: 지속가능교통평가, 지속가능교통지표 선정, 분석적 계층화과정 (AHP), 가중치 부여과정, 교통정책

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