International Journal of Sustainable Development and Planning
Vol. 17, No. 4, July, 2022, pp. 1285-1296
Journal homepage: http://iieta.org/journals/ijsdp

Towards Sustainable Transportation in Urban Areas: A Case Study

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https://doi.org/10.18280/ijsdp.170426

Received: 11 March 2022
Accepted: 8 June 2022

Keywords:
transportation, sustainable development strategy, urban area

ABSTRACT

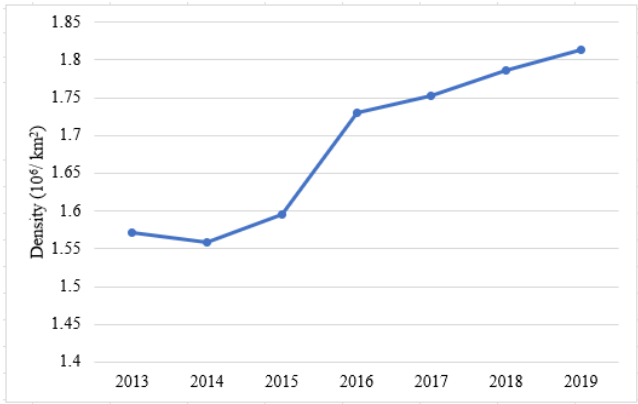
This study aims to develop a sustainable transportation development strategy in Semarang City. Collecting data using interviews, and questionnaires. Source of data from keyperson with purposive sampling technique. Keypersons consist of the Head of Sub-Division of Transportation and Water Resources Planning, Expert Staff of Transportation and Water Resources Planning, Head of Pollution Control and Environmental Conservation Division of the Environment Service, Operational Manager of Trans Semarang BRT, Expert Staff of the Public Service Agency of the Regional Technical Implementation Unit (UPTD). BRT Trans Semarang, Civil Engineering Lecturer in the Transportation Sector. Data were then analyzed using the Analytical Hierarchy Process (AHP) technique. The findings revealed that the development of transportation system facilities and infrastructure is the top priority for policy. The second priority is improving environmental quality and Government policy turns out to be the next strategic priority. The practical significance of this research is that the determination of strategic priorities can be applied to other cities that have characteristics as metropolitan cities and have a commitment to carry out sustainable transportation in order to achieve effective and optimal results.

1. INTRODUCTION

The issue of reducing carbon emissions has started since the Kyoto protocol agreement was signed on December 11, 1997. This commitment requires every country and region to review policies that can cause environmental pollution. In 2019, the transportation sector accounted for a third of Indonesia's total Greenhouse Gas (GHG) emissions. Therefore, the importance of the concept of sustainable transportation is considered by looking at the value of positive and negative externalities of transportation and traffic in the short and long term [1]. Sustainable transportation has several indicators that emphasize economic, environmental and social balance [2] towards a healthy city.

Semarang City is the capital city of Central Java in Indonesia and an industrial city, which is attractive for immigrants to work, study, or live in. Many immigrants who later settled in Semarang City made this city even more densely populated [3, 4]. The population in the Semarang continues to increase every year. In a couple of years (2013-2019), the population in Semarang has continued to grow. The high population growth in Semarang is caused by several factors, including birth, death, arrival, and immigration. The increase in population has an impact on population density with an increasing trend. The following is a Figure 1 of the increase in population density in Semarang City in 2013-2019.

The population density in Semarang City from 2013 to 2019 continues to increase. In 2013, the population density was 4,206 people/km^2. Although, in 2014, it decreased to 4,172 people/km2 but in 2015, it increased again until 2019, which reached 4,855 people/km2. The density of the population in Semarang has made the traffic of community activities even denser. The increasingly dense traffic and people's movement are in line with the increasingly dense demand for transportation, which has consequences for the energy and the environment. The higher the activities carried out by urban communities, the higher the environmental impact [5-9].



Source: Central Bureau of Statistics Semarang, 2020

Figure 1. Population density in Semarang City 2013-2019

Semarang City transportation development has been continuously pursued through spatial and territorial planning in the 2016-2021 Semarang's RPJMD (Regional Long-Term Development Plan). The RPJMD contains Semarang City's vision and mission. Semarang City's vision is "*Semarang Kota Perdagangan dan Jasa yang Hebat Menuju Masyarakat Semakin Sejahtera*" (Semarang, a City of Great Trade and Services Towards an Increasingly Prosperous Society). There is also a mission in that vision, one of which is "*Mewujudkan*

Kota Metropolitan yang Dinamis dan Berwawasan Lingkungan" (Creating a Dynamic Metropolitan City with Environmental Insights). In line with the Regional Development Planning of Semarang City for 2016- 2021 that states development is prioritized on optimizing the use of spatial planning and enhancing the development of regional infrastructure that is planned, harmonious, balanced, and considered environmentally sound and sustainable.

As stated in the 2016-2021 RPJMD of Semarang City, the city of Semarang's vision and mission clearly illustrate that the development of Semarang is directed towards environmentally sound and sustainable development. Likewise, the development and growth of Semarang transportation can also be carried out regardless of environmental elements. To support the realization of Semarang City's vision and mission, in this case, the Semarang City Transportation Office, in accordance with its main duties and functions, plays a role in the success of Semarang transportation development, referring to the development mission of Semarang, such as creating a dynamic and environmentally sound metropolitan city.

The government has provided mass transportation modes, such as city transportation, buses, rickshaws, and others. These transportation modes are also equipped with adequate amenities and infrastructure, such as bus stops, paved streets, public street lightings, pedestrian paths, and other infrastructures. The government provides a public transportation mode called BRT (Bus Rapid Transit) or *Trans Semarang Bus,* with routes that pass through strategic places in Semarang.

The availability of mass transportation modes that are deemed inadequate makes people prefer to use private vehicles, and the existence of these private vehicles continues to increase every year. The number of private vehicles in Semarang City is much greater than the number of public vehicles. Based on data from the Regional Revenue Management Agency of Central Java in 2018 showed that the number of private vehicles in Semarang from 2013 to 2017 has increased. In 2013 alone, two- and three-wheeled private vehicles were 681,443 units. Then, in the following year, it continued to increase until 2017 up to 1,387,600 units (103.63%). Private two and three-wheeled vehicles and four-wheeled private vehicles in Semarang also continued to increase from 121,782 units in 2013 to 238,152 in 2017 (95.59%) (see Figure 2). The increase in private vehicles in Semarang City has been followed by increased public transportation, both small and large public vehicles. However, the number of public transportations is still far less than that of private vehicles.

The high number of private vehicles in Semarang City, which continues to increase every year, will undoubtedly cause various problems, such as worsening congestion, hindering economic activity, and increasing environmental pollution. Apart from congestion, the problem caused by the high number of private vehicles is environmental pollution, especially air pollution. The impacts of the high number of private vehicles are to make traffic flow denser and increase air pollution. This shows that there is still a lack of attention to environmental quality. The decline in urban air quality is caused by increased use of motorized vehicles, disincentives for fuel-free transportation (FFT), and a decrease in urban areas' green areas. The same study was also conducted by Qiu et al. [10] and Liang et al. [11].

The enhancement of private vehicles causes the amount of CO_2 to rise. As one of the causes of air pollution, the greater CO_2 has an impact on the decline in environmental quality. If this condition continues, it will affect people's quality of life [10-12].

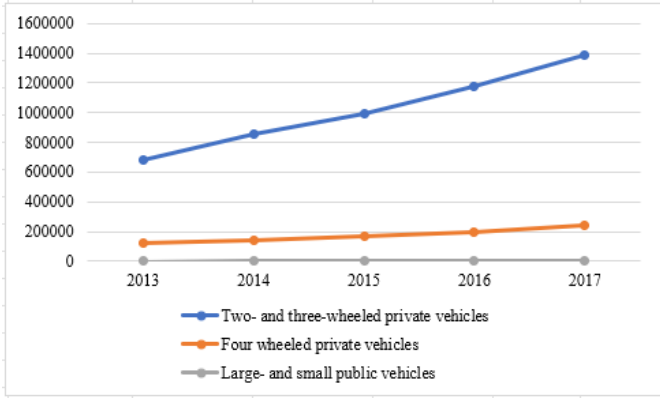


Figure 2. Number of Motorized Vehicles in Semarang City in 2013-2017 (Units) Regional Revenue Management Agency of central Java, 2018

The government is currently making serious efforts to build more advanced and environmentally friendly transportation to reduce congestion and air pollution by implementing sustainable transportation development. However, the results are still not effective and optimal. Base on interview with keyperson, although several pedestrian paths are already in poor condition and are used as parking lots and trading. There is no separation of public transportation routes from other transportation yet. The pedestrian's condition can be measured by the condition itself, crowdedness, and other aspects such as trees, benches, water fountains, and so on [13]. The provided mass public transport (BRT) does not cover the entire area, and services are still lacking. This shows that the available facilities and infrastructure and local government policies towards sustainable transportation are still lacking. In fact, it is well known that sustainable transportation reflects the concept of sustainable development in the transportation sector. According to Rasiah et al [14], discussing sustainable development has become an important part of alternative green paths. The effect of sustainable transportation cannot be ignored in an urban area's growth and development process [8, 15-17].

Based on the Regional Medium Term Development Plan Based (RPJMD) and the phenomenon of transportation in the Semarang city, it is important to develop strategic priorities towards sustainable transportation from the criteria for facilities and infrastructure, government policies and environmental quality so that results can be optimally achieved according to the plan. This study aims to elaborate a strategy for sustainable urban areas transportation development, especially in Semarang City as an industrial city center in a region. This research is urgent because currently, many cities face the same problem. Even though the government policies have been made and tried to accommodate the vision and mission to be achieved, the implementation often does not work properly, so it is necessary to look for root cause-based policy priorities.

The previous research done by Ameen and Mourshed [18] focuses on providing sustainable means of transportation to developers (stakeholders). According to Xu et al. [19], policies in providing sustainable transportation facilities must combine the combination of human impacts, efficiency impacts, and

sustainability impacts into one framework. However, there is no element of equity and policy efficiency. Meanwhile, Cascetta et al. [20] implemented the three processes required to integrate transportation facilities, namely cognitive decision-making, stakeholder engagement, and quantitative analysis. The difference between this study and previous research is that the policy-making for the provision of sustainable transportation means involves not only users (stakeholders) but also development planners and academics. The elements of efficiency and effectiveness of policy are carried out by determining the priority scale in each existing program, which previous researchers have not carried out. This difference is expected to enrich the treasury of knowledge and produce various policies to solve the complexity of transportation problems.

2. METHOD

This type of research is qualitative and quantitative research. The location used for this research was Semarang City, Central Java Province – Indonesia, as a metropolitan city with a mission to implement sustainable transportation. The data were acquired using primary and secondary data, where primary data were obtained by doing interviews, and questionnaires. At the same time, secondary data were acquired from scientific literature, articles, journals, and websites. Moreover, secondary data were achieved from the Semarang City Regional Planning and Development Agency (BAPPEDA), Semarang City Transportation Service, and Semarang City Environmental Service.

The sampling technique was the purposive sampling technique, where six key people were considered experts in knowing the problem studied and understood what is expected in the study. Key persons consist of the Head of Sub-division of Transportation and Water Resources Planning, Expert Staff of Transportation and Water Resources Planning, Head of Pollution Control and Environmental Conservation Division of the Environment Service, Operational Manager of Trans Semarang BRT, Expert Staff of the Public Service Agency of the Regional Technical Implementation Unit (UPTD) BRT Trans Semarang, Civil Engineering Lecturer in the Transportation Sector. Data collecting techniques comprised interviews, documentation, discussion, and questionnaires. The hope is that by using analytical tools AHP, combining several key persons, and scientific analysis can produce precise policy directions for problems related to government policies and funding of public facilities such as sustainable public transportation and improving the economy through a reputation for institutions [21-23]. Criteria, alternative in analysis AHP see Table 1.

In determining the priority strategy, steps are needed to determine the priority strategy: first, determine the research objectives, is a strategy for developing sustainable transportation in the city of Semarang; Second, determine the criteria and alternatives. The criteria and alternatives were obtained from the results of qualitative data analysis and interviews from competent keypersons. There are 3 criteria, namely government policies, development of facilities and infrastructure, and improvement of environmental quality. There are 11 alternatives, namely A1-C4 (Table 1). Third, distributing questionnaires to a number of keypersons that have been determined based on the fundamental scale (Table 2) and guiding the process of filling out the questionnaires; Fourth, compile a matrix of the average results of the keyperson. Then the results were processed using expert choice version 11.0. The fifth is to score each informant's answer on the pairwise comparison matrix and present its geomean. The sixth is analyzing the output of expert choice version 11.0 by looking at the inconsistency and priority values. From these results, the criteria and prioritized alternatives can also be known. If the value is more than 10%, then the data judgment assessment must be corrected. If the Consistency Ratio (CI/IR) 0.1, then the calculation results can be declared correct. When the ratio is consistent then the eigenvalues do not exceed n. The eigenvalues that do not exceed n are considered as a measure of consistency by forming a consistency ratio of differences in the correspondence mean of the n eigenvalues of a large matrix of randomly selected judgments [24]. The seventh is determining the priority scale of the criteria and alternatives to determine the strategy for developing sustainable transportation in the city of Semarang.

Table 1. Criteria and analysis AHP

Goal	Criteria	Alternative
Sustainable Transportation	Government Policy	(A1) Increasing the integration between mass transportation modes
		(A2) Stipulation of the prohibition on on-street parking along with public areas
		(A3) Mass public transportation separated routes from other transportation
		(A4) Increasing the quality of service, convenience, and safety of mass public transportation
	Facilities and Infrastructure Development	(B1) Pedestrian and bicycle paths development
		(B2) Park and ride facilities provision
		(B3) Modern mass public transportation with large passenger capacities provision (MRT, LRT)
	Environmental Improvement Quality	(C1) Private transportation modes shift to public transportation modes to reduce fuel consumption
		(C2) Progressive vehicle tax based on exhaust emission test results
		(C3) Reducing the need for travel in cities through land use
		(C4) Establishment of a green belt along the newly constructed road with productive and non-breakable shade trees

The analysis technique employed the Analytical Hierarchy Process (AHP). AHP helps set priorities and objectives from various options. It establishes the priority of elements in a

decision problem by making pairwise comparisons on each element, fairly compared against a specific criterion [10]. Analytical Hierarchy Process (AHP) method would obtain several strategies that can be worked as materials for a sustainable transportation development strategy in Semarang City according to hierarchy or priority.

Compilation of the criterion and sub-criterion variables as alternatives to determine policy priorities with the Analytical Hierarchy Process (AHP) encompassed government policies, development of facilities and infrastructure, and environmental quality improvement. Various program alternatives were within these three variables to determine a sustainable transportation development strategy in Semarang City: four alternatives for government policy criteria, three alternatives' criteria for developing facilities and infrastructure, and four criteria for improving the environment's quality.

Table 2. The fundamental scale

Intensity of importance on an absolute scale	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgment strongly favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favor one activity over another
7	Very strong importance	An activity is strongly favored and its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
Reciprocals	If activity i has one of the above numbers assigned to It when compared with activity j, then j has the reciprocal value when com	
Rational	Ratios arising from the scale	If consistency were to be forced by obtaining n numerical values to span the matrix

3. RESULTS

Analytical Hierarchy Process (AHP) was used to prioritize strategies for developing sustainable transportation in Semarang City. The components used in this study included several criteria and alternatives based on the results of literature reviews, previous research, and interviews with predetermined and competent key persons in the transportation sector.

Six key persons were involved from Bappeda Semarang City, Semarang City Transportation Office, Semarang City Environmental Service, and Academics. Priority strategies were obtained by selecting several criteria and alternatives based on observations and interviews with the Semarang City Development Planning Agency for Transportation Planning and Water Resources. At the end of the interview, three criteria were achieved: government policy, facilities development, infrastructure, and improvement of environmental quality. Then, they were compiled based on the Analytical Hierarchy Process (AHP).

According to calculation using AHP on all criteria for sustainable transport development in Semarang City utilizing the Expert Choice 11 program, the following results were obtained in Figure 3.

Figure 3 can be interpreted that the most prioritized criterion in the development of sustainable transportation in Semarang City is the development of facilities and infrastructure, with a weighting value of 0.413. Then, the second priority criterion is the improvement of environmental quality with a weighting value of 0.327, and the third priority criterion is government policy with a value of 0.260. These calculation results were utilized as a basis for determining the priority order of each of the criteria, which can be used as the basis for developing sustainable transportation in Semarang City.

The government policy criteria consist of four alternatives, including increasing the integration between modes of mass public transportation, stipulating a prohibition on parking on streets along with public mode areas, separating mass public transportation routes from other transportation, and improving service quality, convenience, and safety of mass public transportation. The criteria for developing facilities and infrastructure have three alternatives: the development of pedestrian and bicycle paths, the provision of park and ride facilities, and the provision of modern mass public transportation with a large passenger capacity (MRT, LRT). Meanwhile, the criteria for improving environmental quality have four criteria, covering the transfer of private modes of transportation to public modes of transportation to reduce fuel consumption, progressive vehicle taxes based on the results of exhaust emission tests, reducing the need for travel in urban areas through land use, and the realization of green belts along newly built road routes with productive and non-fragile shade trees.

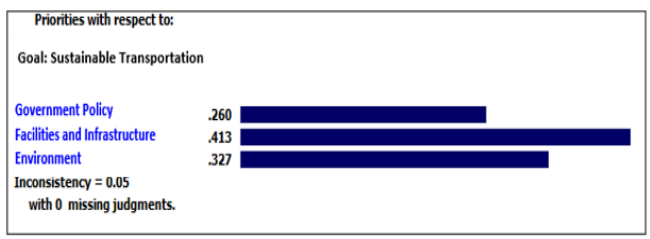


Figure 3. Overall sustainable transportation development criteria in Semarang City based on AHP outputs

3.1 Facilities and infrastructure development criterion

The development of facilities and infrastructure is the most prioritized criterion for developing sustainable transportation

in Semarang City. The development of facilities and infrastructure is essential in developing sustainable mass transportation in Semarang City. With the availability of adequate and comfortable transportation facilities and infrastructure for the community, this will minimize various existing problems, such as pollution congestion and high use of private vehicles.

In the criterion for developing these facilities and infrastructure, there are three alternatives: the development of pedestrian and bicycle lanes, the provision of park and ride facilities, and the provision of modern mass public transportation with large passenger capacities (MRT, LRT). The calculation results of the Analytical Hierarchy Process (AHP) on the criterion for developing facilities and infrastructure are shown in Figure 4.

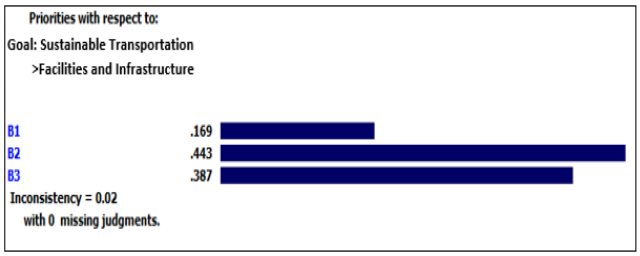


Figure 4. AHP outputs of facilities and infrastructure development criterion

Caption: B1: Pedestrian and bicycle paths development; B2: Park and ride facilities provision; B3: Modern mass public transportation with large passenger capacities provision (MRT, LRT)

Figure 4 exhibits that the most prioritized alternative on the criterion for developing facilities and infrastructure regarding developing sustainable transportation in Semarang City is the provision of park and ride facilities, with a weight value of 0.443. The provision of parks and rides is the provision of parking lots at strategic places and integrated transportation nodes, such as bus stops, terminals, and stations.

The provision of park and ride facilities is intended for private vehicle drivers to park their vehicles in parking pockets and then switch to using public transportation to reduce congestion in city centers. Providing parking pockets in several strategic places and transportation nodes will minimize the number of private vehicles in the city center so that it will reduce congestion and CO emissions [25].

Nag et al. [26] stated that providing parking lots in busy urban areas will reduce vehicle mobility so that it can avoid congestion and at the same time attract tourists to travel in urban areas. However, it is different from what Yin & Wang [27] said that the availability of excessive parking lots increases people's dependence on car use. The provision of park and ride facilities planned by the Semarang City government is specifically for construction in community activity centers, namely in the Tugu Muda area, Johar area, and Mataram Plaza.

The second priority alternative is the provision of modern mass public transportation with a large passenger capacity (MRT, LRT), with a weight value of 0.387. The dense movement of urban communities certainly requires adequate transportation facilities, especially mass public transportation. The provision of mass public transportation in urban areas is crucial to support this dense movement. Therefore, the Semarang City government has provided mass transportation in the form of the Trans Semarang BRT. However, the existence of the Trans Semarang BRT has not been able to accommodate all the needs of the community's movement because of the relatively small bus capacity, so that passengers have to jostle to catch time.

Kelle et al. [28], affirmed that changing transportation mode from the road to rail has a major effect on local road transportation, increasing speed, reducing congestion, reducing delays in shipping goods, and reducing pollution. It is because rail transportation by train has several advantages, such as system reliability, speed of travel time, and greater transport capacity.

The Semarang City government has launched to provide mass public transportation with a larger capacity like the MRT and LRT. MRT (Mass Rapid Transit) is an effective and comfortable rail-based mass transportation and fast transit system with a large passenger-carrying capacity. Meanwhile, the LRT (Light Rapid Transit) is a rail-based metropolitan transportation system with monorail and tram lines along its lines. Currently, the MRT and LRT implementation plans in Semarang City are still being studied more deeply and are planned to be built in community activity centers.

The last priority alternative is the development of pedestrian and bicycle paths, with a weight value of 0.169. Pedestrian paths and bicycle lanes in Semarang City have been implemented for a long time, but the implementation has not been optimal. There are still many roads in the city center that are not yet available for pedestrians and bicycle lanes, and many are in poor condition. Therefore, it is necessary to develop by improving the damaged pathways' condition and adding supporting facilities to provide pedestrians and bicycle users safety and comfort. In line with [29] that said pedestrian path conditions attract people to walk easily from various places, and the quality of the pedestrian paths makes users comfortable using them.

If pedestrian and bicycle paths are considered safe and comfortable, there will certainly be more people who are interested in choosing to walk and cycle instead of using motorized vehicles. In a study by Boettge et al. [30], it was stated that bicycle users generally feel less comfortable and safe when cycling because road traffic sometimes ignores bicycle users, so that bicycle development should be prioritized on roads with lighter traffic intensity or on roads that are not too crowded of vehicles to ensure the safety and comfort of cyclists.

3.2 Environmental improvement quality criterion

The second priority criterion in the strategy for developing sustainable transportation in Semarang City is improving environmental quality. This study's results are different from the research by Kumar et al. [31], which stated that environmental indicators are the most prioritized aspects of the realization of sustainable transportation in Delhi City.

Based on observations and interviews with the Semarang City BAPPEDA, in the criterion for improving environmental quality, there are four alternatives, including the transfer of private transportation modes to public transportation modes to reduce fuel consumption, progressive vehicle taxes based on exhaust emission test results, reducing the need for travel in urban areas through land-use planning, and the embodiment of a green belt along the newly constructed road with productive and non-fragile shade trees. The calculation results from the

Analytical Hierarchy Process (AHP) on the criterion for improving environmental quality are shown in Figure 5.

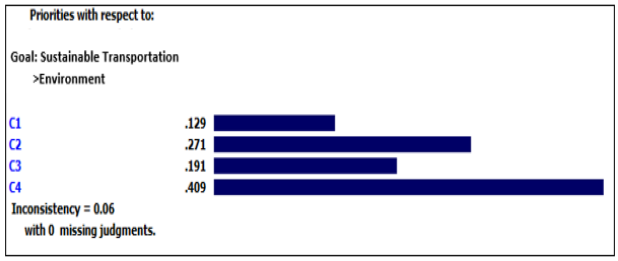


Figure 5. AHP outputs of environmental improvement quality criterion

Caption: C1: Private transportation modes shift to public transportation modes to reduce fuel consumption; C2: Progressive vehicle tax based on exhaust emission test results; C3: Reducing the need for travel in cities through land use; C4: Establishment of a green belt along the newly constructed road with productive and non-breakable shade trees

Figure 5 displays that the most prioritized alternative on the criterion for improving environmental quality in developing sustainable transportation in Semarang City is the embodiment of a green belt along the newly constructed road with productive and non-breakable shade trees, with a weight value of 0.409. The increasing number of motorized vehicles in Semarang City will result in increased air pollution. It certainly makes the air quality in Semarang City decrease. Therefore, the Semarang City government has launched a green belt program or planted shade trees along the newly constructed road that is busy with vehicles.

The types of trees planted are trees that do not break easily and can absorb pollutants, such as *Dadap Merah, Mahoni, Asam Jawa, Flamboyan*, etc. The realization of the green belt aims to clean the air from pollutants, especially CO2, and absorb noise so that it will reduce pollution in Semarang City. Jin et al. [32] said that green vegetation as a shade for cities should always be available to improve air quality in cities due to high urban traffic.

The second alternative priority is a progressive vehicle tax based on the exhaust emission test results, with a weight value of 0.271. The relatively high number of motorized vehicles in Semarang City is a particular concern for the local government, considering that motorized vehicles contribute to pollutants by 80%. There are still many motorized vehicles whose exhaust emissions exceed the specified threshold. Therefore, the Semarang City government has issued a progressive vehicle tax based on the vehicle's exhaust emission test results. In implementing this tax, exhaust gas emissions are prerequisites for motor vehicle roadworthiness. Motorized vehicles that exceed the exhaust gas emission threshold will be subject to a progressive tax. Meanwhile, motorized vehicles that can manage exhaust emissions properly will receive tax relief.

The third alternative priority is to reduce the need for travel in urban areas through land-use planning, with a weight value of 0.191. The more densely populated a city is, the denser the travel activities of its residents will be. As the capital of Central Java Province and a city of trade and industry, Semarang City makes its population's travel activities very dense, both trips by local residents and outside the city. Not a few residents outside the city work in Semarang and migrate every day.

Industrial and trade areas that are still spreading in several points in Semarang City have moved the people not yet centralized, causing congestion. Through proper land use, it is hoped to reduce these problems. Land use management will be applied by directing spatial use changes in the periphery areas to be developed by various production facilities and areas. It is intended to regulate the movement to not concentrate in the city center.

The fourth priority alternative is private transportation transfer to public transportation to reduce fuel consumption, with a weight value of 0.129. The high public interest in the use of private vehicles causes high fuel consumption, which results in increased pollution in Semarang City. BBM is a motor vehicle fuel that comes from fossils so that the pollutants produced from this fuel are very high. Therefore, the tendency of the community to use private vehicles must be diverted to using public vehicles.

Steps that can be applied to realize the program are to increase the cost of travel by private mode by increasing the tax on private vehicles, increasing parking fees, and imposing tolls for specific areas, additional costs for fossil fuels, and tax on luxury goods. Thus, people who want to use private vehicles will think twice considering the huge costs they have to bear.

3.3 Government policy criterion

Government policy is the third criterion in the transportation improvement strategy in Semarang City. The government is the party with the authority to set a policy to achieve a goal. Government policy here is very closely related to programs and regulations that have been launched and related to transportation. With these programs and regulations, it is hoped that they will be able to realize sustainable transportation in Semarang City. Based on the results of surveys and interviews with the Semarang City BAPPEDA, several alternatives were found in government policy criterion that increases the integration between shared public transportation modes: determining parking restrictions on roads along with public mode areas, separating public transportation routes along with other transportation, and improving service quality convenience and public transportation. The calculation results of the Analytical Hierarchy Process (AHP) against the government policy criterion are shown in Figure 6.

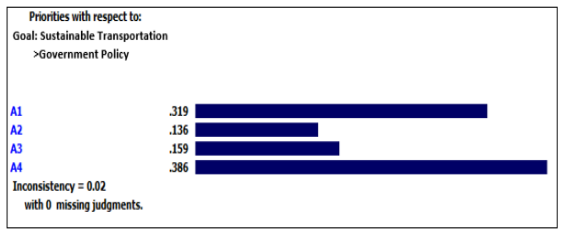


Figure 6. AHP outputs of government policy criterion

Caption: A1: Increasing the integration between mass transportation modes; A2: Stipulation of the prohibition on on-street parking along with public areas; A3: Mass public transportation separated routes from other transportation; A4: Increasing the quality of service, convenience, and safety of mass public transportation

Figure 6 can be interpreted that the most prioritized

alternative to government policy criterion in developing sustainable transportation in Semarang City is the improvement of service quality, convenience, and security of mass public transportation, with a weight value of 0.386. Mass public transportation is a public vehicle that can support people's movement in big cities such as Semarang City.

People do not need to use private vehicles to support their daily activities with this mass transportation. However, what is of concern is that there are many modes of mass public transportation with quality of comfort and safety below the community's expectations, such as relatively long waiting times, travel times that are not much different from private vehicles, and small passenger capacities so that passengers have to jostle. These will decrease the public's interest in using mass public transportation. Therefore, efforts are needed to improve service quality, comfort, and safety in mass public transportation, such as increasing the number of fleets so that waiting times are faster and replacing old transportation modes with new ones and a larger capacity so that passengers do so not need to overcrowd. The convenience of mass public transportation is an essential aspect so that people are still willing to use public transportation rather than private transportation [33].

The second priority alternative is to increase the integration between mass public transportation modes, with a weight value of 0.319. The movement of urban communities that are not only centered in one area requires an integrated mass public transportation mode to facilitate their activities, especially those on the outskirts of the city and those outside the city. If the mass public transportation modes are not integrated, then people from the suburbs and outside the city will choose to use private vehicles to go to the city center. Vice versa, if modes of public transportation are integrated, people will choose to use mass public transportation. Therefore, there is a need to integrate mass public transportation modes such as BRT by train or other public vehicles so that people can take advantage of them optimally.

The importance of integration between transportation system planning elements is that allocating resources will face situations and changes in the urban physical environment that are growing and developing dynamically [34, 35]. If it is not appropriately anticipated, it will affect the quality of people's lives.

Then, the third priority alternative is the separation of mass public transportation routes from other transportation, with a weight value of 0.159. So far, the mass public transportation route in Semarang City is still integrated with other vehicles, both private vehicles and goods transportation, so that when there is a traffic jam, the mass public transportation will also experience congestion. It causes the travel time for mass public transportation to be no different from private transportation.

The Semarang City government has announced to separate public vehicles from goods and private vehicles. The currently being pursued program is the construction of the Semarang city ring road intended for goods and heavy vehicles to reduce the volume of vehicles on the city route. While programs to separate public vehicles from private vehicles are being pursued by separating routes and building the Bus Way route.

The fourth priority alternative is the imposition of on-street parking restrictions along the public mode area, with a weight value of 0.136. Dense urban community activities and the high use of private vehicles that are not matched by the provision of adequate parking pockets have caused many private vehicles to be parked on the road, thus obstructing traffic flow, which will impact congestion. It has occurred on various roads in the center of Semarang City, such as the Jl. Pemuda, Jl. Pahlawan, Jl. Veteran, Jl. Pandanaran, and many others. Even though these roads connect several facilities in the city, the traffic is very congested. In fact, not a few private vehicles are parked in the bicycle lane, disturbing bicycle users. Therefore, the Semarang City government has implemented a prohibition on on-street parking along public mode areas to reduce the impact of congestion.

3.4 Sequence of alternatives for sustainable transportation development strategies in Semarang city

Using AHP on all alternative strategies for sustainable transport development in Semarang City shows the results in Figure 7.

Figure 7 above shows that in the development of a sustainable transportation development strategy in Semarang City, the most prioritized alternative is the provision of park and ride facilities, with a weight value of 0.172. As the center of industry and trade, traffic in this city is very dense, causing congestion and air pollution. The very high volume of vehicles causes congestion in the city center due to the high use of private vehicles.

People who live in suburban and out-of-town areas prefer to use private vehicles to support their city center activities. To overcome the high volume of vehicles, park and ride facilities are needed in several strategic areas: near bus stops/bus shelters, stations, and other strategic places. With this park and ride facility, it is hoped that people who use private vehicles from the outskirts and outside the city park their vehicles in the parking pockets that have been provided and then switch to mass public transportation to their destination. Thus, it will be able to reduce the volume of vehicles and reduce congestion.

Apart from providing park and ride facilities, it is also necessary to offer modern public transportation with a large passenger capacity (MRT, LRT) to develop sustainable transportation in Semarang City. So far, mass transportation in Semarang City like BRT Trans Semarang has not accommodated the people's movements in Semarang City. The relatively small capacity and routes still integrated with other vehicles make the travel time and waiting time for this transportation mode quite long. Therefore, it is necessary to provide mass public transportation that is more effective and efficient with a faster travel time, namely by providing MRT (Mass Rapid Transit) and LRT (Light Rapid Transit).

MRT and LRT are rail-based mass public transportation that has been widely implemented in big cities. The rail-based line will not collide with other vehicles to be more effective and efficient. Yu et al. [36] stated that shifting road public transportation modes to rail-based transportation in several cities in China has been shown to reduce road pressure and reduce pollution significantly. Thus, it will attract people to use mass public transportation more than private transportation because it is more effective and efficient.

Moreover, the level of air pollution in Semarang City is very worrying due to the high volume of vehicles. Many pollutants are contained in the air of Semarang City due to fossil fuels used by motorized vehicles. The high level of community activity will cause high levels of pollutants in the air. As a result, it will interfere with health and affect the community's productivity, resulting in per capita income earned [10].

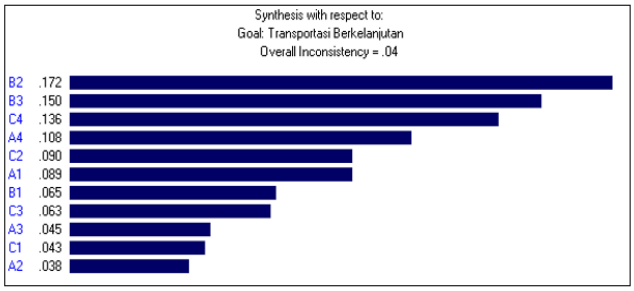


Figure 7. AHP outputs towards all available alternatives

Caption: B2: Park and ride facilities provision; B3: Modern mass public transportation with large passenger capacities provision (MRT, LRT); C4: Establishment of a green belt along the newly constructed road with productive and non-breakable shade plants; A4: Increasing the quality of service, convenience, and safety of mass public transportation; C2: Progressive vehicle tax based on exhaust emission test results; A1: Increasing the integration between mass public transportation modes; B1: Pedestrian and bicycle paths development; C3: Reducing the need for travel in cities through land use; A3: Mass public transportation separated routes from other transportation; C1: Private transportation modes shift to public transportation modes to reduce fuel consumption; A2: Stipulation of the prohibition on on-street parking along with public mode areas

Steps that can be taken to overcome this problem are to create a green belt along the newly constructed road with productive shade trees that do not break easily. The green belt is in the form of tree planting along busy roads and those that have recently been built to reduce the level of pollution in Semarang City. Trees planted are trees that can clean pollutants, provide shade, and reduce noise, such as *Dadap Merah, Mahoni, Asam Jawa, Flamboyan,* and so on.

The fourth alternative priority is improving the quality of service, convenience, and safety of mass public transportation, with a weight value of 0.108. The dense movement of the people of Semarang City certainly requires adequate transportation. Mass public transportation is a mode of transportation that can support the density of community activities. However, the quality of service, comfort, and safety of mass public transportation is still inadequate, such as long waiting times and passengers tend to overcrowd. Therefore, the quality of service and convenience must be improved immediately so that mass transportation is always the first choice to support their activities. If it is not immediately improved, it can be that the community preference is to use private vehicles rather than mass public transportation. The public will not mind having to pay more if later they will be able to get greater benefits, namely safety and health and better air quality [10, 37].

The next prioritized alternative is a progressive vehicle tax based on the exhaust emission test results, with a weight value of 0.090. The high level of pollution due to exhaust emissions produced by motorized vehicles can be overcome by implementing a progressive motor vehicle tax based on exhaust emissions. It has been stated in Government Regulation Number 55 of 2012 concerning vehicles. Article 64 paragraph 1 states that exhaust gas emissions are a condition for motor vehicle roadworthiness. A progressive tax will be imposed for vehicles whose exhaust emissions exceed the threshold. Vice versa, vehicles that can control exhaust emissions properly will receive tax breaks.

Increasing the integration between mass public transportation modes is the sixth priority alternative in developing sustainable transportation in Semarang City, with a weight value of 0.089. The provision of mass public transportation also requires integration between modes. The lack of integration of mass public transportation modes will discourage the public from using them. The integration between modes of mass public transportation will be able to support the activities of the people's movement at several points in Semarang City. It can be done by building several Trans Semarang BRT stops connected to the Trans Central Java bus stop with other transportation modes, such as stations, terminals, and so on.

Furthermore, an alternative that is no less critical to prioritize is the development of pedestrian and bicycle lanes as the seventh priority sequence, with a weight value of 0.065. The provision of pedestrian and bicycle lanes is crucial to minimize the use of motorized vehicles. Walking and cycling are environmental-based transportation that can reduce air pollution caused by motorized transportation. Therefore, this transportation must always be considered by providing adequate pedestrian facilities and bicycle paths. It would be better if the planning is made bottom-up. Boettge et al. [29] argued that in planning to develop bicycle paths in urban areas, bicycle users should be involved because, after all, they are the ones who will take advantage of these facilities. For instance, the development of bicycle lanes in Louis has not involved cyclists, so that most of the bicycle lanes are not traversed by cyclists because the road traffic is too dense, which endangers bicycle users. Pedestrian paths must be integrated with several modes of mass public transportation. Likewise, bicycle lanes must also be integrated with public transportation modes and ensure the comfort and safety of these bicycle users. Besides, other facilities must also be provided, such as seats, trash cans, shelters, and bicycle parking bags.

Reducing the need for travel in urban areas through land-use planning is the eighth priority alternative, with a weight value of 0.063. The Semarang City people's activities are generally still focused on the city center, which causes congestion and high air pollution in the city center. It is because many facilities and offices are in the center of Semarang City. It needs land use that can reduce the dense activity in the city center. It can be done by planning an RTRW that regulates the use of peripheral areas for public facilities and trade and industrial centers to not focus on the city center.

Furthermore, the roads in the city of Semarang are classified as very dense. It is because private vehicles, goods transportation, and mass public transportation are still in one lane. An effort is needed to separate mass public transportation routes from other transportation to break down the city center's dense traffic. One of the programs launched by the Semarang City government is to build the Semarang city ring route as a route for goods and heavy vehicles. Thus, traffic volume on city routes can be reduced and will result in reduced congestion and pollution in the city center.

The high ownership of private vehicles is one of the causes of congestion and pollution in Semarang City. Furthermore, more concerning is that most private vehicles use fossil fuels and obviously the pollution emitted by these vehicles is also high. Fossil fuel motorized vehicles are a contributor to 80% of pollutants in urban areas. It, of course, must be handled immediately.

One of the programs that can be implemented is by shifting private transportation to public transportation to minimize fuel consumption by increasing travel costs by private mode, increasing private vehicle taxes, increasing parking fees, and imposing tolls for specific areas, additional fuel costs coming from fossils, and the luxury tax. Thus, people who want to use private vehicles will think twice, considering that they must bear costs are not small.

The last priority or eleventh priority alternative in the sustainable transportation development strategy in Semarang City is the stipulation of the prohibition of parking on streets along with the public mode areas, with a weight value of 0.038. The lack of parking facilities in the city of Semarang has caused some people who use private vehicles to park their vehicles on the shoulder of the road, thus disturbing other motorists' traffic. Besides, many private vehicles are parked in the bicycle lane. As a result, bicycle users have become less comfortable and secure. The Semarang City government has imposed on-street parking bans along public mode areas to overcome this problem. However, many motorists still deliberately park their vehicles in the bicycle lane until now.

4. DISCUSSION

This study aims to determine the appropriate sustainable transportation system development strategy in an urban area as an industrial center in a region. This study's findings show the importance of developing transportation system facilities and infrastructure to support sustainable urban growth. The importance of transportation infrastructure to support sustainable transportation development and urban growth was also highlighted by the studies of ref. [7, 9, 12]. The next finding is the importance of improving the quality of the urban environment. It dramatically affects the quality of life of urban communities, which in turn will affect the city's activities and productivity. As stated by the studies of ref. [38-40], it is necessary to provide park and ride facilities, modern mass public transportation, the realization of a green belt along the roadways, and improve service quality, convenience, and safety of mass public transportation. All of that can be realized by the existence of a progressive vehicle tax based on the results of exhaust emission tests, increasing the integration between mass public transportation modes, developing pedestrian and bicycle lanes, reducing the need for travel in cities through land use, separating mass public transportation routes with other transportation, the transfer of private transportation modes to public transportation modes to reduce fuel consumption, and the imposition of on-street parking bans along with public mode areas. A development strategy will be more effective in its implementation if the development process involves community aspirations and participation. These findings emerge where government policies are considered in determining sustainable transportation development strategies. It is reasonable considering that the city will grow and develop dynamically in the future so that the integration of all aspects must work synergistically [34, 41].

People need quality, comfortable, and safe transportation, as stated in Semarang City's RPJMD 2016-2021. It states that the transportation system infrastructure facilities still have problems in terms of the road network that has not been fully developed, road equipment improvement still needs to be optimized, road network integration and road facilities still need to be optimized, and the quality of public transport services still needs to be improved, and management of transportation facilities and infrastructure should be optimized. The Semarang City government needs to create a dynamic and environmentally sound Metropolitan City in the 2016-2021 RPJMD.

The importance of transportation infrastructure to support sustainable transportation development and urban growth is also supported by the studies of ref. [7, 9, 42]. The development of transportation infrastructure facilities can promote access to the distribution of goods and services that impact the regional economy [43, 44]. Starting from the means of transportation to roads that cover the means of public transportation, it needs to be developed in accordance with sustainable principles. It is hoped that the development of new transportation can increase public access.

The next finding is the importance of improving the quality of the urban environment. It greatly affects the quality of life of urban communities, which in turn impacts the activities and productivity of the city. As stated by the studies of ref. [38-40], it is necessary to provide park and ride facilities, modern mass public transportation, the realization of a green belt along the highway, and improve service quality, comfort, and public transportation safety. Improving the quality of the urban environment can be realized by the existence of a progressive motor vehicle tax based on the results of exhaust gas emissions testing, increased integration between modes of mass public transportation, construction of pedestrian and bicycle paths, reducing the need for trips within the city through land use, separating mass public transport routes from other modes of transportation, the shift from private modes to public transport modes to reduce fuel consumption, and the imposition of on-street parking bans along with public mode areas [45-47].

A development strategy will be more effective in its implementation if the development process involves community aspirations and participation. This finding emerged when government policies were taken into consideration in determining a sustainable transportation development strategy. It is reasonable considering the city will grow and develop dynamically in the future so that the integration of all aspects must work synergistically [34, 41]. Community participation is needed in providing feedback on efforts to improve the development of sustainable transportation. According to Duleba and Moslem [44] that passengers, potential passengers, and the government are the three stakeholders who have a role in communicating the design and targets of transportation development. Thus, there is a need for changes in travel behavior at a population level that requires collaboration between the transportation system, the environmental sector, and the health sector [48, 49].

5. CONCLUSIONS

Based on the analysis results carried out using AHP, priorities could be obtained based on the criteria studied: the priority for the criteria of facilities and infrastructure is the development of modern transportation facilities with a large passenger capacity with a score of 44.3 percent, the priority of the environmental quality criteria is the development of open land green roads with shady trees and shrubs with a score of 40.9 percent, and the priority criteria for government policy are the addition of service quality, comfort, and safety of public transportation facilities with a score of 38.6 percent. Overall, by combining selection points on each criterion,

Semarang City's people chose to protect, primarily the development of modern public transportation facilities with additional passenger capacity. This point had the highest priority, with a score of 17.2 percent.

It is hoped that the finding will be able to provide the appropriate information to the city government to decide a strategy. It is bottom-up planning so that implementation and evaluation can be carried out jointly between the government and the community to create a sustainable transportation system for a healthy and comfortable city to live in and provide the appropriate information to the city government to decide a strategy. In addition, the findings of this study are expected to be used in other cities that have the characteristics of being a densely populated metropolitan city, and have a commitment to sustainable transportation that has been explicitly included in long-term urban planning.

The limitation of this research is that using AHP (Analytic Hierarchy Process) analysis could only be seen by priority programs but could not see the efficiency of the priority programs obtained both in terms of economic and technical efficiency. For this reason, a further research agenda is to combine priority and efficiency programs using the Data Envelopment Analysis (DEA). It is expected that the relative efficiency analysis tool can be obtained from each priority in the criteria.

ACKNOWLEDGMENT

This work is supported by Faculty of Economics, Universitas Negeri Semarang as the funding of this research.

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