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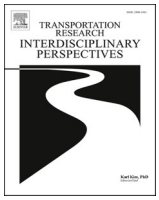

Future of mobility in Jakarta Metropolitan Area: A Multi-Stakeholder scenario planning

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ABSTRACT

The growth of the urban population and their mobility, added with the COVID-19 pandemic and its impacts, requires the capability to anticipate uncertainties. As a developing country, Indonesia has progressed with many developments in urban mobility, but at the same time, challenges still may affect its future, particularly in a metropolitan like Jakarta. Despite the widely understood challenges faced by the metropolitan, there has been limited understanding about its possible futures of mobility and the ways to go in its respective future. A multi-stakeholder scenario planning was used to develop future scenarios of urban mobility in Jakarta Metropolitan Area (JMA), utilizing stakeholders' point of views regarding the driving forces and critical uncertainties that may shape the future of mobility to create action-oriented strategies to achieve the desired future. A medium-term time scale of ten years (2021–2030) was used to give viable and practical recommendations. Four scenarios were developed, which consisted of: 1) one seamless ecosystem, 2) the culture of public transportation, 3) the exclusive green community, and 4) the social dilemma of public versus private transportation, which emphasized the forms of mobility that would dominate in the next ten years. With implications of each scenario explained from several aspects, six efforts should be considered to direct the future of mobility in Jakarta Metropolitan Area: vehicle electrification, limitation of fossil fuel vehicles and broader use of public transportation, implementation of MaaS and TOD, commuters' behavior changes with push and pull policies, and boosting funding for mobility facilities.

Introduction

Since the 18th century, transportation has been evolving with the help of technological innovations and human behavior. The motivation to develop transportation is pushed by the need to solve transportation problems, such as travel time. For example, the development of the first automobile enabled people to move faster and further and changed the primary transportation method. However, the advancements of transportation modes, which have solved the effectiveness problem, have caused other problems in the modern world. For example, the development of the motorized car solved the problem of travel time yet has raised other substantial issues in the future. According to the Transport Research and Innovation Monitoring and Information System (TRIMIS), five main transportation problems are faced in the modern world, which are land use, car dependence, environmental problems, congestion, and other issues, including safety, political difficulties, and economic prosperity (Zavitsas et al., 2010). Therefore, policies regarding the transportation sector need to be converted into concrete actions to overcome those transportation problems. Furthermore, technological advancements such as electric mobility, autonomous vehicles, and sharing mobility are game changers in mobility patterns, especially in urban areas. Aside from that, human behavior in being willing to shift must be influenced by incentive-based policies such as fuel taxes, low transit fares, and land-use policies to reduce the congestion (ITF, 2017).

However, there is no guarantee that the proposed idea can solve the current transportation problems and future mobility problems since the future is unpredictable due to the long-term contextual shift such as political instability, social inequality, ecological threats, artificial

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intelligence, and a crisis cycle. Previously, Purnomo et al. (2020) studied gap analysis of the future transportation in Indonesia, which emphasized on identifying the challenges of the future of transportation. However, it is considered vital to study further about other possibilities with the perception from stakeholders, as well as the action that may be needed to direct the better transportation quality. Therefore, future studies can be used as it can construct a more sensible future with prolonged domain of time, ensure ingenuity, better stakeholders' involvement, and more action-oriented contrasted to planning (Inayatullah, 2013; Inayatullah, 2002). One of the methods is scenario planning, which can scour possible futures and produce better results because traditional strategic planning approaches have failed to notify the stakeholders about environmental, political, economic, or societal changes (Vallet et al., 2020; Varum and Melo, 2010; Chermack, 2011). Scenario planning is widely used in future mobility in the previous studies regarding the development of urban areas and electrified and automated vehicles (Hannon et al., 2019;; Urry, 2016). On the other hand, it has been also utilized in numerous studies, such as in work participation in organization (Chermack et al., 2020; Hawkins and Chermack, 2014), information, communication, and technology (Moqaddamerad et al., 20177), and business model forming in developing countries (Ghazinoory et al., 2018).

In this research, scenario planning is used to develop future mobility scenarios of the Jakarta Metropolitan Area with its dynamic changes in several aspects. An important aspect is the population in an urban area. According to the United Nations (2018), the world's urban population is predicted to increase by 18% in 10 years, with Asia the most significant by 18.67%. As a country with the third highest population in Asia, Indonesia is predicted to increase by 20.47%, exceeding Asia's growth. In line with urban population growth, motorized mobility is forecasted to rise 41% in 2030 and 94% by 2050 from 2015, which can cause CO2 emissions to increase by up to 60% by 2050. With an increasing population density, the rapid development of mobility infrastructure in Indonesia is underway by adding a variety of public transportation and integrated mobility, such as mass rapid transit (MRT), light rail trains (LRT), and commuter lines, as well as the more integrated road-based public transportation. However, the number of private vehicle users has also increased due to the economic growth, which allows the new middle class to buy private cars.

Furthermore, the COVID-19 pandemic has also affected mobility in urban areas. According to the Greater Jakarta Transport Authority (BPTJ), public transport users in Jakarta and its surrounding area (often called Jakarta Metropolitan Area or Jabodetabek) are lower due to the COVID-19 pandemic and the social distancing policy (BPTJ, 2020). With the uncertain environment, both in favor of and opposed to mobility, scenario planning can be utilized to foresee the future mobility of Indonesia.

This study aims to develop plausible scenarios of future mobility in 2030 using a participative multi-stakeholder scenario planning approach. To build the scenarios, an identification of the key driving forces and their relationships is required. The scenarios emerge from an iterative dialog process based on these driving forces. The implications of each scenario are then identified and discussed to obtain possible strategic options/interventions.

Literature review

Scenario planning

Scenario planning is an approach to do strategic planning to unveil different possibilities in the future. It is used to support decision-making in a shifting environment which is uncertain and complex (Lehr et al., 2017). Despite that, scenarios are not precise representations of the future reality; scenario planning is often used to give reasonable ideas to build a transparent process to achieve preferable futures from many possibilities. It is also intended to challenge the current mindset by exploring the previously unknown aspects of the narratives. The power of scenario planning is to capture the comprehensive possibilities in many details and accounts more explicitly for the complexity and uncertainty of the environment (Porter, 1985; Mintzberg, 1994; Gordon, 2013; Dean, 2019) and is seen as remarkable among other tools for strategic planning (Schoemaker, 1995). The method can be used for several purposes or projects, such as developing a business model canvas, business strategy, portfolio planning, specific policy development, persona identification, and crisis management (Vallet et al., 2020).

The concept of a scenario as a decision-making tool has been acknowledged since the age of philosophers such as Plato. In its development, scenario planning was used in the late 1950s by the US Research and Development Corporation to analyze the world's feasible future conditions to decide which alternative military and weaponry strategies would be used (Kahn and Wiener, 1967; Dean, 2019). For business operational purposes, scenario planning was started in the late 1960s by Royal Dutch/Shell to analyze their corporate planning procedures (Wack, 1985). In addition, scenario planning is broadly used in various institutions, such as companies and governmental bodies (van Notten, 2006; Gordon, 2013; Dean, 2019).

In an ordinary scenario planning process, possible futures are pictured based on assumptions that evolve from present elements and states (Kosow and Gaßner, 2008; Martelli, 2014; Dean, 2019). Seeing the importance of the present elements and states in every type of scenario planning as explained by van Notten (2006), the research scope is continued with an information search to discover the current condition and the variables that potentially affect the future condition. With an abundance of data on the current condition, a further analysis is needed to identify the most relevant variables regarding the topic studied – this step is needed to find the trend and analyze the uncertainty that has made evolution possible. The identified trends and critical points are then converted from the trend groups, which define the different possible futures in certain conditions (Schwartz, 1991; Schoemaker, 1995; Dean, 2019). Finally, when the scenarios have been defined, various decisions and options are assessed according to the plausible future conditions (Schwartz, 1991; van der Heijden, 2005; Dean, 2019).

The scenarios are developed based on the predetermined variables to reduce biases, such as congeniality and overconfidence biases (O'Brien & Meadows, 2013). Meissner & Wulf (2013) corroborated this statement which claims that scenario planning can support and has been taken into account toward the positive effect on the decision quality rather than the conventional tools. Furthermore, stakeholders are included in the research to address the critical issues related to the topic to strengthen and deepen the analysis. With an unbiased design and narrative of scenarios derived from the matrix, the impact can be well-assessed at a certain level (Kamprath & Mietzner, 2015). For example, the objective is to dig into the potential business strategy by understanding the scenarios in the future and how to adapt to the potential changes.

Scenario planning has been used in previous studies, varying from the natural environment to the socio-technological development context that is often integrated with another methodology. Some studies have used scenario planning in land-use planning (Bonsu et al., 2017; Von Wirth et al., 2014), communication industry (Tavana et al., 2021), business and management (Hidayatno et al., 2019), urban mobility and transportation planning (Vallet et al., 2020;; Spickermann et al., 2014; Zahraei et al., 2019), and even for examining the integration between land use and transportation (Ariza-Álvarez et al., 2021).

Different methods are also often combined with scenario planning in investigating the contexts mentioned earlier. System dynamics is one of the methods commonly used in complementing scenario planning. Hidayatno et al. (2019) utilized system dynamics to evaluate and analyze the scenarios, including their uncertainties, when implementing the scenario planning results. Another study by Von Wirth et al. (2014) used a formative scenario analysis, which also incorporated an analysis of the system feedback loop in coping with the relational complexity of

the system. Tavana et al. (2021) applied causal modeling combined with a decision-making trial and evaluation laboratory (DEMATEL) method in their scenario planning study in the communication industry. Zahraei et al. (2019) generated the scenario in their research by conducting a foresight study which assumed that an uncertain future was the product of today's actions, not an extrapolation of predetermined trends and innovations. A study by Vallet et al. (2020)combined scenario planning with the personas method, then called the scenario personarrative method. On the other hand, Ariza-Álvarez et al. (2021) generated their scenario-building narratives using an experimental approach. Lastly, Bonsu et al. (2017) combined collaborative learning with a scenario analysis to conceptualize the methodology for multiple stakeholders' joint decision-making in forest land-use planning.

Changes in mobility priorities caused by climate change and energy resources require a change in philosophy and method in urban transport studies. Other changes are to do more of a plausibility analysis than calibration and more backcasting than forecasting (Wegener et al., 2013). Scenario planning can do all of these.

Scenario planning for mobility

In previous literature, the timescale of scenario planning for urban mobility studies was often in the medium-term of 2030–2035 (Ecola et al., 2015; Marletto, 2014; Rohr et al., 2016; Townsend, 2014; Trommer et al., 2016; Zmud et al., 2013; Vallet et al., 2020) or the long-term in 2050 (Fulton et al., 2017; Kaufmann & Ravalet, 2016; Urry, 2016). Both quantitative and qualitative methods are the foundation of the scenario planning analysis for the methodology.

Scenarios of future mobility were developed based on key uncertainties that may come from driving forces that may come from social factors, environmental issues, technological factors, economic growth, and governance (Vallet et al., 2020). Another approach uses the combination of social, technological, economic, environmental, and political (STEEP) factors (Lyons & Davidson, 2016; Lyons et al., 2021). From these variables, technological and environmental variables are widely discussed to forecast mobility for the upcoming ten years or more. A study from WSP Global Inc. in WSP (2017), for example, primarily used the technological factors that resulted in the four different potential business models of future mobility.

On the other hand, Vallet et al. (2020) and Hannon et al. (2019) used the combination of technology and societal change in their research, which could also conclude different scenarios. Lyons also mainly used technological variables in his articles, such as scenario planning for transportation's transition to the digital age (Lyons, 2015) and the combination of technological and energy costs for scenario planning in New Zealand (Lyons & Davidson, 2016). In addition to technology as a variable, its derivations, such as MaaS, were also discussed by Nikitas et al. (2020) and Alyavina et al. (2020), which can contribute to the future developments of urban and public transportation. The environment variable for the future mobility and scenario planning came from Zmud et al. (2013), which combined the economic factors: oil prices, revenues, expenditures, and environmental regulations. Similar to Zmud et al., Silva & Teles (2020) also presented scenario planning in mobility using Sao Paulo as the case study, resulting with four different scenarios that differed from their GHG levels. Kane and Whitehead (2017) explored scenarios on the impacts of vehicle electrification and sharing economy on the future of urban mobility. They found that proactive planning and policymaking are needed to deal with these technology disruptions. Lyons et al. (2018) stated the need to focus on uncertainties concerning future lifestyles to develop a three-pronged system of accessibility (physical mobility, proximity, and digital connectivity) where digitalization has influenced people's everyday lives.

However, scenario planning for mobility can also be acquired by expanding another scenario planning. For example, Shergold et al. (2015) used the existing scenario for living in later life that focused on assistive technological engagement and state provision of care as the basis to identify older age mobility. In addition, the study identified the social practices from the scenario. Thus, it combined technology and social factors, formulating implications and policies regarding mobility for older society.

Methodology

In this study, the researchers created a model by understanding the concepts of stakeholders based on their responses toward the current condition and future perceptions of Indonesia's future mobility in 2030. This methodology can also be said to be interpretivism philosophical thinking with an inductive approach (Okasha, 2002; Hutajulu et al., 2020). The model formulation uses the scenario planning method since this study aims to unveil the future of mobility affected by infrastructure development, emerging technology, and the pandemic. The inductive scenario planning starts from the Shell Method, one of the first-generation scenario planning methods. Unlike deductive scenario planning methods, such as the four archetypes and the 2×2 method, narratives are created from the data without categorical imposition beforehand in the Shell Method. It also does not clearly indicate that every scenario is the final future; the process is ongoing.

Generally, the steps of the Shell Method are identifying the driving forces, distinguishing the driving forces from predetermined elements and critical uncertainties, and creating several scenario narratives. The key feature of this method is iteration. Specifically, the scenario planning for mobility was previously studied by Vallet et al. (2020).

This study limited the stakeholders in the scenario planning process to service providers and policymakers. These stakeholders were chosen based on the categorization of their relative influence to facilitate or impose changes or policies in the near future related to mobility. This was in accordance with what has been explained in the study of Bonsu et al. (2017)regarding several models that can be used in stakeholder selection. As for the community in general, such as consumers and interest groups, who were considered beneficiaries, they were not included in the scenario planning. Furthermore, the scenario planning itself mainly focused on Jakarta as the capital city of Indonesia that currently has the most issues concerning urban mobility.

Adapting from the steps explained in Fig. 1 and the Shell Scenario Method, the steps of this research methodology were: (1) to determine the stakeholders' current and future perceptions, (2) to identify the driving forces and key uncertainties, (3) to visualize the future headlines and scenario elements, (4) to identify the implications, and (5) to formulate the strategic options for each scenario.

Stage 1: Determine the perceptions (Current & Future)

Scenario planning typically involves participants representing various functions of a company or industry and other stakeholders such as customers, those with key positions in the organization, suppliers, distributors, regulators, or industry experts to provide information from broader perspectives. In this research, the stakeholders involved were those having important roles in mobility.

Table 1 below shows the stakeholders that are related to the transportation industry that were chosen as participants. They were chosen from different sub-industries, so that they could give different perspectives and enrich the analysis. Previous studies involved up to eighteen different stakeholders or experts in the scenario development processes where one of the considerations was the knowledge requirement needed (e.g., Shergold et al., 2015; Bonsu et al., 2017; Shaheen and Wong, 2021). It can be seen from the number of stakeholders, the relevance of all the stakeholders, and their experience in the relevant industries can cover wider perspectives of mobility and provide sufficient knowledge requirements. Moreover, the researchers also participated in the analyses of interview results.

The objective of this stage was to collect the views and thoughts of the stakeholders. The mobility stakeholders were asked to complete

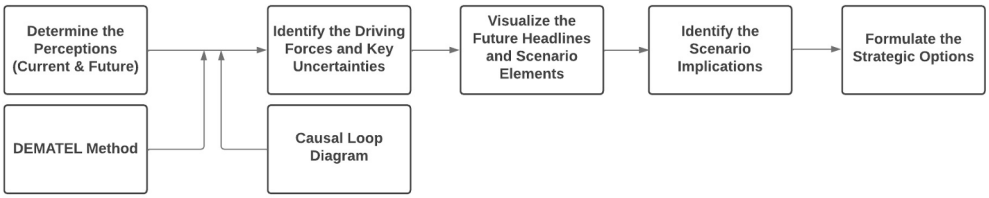


Fig. 1. Scenario planning methodology.

written interviews individually via an online form or face-to-face interviews through a virtual conference. The interviews are semi-structured with open ended questions that covers interviewees' opinion towards current and future mobility, their contribution and experience in servicing and increasing the quality of mobility, and how their plan and anticipation to cope with the future mobility condition. The interviews were conducted by the research team members, who were tasked to obtain answers from the informants based on the prepared list of questions. The interviewers were allowed to do probing in order to clarify or search for clear perspectives from the interviewees but without imposing their point of views to them. The interviewees were experts chosen to represent each stakeholder in order to cover different points of view, ensuring the saturation of the information. The interview transcripts were analyzed using content analysis to find words or sentences that are relevant to the question. They were highlighted and then coded using keywords. The keywords were then categorized into several categories using axial coding based on similarity or closeness of meaning within each category. The processes were done iteratively. The results were used to identify the obstacles of the current mobility, challenges of the future mobility, and the key drivers, which were then discussed in Stage 2, so that the collective perceptions of the stakeholders could be understood better.

Stage 2: Identify the driving forces and key uncertainties

This stage focused on identifying the driving forces that affect the future of mobility in the Jakarta Metropolitan Area. Based on the interviews, a list of driving forces was analyzed and ranked based on the levels of uncertainty and importance to identify the key drivers of future scenarios. Finally, the relationships between these driving forces were visualized using a causal loop diagram (CLD).

Stage 3: Visualize the future headlines and scenario elements

In this stage, the research team discussed the future headlines based on the key drivers and CLD identified in stage 2. Each researcher prepared his/her future headlines, and then presented and discussed them with all the team members to synthesize and agree on the future scenario headlines for a further analysis. The elements of each future headline were then identified to explain the main "characteristics" of each headline, which would become the scenario elements. Narratives were then used to connect those elements in each headline and describe the scenarios by leveraging the team's imagination involved in the scenario planning process. The narratives had to be logically coherent and consistent, simple to understand but exciting enough to stimulate new thinking.

Stage 4: Identify the scenario implications

Each scenario's implications (effects or consequences) towards the various mobility aspects were identified, including traffic and the environment, public transport services, the automotive industry, the government, logistics, supporting industries, infrastructure developers, and the community.

Results

In this section, the development of future scenarios of the Jakarta Metropolitan Area mobility in 2030 is presented. It started from a discussion about current obstacles and future challenges of mobility and is followed by discussions on driving forces and their relationship, development of scenarios, and finally on the implications of each scenario.

Current obstacles and futures challenges of urban mobility

The perceptions of the stakeholders were taken from interviews and questionnaires. After that, a content analysis was conducted for the online interview transcripts. For this section, text-coding was done from the questions about the current obstacles and future challenges of the Jakarta Metropolitan Area mobility by taking the keywords of each stakeholder. The summary can be seen in Table 2 below.

For current obstacles in mobility, the top four answers that emerged were infrastructure, regulations, road users' behavior, and inter-mode integration. The first most frequent keyword was infrastructure, specifically the inequitable and inadequate infrastructure conditions in several areas. Most of the respondents viewed both the limited availability and the poor conditions of the infrastructure as significant obstacles to mobility in Indonesia. Based on the answers, examples of this obstacle are the lack or unavailability of dedicated lanes for bus rapid transit (BRT), non-uniform road width, and the slow development of road infrastructure. The next most significant obstacle was the regulation and policy enforcement to encourage public transport usage. This keyword was captured based on the respondents' answers, such as inconsistent and unclear law enforcement and a lack of execution in private vehicle limitation policies. The third keyword was road users and community behavior. Most respondents viewed that road users' behavior, such as their lack of discipline and knowledge of the regulations related to transportation, is a significant obstacle in JMA's current mobility. Moreover, one respondent explained that one of the obstacles is the unruly characteristics of Indonesians. The fourth keyword was inter-mode integration, which most of the respondents commented that currently, the transportation system available is not yet integrated. This condition affects mobility, reducing its quality due to the tangible and intangible costs that the travelers incur.

Regarding future challenges in JMA's mobility, the top four answers were quite similar. Infrastructure and regulations were the top two answers. The only difference is the changed position between inter-mode integration and road users' behavior. Based on the respondents' answers, infrastructure readiness, e.g., equally developed infrastructure in all areas, will become the main challenge in future mobility, including supporting facilities such as the Internet or electricity networks. As for the second most important challenge, regulations and policies with good law enforcement were based on the respondents' answers that private vehicle limitations are still not enacted in Indonesia. The road users' behavior and inter-mode integration changed because, in the future, most of the respondents believe that integration will be more challenging to increase the quality of mobility and eventually affect the behavior itself. Most respondents also explained that integrating different modes of transportation would be a significant challenge for future mobility. In addition to this, the current lack of integration and coordination between various transport service providers or regional

Table 1
Study respondents.

No	Institution Role	Position	Experience	Relevance
1	Automotive Manufacturer	Department Head	12 years	Future of the automotive industry
2	Automotive Manufacturer	Project Leader	20 years	Future of the automotive industry
3	Automotive Manufacturer	Division Head	13 years	Future of the automotive industry
4	Automotive Manufacturer	General Manager	32 years	Future of the automotive industry
5	Automotive Components Manufacturer	CEO	25 years	Future of the automotive industry
6	Consultancy Company	Consultant	8 years	Future market of mobility services
7	Freight Transport Provider	Country Director	18 year	Future of logistics business
8	Government (national road infrastructure agency)	Board Member	11 years	Regulation and future of road infrastructure
9	Government (regional transport agency)	Senior Engineer	5 year	Regulation and future of innovation in mobility
10	Government (national transport agency)	Head of Agency	36 years	Regulation and future of transportation system
11	Healthcare Provider	Commissioner	5 years	Pandemic effect on future mobility
12	Investment Company	Division Head	10 years	Investment in future mobility (infrastructure)
13	IT & Communication Provider	Commissioner	30 years	Connectivity support for future mobility
14	Logistics Provider	Director	18 years	Future of logistics business
15	Logistics Provider	Director	11 years	Future of logistics business
16	Logistics Provider	Deputy CEO	20 years	Future of logistics business
17	Online Media Provider	Division Head	16 years	Online media influence on mobility
18	Public Transport Provider (rail-based)	Director	28 years	Future of public transport (rail-based)
19	Public Transport Provider (road-based)	Director	17 years	Future of public transport (road-based)
20	Public Transport Service (road-based)	Director	20 years	Future of public transport (road-based)
21	Ride-hailing Service	President Director	15 years	Future of ride-hailing in mobility
22	Transportation Analyst	Solution Specialist	16 years	Data analytics in mobility
23	Utility Company	Business Development	14 years	Energy supply for future mobility
24	Utility Company	Supervisor	19 years	Energy supply for future mobility
25	Utility Company	Director	10 years	Energy supply for future mobility
26	Venture Capital	Associate Consultant	3 years	Investment in future mobility (new business)
27	Venture Capital	Director	16 years	Investment in future mobility (new business)

Table 2
Current Obstacles and Future Challenges of JMA's Urban Mobility.

Topics	No. of Keywords (Current Obstacles)	No. of Keywords (Future Challenges)
Infrastructure and supporting facilities	17	16
Intermodal integration and accessible mass public transport	17	13
Regulations regarding public transport usage and law enforcement	15	15
Road user or community behavior	10	7
Management (including logistic cost and financial aspect)	4	9
Environmental condition	6	–
Others	–	3

governments was evidence that inter-mode integration will become one of the main challenges in JMA's future mobility.

Driving forces and key uncertainties of future mobility in JMA

The interview process also analyzed the identification of driving forces in describing JMA's future mobility. Similar to the identification of the current obstacles and future challenges, the list of the driving forces is identified from the text-coding of the questions related to the political, economic, sociocultural, technological, environmental, and legal (PESTEL) aspects of the future mobility in JMA, which can be seen in Table 3 below. As a result, there are 25 driving forces identified as follows:

A causal loop diagram (CLD) is also used to understand the relationship between driving forces driving system behavior in each mobility scenario. CLD can also identify the driving forces that are policy resistant and explore the consequences of the proposed action. As scenario planning is used to look into the future, CLD becomes vital because stakeholders can see the implications of the options that they may choose to create supportive behavior in the future.

To develop a causal loop diagram representing the cause-effect relationships between driving forces, the DEMATEL method is used. Tavana et al. (2021) applied this method for analyzing and investigating complex systems with intertwined components. Furthermore, Si et al. (2018) stated that the most important features of DEMATEL are the ability to describe the interdependencies in a cause-and-effect relationship, notify the essential factors, and build a causal relationship map among them. The method can estimate the direct and indirect causal relationships among the driving forces. It starts with establishing a matrix (A) depicting the direct impact between pairs of driving forces. It can be seen in Estimation (1). In making matrix A, this study tries to map the relationship between the driving forces that have been identified. For example, driving force 1, namely good governance, has a relationship with driving force 6, namely equitable and inclusive infrastructure, so the value of cell a_{16} is 1 (1 indicates a relationship, while 0 indicates no relationship). And so on, this is also done for other driving forces to form a relationship matrix A.

$$A = \left[a_{xy}\right]_{y=1,\ldots,n}^{x=1,\ldots,n} \tag{1}$$

$$s = Max\left[\frac{1}{Max\ 1 \le x \le n \sum_{y=1}^{n} a_{xy}}\right], \left[\frac{1}{Max\ 1 \le y \le n \sum_{x=1}^{n} a_{xy}}\right] \tag{2}$$

$$B = A/s \tag{3}$$

Then it is followed by obtaining a total influence matrix (T), which includes both the direct and indirect influence of the factors. The matrix is obtained by determining s and calculating the matrix (B) that can be seen in Estimation (2) and Estimation (3). The relationship values that exist in each driving force in matrix A are added up either by column or

Table 3
List of driving forces.

Driving forces	Occurrences
ECONOMIC	
Social welfare (including purchasing power, disparity).	14
Equitable and inclusive infrastructure.	11
Subsidy and incentives policies for electric vehicles (for users and/or producers).	5
Investment climate & scheme and public–private partnership (PPP).	7
Infrastructure development.	7
Government budgeting and revenue allocation to improve transportation system & capital financing.	11
Logistic mobility development & policy.	10
Macro-economic indicator.	27
Infrastructure and product development related to EV implementation.	8
Subsidy distribution and policies related to public transportation.	17
Supportive environment for local industry (including EV and mobility-related start-up).	8
ENVIRONMENT	
External causative/drivers (environment externalities).	5
Eco-friendly activities, policies, regulations, and vehicles (including renewable energy).	7
LEGAL/REGULATION	
Legal/law certainty in automotive industry development & law enforcement consistency.	14
Regulation to support mass transportation development and to control private vehicles.	6
POLITIC	
Good governance.	17
SOCIAL	
Human behavior drivers; technology to prevent human behavior drawbacks (i.e., the autonomous vehicle, long-distance vehicle control).	6
Equitable transport services.	7
Public transport service quality.	13
Consumer behaviour (car ownership, residential location, and public transport adoption).	7
New technology use.	6
TECHNOLOGY	
Aspiration/expected result/desirability consequences related to mobility technology and its impact on the environment.	17
Impact on the automotive and transport industry.	8
Intermodal integration and connectivity (including MaaS and cashless payment).	9
Digitalization & disruptive business model.	29

row. For example, the driving forces 9 namely investment climate, scheme and public–private partnership (PPP) have a relationship with other three driving forces namely social welfare, subsidies and incentives policies for electric vehicles and macro-economic indicators so that the total value of the relationship of driving forces 9 is 3. All driving forces will be calculated for the total value of their relationship with other driving forces, so that later the largest total relationship value in columns and rows is sought from matrix A as the value of s in estimation 2. From this calculation, driving forces 14 are obtained, namely consumer behavior in columns has the largest total relationship value of 6 because it has a relationship with 6 driving forces such as social welfare; regulation to support mass transport; infrastructure development, equitable transport service; subsidy distribution and policies related to public transport; and eco-friendly activities, policies, and vehicles (including renewable energy). So the value of s from this calculation is 6. This s value becomes the divider for all those a_{xy} values in matrix A to get the b_{xy} value in matrix B for all the driving forces, the formula of which can be seen in Estimation (3).

After identifying matrix B, this matrix is the input to produce matrix T in Estimation (4) and Estimation (5). The value in matrix B for the relationship between driving forces 1, namely good governance and driving forces 6, namely equitable and inclusive infrastructure, is 0.166 which is obtained from the a_{16} value of 1 divided by the s value of 6. Furthermore, by using the formula from Estimation (5), the value of t_{16} is 0.166 divided by 1 minus 0.166 which equals to 0.2. This is then done for other values from all the driving forces in the B matrix so that new values for the T matrix are obtained.

$$T = \left[t_{xy}\right]_{y=1,\ldots,n}^{x=1,\ldots,n} \tag{4}$$

$$T = B(1-B)^{-1} \tag{5}$$

The next step that should be calculated is the sum of rows and columns in matrix T to identify the importance level of the relationship among driving forces. The calculation can be found in Estimation (6) and Estimation (7) for values of the row (denoted by R_x) and column (denoted by C_y), respectively. At the end of the matrix calculation, the row and column values are added with the results in Table 4. It is calculated that for all the 25 driving forces, the average of the row and column values is 0.624. In Table 4, it is identified that only 9 driving forces have a row and column value higher than 0.624.

$$R_x = \sum_{x=1}^{n} t_{xy} \tag{6}$$

$$C_y = \sum_{y=1}^{n} t_{xy} \tag{7}$$

In the last step, finally, DEMATEL builds an impact-relation map (IRM), considering both the direct and indirect impacts of the factors. The detailed calculation can be found in the Appendix to determine the key drivers from these 25 driving forces. The key driving forces and their relationships are shown in Table 5.

Based on Table 5, the seed structure of CLD is developed. Then, additional relationships and variables are added to complete this seed structure. The final structure of CLD is depicted in Fig. 2.

Future headline and scenario elements of Indonesia's future mobility in 2030

The scenarios were built using Shell Scenario method with the help of the CLD and through iterative dialogue between members of the scenario planning team by asking how the driving forces, predetermined elements and critical uncertainties would behave in various plausible scenarios, thus producing an improving story lines in an iterative manner. As seen in Fig. 3, the areas within each line (red, yellow, brown and green) represent the situation in Scenarios 4, 3, 2 and 1 respectively.

As a result, four scenarios were obtained, which are:

Scenario 1: Infrastructure development focuses on improving intermodal integration and connectivity, thus increasing public transport quality. Better quality increases public transport adoption. In

Table 4
List of selected driving forces.

Code	Driver	R_x+C_y
CB	Consumer behaviour (car ownership, residential location, and public transport adoption).	1.2
EF	Eco-friendly activities, policies, regulations, and vehicles (including renewable energy).	1.2
GB	Government budgeting and revenue allocation to improve transportation system & capital financing.	1
PT	Public transport service quality.	1
IC	Investment climate & scheme and public–private partnership (PPP).	0.8
ID	Infrastructure development.	0.8
IA	Impact on automotive and transport industry.	0.8
NT	New technology use.	0.8
IM	Intermodal integration and connectivity (including MaaS and cashless payment).	0.8

Table 5
Relationships of the selected driving forces.

Code	Drivers	CB	EF	GB	PT	IC	ID	IA	NT	IM
CB	Consumer behavior (CB)	0	0	0	0	0	0	0	0	0
EF	Eco-friendly activities, policies, regulation, and vehicles (EF)	1	0	0	0	0	0	0	0	0
GB	Government budgeting and revenue allocation to improve transportation system & capital financing (GB).	0	0	0	0	0	1	0	0	0
PT	Public transport service quality (PT)	0	0	0	0	0	0	0	0	0
IC	Investment climate & scheme and public–private partnership (IC).	0	0	1	0	0	0	0	0	0
ID	Infrastructure development (ID)	1	0	0	0	0	0	0	0	0
IA	Impact on the automotive and transport industry (IA)	0	1	0	0	0	0	0	0	0
NT	New technology use (NT)	0	0	0	0	0	1	1	0	1
IM	Intermodal integration and connectivity (including MaaS and cashless payment) (IM)	0	0	0	1	0	0	0	0	0

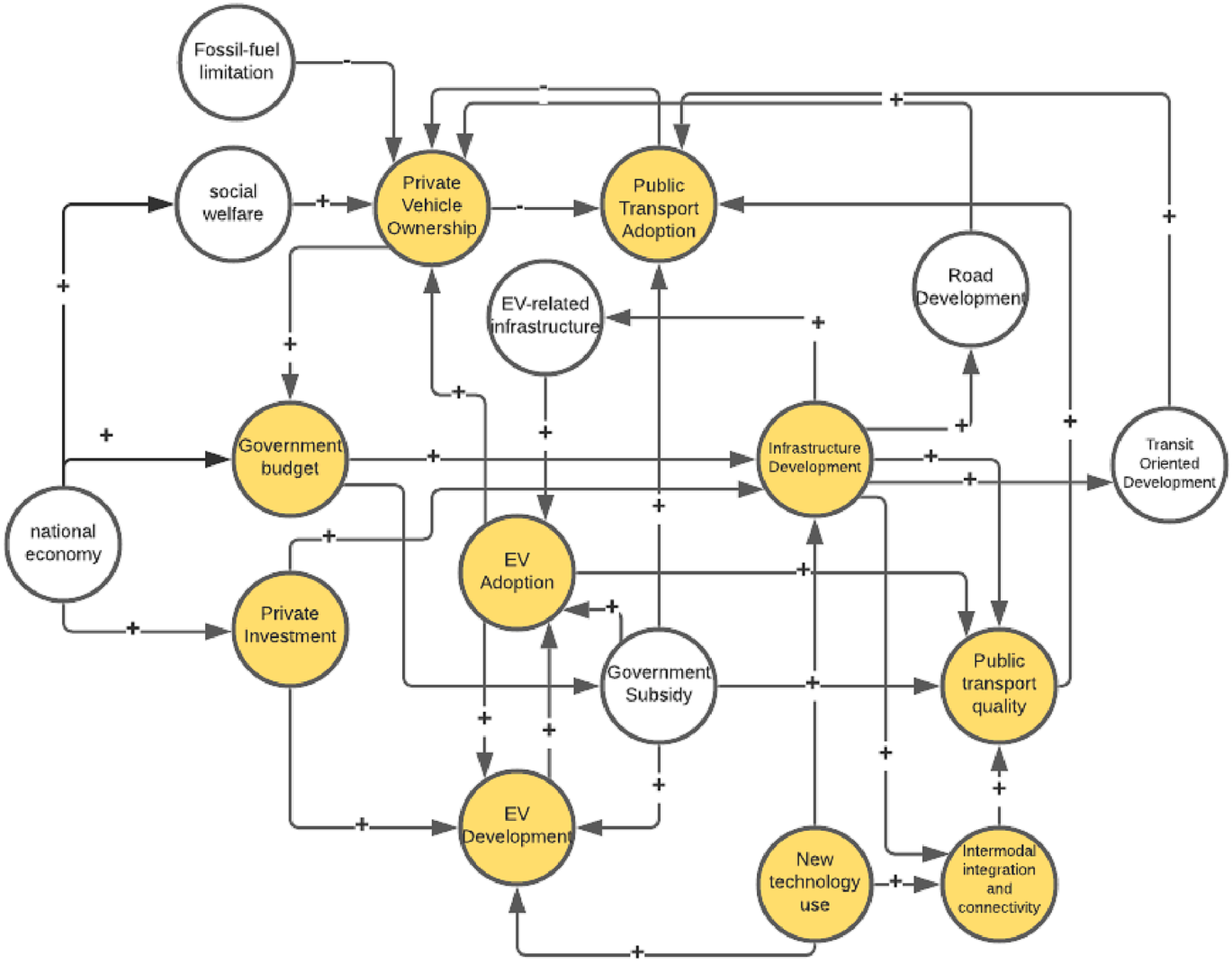


Fig. 2. Causal loop diagram of driving forces.

addition, the fossil-fuel limitation also supports the adoption. Thus, EV adoption in public transportation is also increasing.

Scenario 2: Infrastructure development focuses on increasing transit-oriented development, and fossil fuel limitation is applied to increase public transportation adoption. On the other hand, private vehicle ownership decreases in large cities, influencing EV adoption more in public transportation than private vehicles.

Scenario 3: The government partially allocates a budget through subsidies to support EV adoption, which is still limited so that only the middle and upper classes can buy private EV. Meanwhile, infrastructure development still focuses on road development without fossil-fuel limitations.

Scenario 4: There is high private vehicle ownership due to low public transportation adoption, caused by a lack of infrastructure development for improving public transportation quality instead of a higher portion used for road development.

Each scenario is given a title, headline, and illustration that represents the situation inside it. The detailed situation in each scenario is elaborated in a narrative that shows the main characteristics that differentiate one scenario from another and importantly tells about the future mobility situation in 2030. Table 6 explains the headlines and illustrations of the scenarios. Each scenario was then fleshed out with

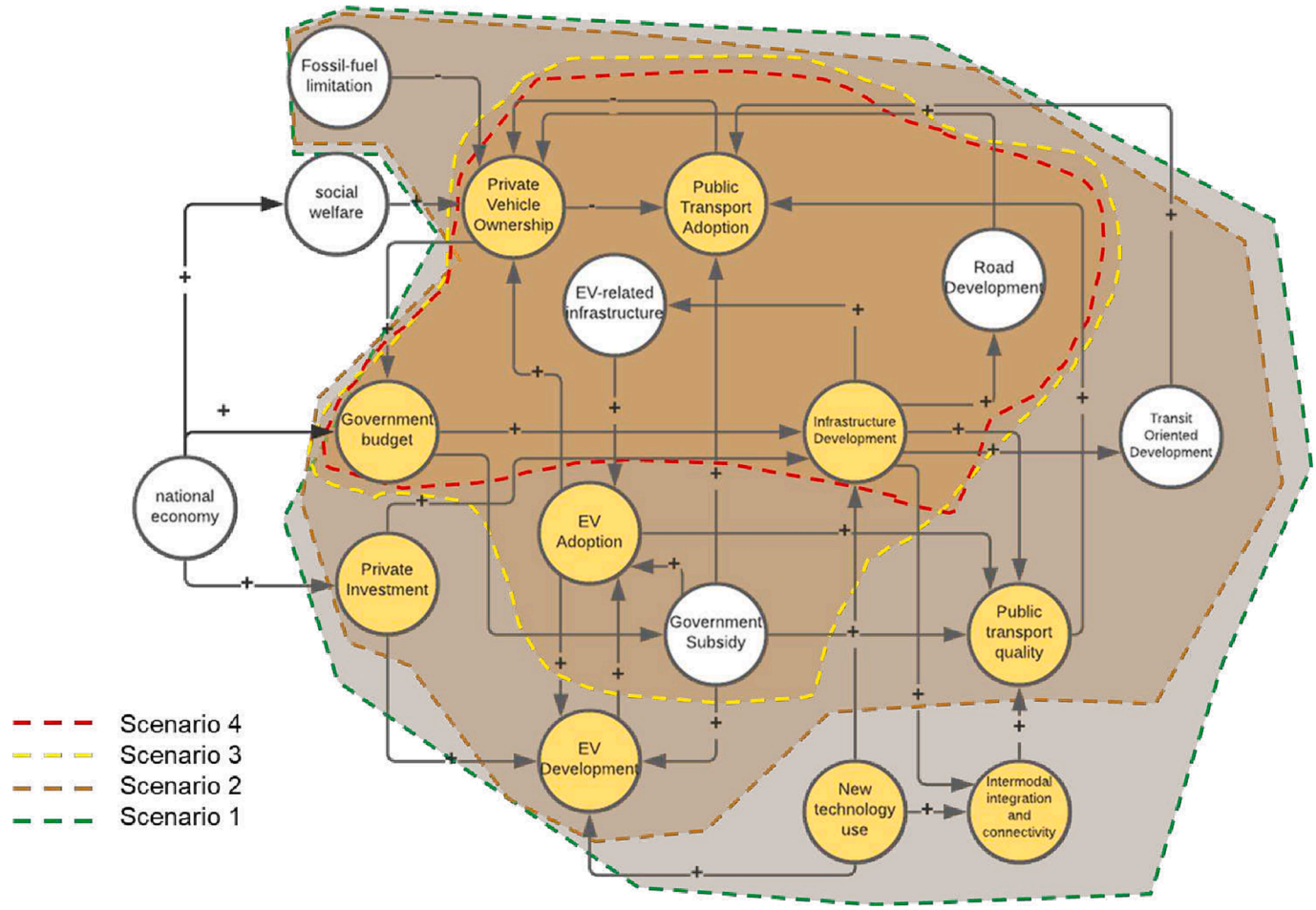


Fig. 3. Causal loop diagram & scenarios.

elements developed based on key drivers as seen in Table 7.

Scenario 1: One seamless ecosystem

The pandemic has ended, and the economic crisis has been resolved. As a result, economic activities are back to normal. Job opportunities that once had been in the period of idleness now start to be active again. Hence, the mobility of the community is back to just like before the pandemic, and consumers begin to demand an integrated service to lower the costs.

The development of transportation infrastructure has taken place equitably, not only in the metropolitan area but also in suburban areas in its surrounding. Even though the urban transportation is not yet integrated, the quality of the public transportation is already good. However, the government does not want to stay idle and is prioritizing integrated mass transportation development. It strives to have an integrated transportation system and sufficient infrastructure that can provide high-quality service and seamless experience to all its users, supported by mobility-as-a-service (MaaS) technology. The use of MaaS applications includes the shared mobility services currently emerging in Indonesia. Should ride-hailing be fully utilized, it can help increase the mobility quality since it can increase the usage of vehicles. It also facilitates those who do not have access to personal mobility, such as non-owners and those who cannot drive, thus increasing the average mobility miles caused by the rebound effect. Aside from that, the shared mobility services can also fulfill the sustainability objective by reducing the number of vehicles on the road, spacing the congestion that results in emissions and cost reductions (Bi et al., 2020).

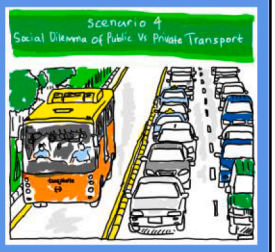
Several government policies to support the effort to use public transportation have been sounded. There is the development of the integration of parking areas with the mass transportation system and the limitation of fossil-fuel vehicle usage. In terms of all these efforts, it is no wonder that the number of public transportation users has increased, not only for daily commuting inside the city but also for trips to other cities. Public transportation has become a mobility service that can be depended on for all classes, from the low economic class to the upper-middle economic class. People who live in suburban areas benefit from reliable public transport service. Reliable public transport services mean better predictability and consistency of travel times for users, which also benefits transit operators as it also improves their efficiency and reduces operating costs. Many who live a shorter distance to the city choose bicycles as their transportation mode, which is happening because environmental awareness in the community has increased.

Public transportation usage does not mean killing the private vehicle industry. On the contrary, the development of the private vehicle industry has transformed into a more environmentally friendly product, particularly electric vehicles. With government policy support through tax incentives, the prices of electric vehicles will be more affordable to all classes. It can support the growth in local electric vehicle industries and more creative financing in private and public cooperation. Supporting infrastructure for electric vehicles such as public and home-based charging stations will influence the increasing use of electric vehicles as an alternative mobility in 2030. The best use of technology has been suggested as a key element of the sustainable mobility paradigm (Banister, 2008).

Scenario 2: Culture of public transportation

The government's success in overcoming the 10-year cycle of the economic crisis phase has increased the upper-middle class, especially in

Table 6
Comparison of each scenario.

Scenario	Scenario 1	Scenario 2	Scenario 3	Scenario 4
	One Seamless Ecosystem	**Culture of Public Transport**	**Exclusive Green Community**	**Social Dilemma of Public vs. Private Transportation**
Headlines	*"Mobility users have a seamless experience supported by integrated and well-connected infrastructure."*	*"In big cities, the middle and upper class want to use public transportation; however, in small cities the congestion conditions increase."*	*"The technology adoption of EVs is increasing; however, it creates the convenience of using private vehicles."*	*"Private vehicles are increasingly diverse; the choice of public transportation is not expanding."*
Illustration				

suburban areas. The sales of motorized vehicles are also rapidly growing in those areas. It is understandable due to the community's flexibility and prestige symbol of owning private vehicles. Then it is not surprising that the increasing volume of private vehicles is highly significant, as indicated by the occurrences of cars and motorbikes along the roads of those suburban areas. This has given rise to new problems, increasing the traffic congestion and pollution. It can be said that the government is late to anticipate those problems. All this time, infrastructure development in the suburban areas has not been a priority and only focuses on the big cities in Java. Moreover, it is not well planned. The result is that the transportation infrastructure capacity in suburban areas can no longer accommodate the rising volume of private vehicles.

The opposite thing has occurred in metropolitan areas. The upper-middle class has started to shift to use public transportation or bicycles to go to work, which has only become a daily option for the lower-middle social class. This does not happen suddenly. For some time, the government has kept developing the infrastructure and public transportation to be integrated in metropolitan areas. Furthermore, the digitalization of public transportation has been implemented. It is indicated by the existence of a digital payment system that is cashless and touchless, so that it can provide satisfying services to the users.

Pull policies need to be complemented by influential policies to promote people's acceptability of sustainable mobility (Banister, 2008). A variety of policies to push the shifting of private vehicle users to become public transport consumers continues to be rolled out by the government. In metropolitan areas, to reduce pollution and support the shifting to environmentally friendly vehicles, fossil-fuel vehicle usage is minimal; thus, some middle and upper classes feel that they are being forced to use public transportation. Moreover, ERP tariffs are also enforced on several main roads of Jakarta. Unfortunately, the prices of electric vehicles, which are more environmentally friendly, are only affordable for middle and upper economic classes. However, the usage of electric vehicles can be applied to public transportation. Ala et al. (2020) stated that EV usage could support the reduction of CO_2 emissions in 2030. Moreover, using EVs compared to fossil-fuel vehicles can reduce greenhouse gas emissions by approximately 60%.

Scenario 3: Exclusive green community

Traffic congestion is still a daily issue on the roads of Jakarta. Although the government has developed infrastructure and integrated public transportation facilities, only a limited number of middle-class people have switched to make public transportation their daily mode of travel. Indeed, it is not an unreasonable event. The government policy to increase road capacity and develop several newly built motorways has made private vehicle users (mostly upper-middle communities) feel spoiled. The ease of access and flexibility in driving makes them comfortable, so they are unwilling to shift to using public transportation. Public transportation, which is expected to become the main option for mobility to the city center, is still the main mode of transportation only for the mobility of lower-middle social class communities.

Although the government has not implemented a policy to limit fossil-fuel vehicle usage, the upper-middle community's consciousness to use more environmentally friendly vehicles is becoming more apparent. It is shown by the high enthusiasm to use electric vehicles, which offer an attractive privilege to the users. The electric vehicle user is privileged by special tariffs, which are cheaper while accessing the motorway. Besides that, they are also exempt from the even–odd number plate policy. Supporting the infrastructure of electric vehicles can also be reached on every street corner in Jakarta and its surrounding cities. As a result, the sales of electric vehicles have increased rapidly

Table 7
Scenario elements.

Key drivers	Scenario 1 One seamless ecosystem	Scenario 2 Culture of public transportation	Scenario 3 Exclusive green community	Scenario 4 Social dilemma of public vs. private transportation
Socio-economic factors	The post-pandemic economic crisis has been resolved. Sharing economy. Integrated service is demanded.	The post-pandemic economic crisis has been resolved. The rise of the middle class in secondary cities.	The post-pandemic economic crisis has been resolved. EVs have become affordable for the middle class.	The recovery phase of the post-pandemic economic crisis. Inequitable economy. Private vehicles are more popular.
Infrastructure development and its equitability	Evenly distributed and integrated infrastructure. Very good accessibility to the regions. Good quality of public transportation.	Integrated infrastructure development focuses on the big cities of Java. The regions develop transportation infrastructure.	Integrated infrastructure development focuses on the big cities of Java.	Infrastructure development both in cities and the regions is hampered.
Governance (policies, law enforcement, development focus)	Policies focus on improving the quality of public transportation. A smart city concept is applied. Development focuses on integrated public transportation and non-motorized vehicles.	Policies focus on restricting the use of private fossil fuel vehicles. Separate working systems such as ERP and e-ticketing are used. A focus on public transportation development.	The policy has not limited the use of private fossil fuel vehicles. EV incentives are still limited so that the price is high. Regulation implementation relies on the integrity of the officials. Road construction or increasing the volume of roads.	The policy has not limited the use of private fossil fuel vehicles. EV incentives are still limited so that the price is high. Regulation implementation relies on the integrity of the officials. Road construction or increasing the volume of roads.
Mass transportation development	Integrated and high-quality service public transportation is available. The upper-middle class uses public transportation for short or long trips. Parking pocket facilities are built to support the transportation integration in the suburban areas.	The mass transportation system is the mainstay of the lower-middle class. Some of the upper-middle class switched to use mass transportation.	Integrated public transportation is still the mainstay of the lower middle class. Only a few of the upper-middle class are interested in moving here.	Slow integrated public transport construction. Public transportation competes with private two-wheelers.
EV & eco-friendly policy	Fossil fuel vehicles have begun to be limited. An eco-friendly lifestyle is supported by the growing local EV industry and private charging station development. . The number of EVs is increasing.	Fossil fuel vehicle big cities start to be limited. EV is only affordable to the middle and high market segment with privilege and infrastructure.	No limitations of fossil fuel vehicles. The implementation of standard emissions has begun to be enforced. Incentives push EV ownership for the middle and upper classes.	No limitation of fossil fuel vehicles. No strict rule in the standard emission rule implementation. Incentives slightly push EV ownership for the middle and upper classes.
Consumer behavior	Eco-friendly behavior is adopted. Public transportation is considered as an option for urban mobility by middle and high markets.	Public transportation use is urged for middle and upper classes. An increasing number of private vehicle users in small cities. A living place near public transportation is chosen. Private vehicles are no longer a priority.	Middle and upper classes start to consider the environmental impact.	Decreasing trust in public transportation. Private vehicles are everybody's choice.
Investment climate and scheme (PPP)	Investments are focused on environmental impacts and mobility access inclusivity for the people. More implementation of creative financing in private and public cooperation.	Investments are focused on environmental impacts and mobility access inclusivity for the people. Creative financing starts to be implemented in public and private cooperation.	Investments are focused on the capital search for bankable infrastructure. Investment choices start to vary where one of them is a promising climate for the EV industry.	Unsustainable investment relationship. Investment choices are still very limited to road infrastructures.
Impact of the pandemic	Mobility of people decreases. Intercity trips increase because of WFH. E-commerce boosts logistic mobility.	Mobility conditions return to the way it was with the business district as the center point of mass transport users. E-commerce boosts logistic mobility.	Mobility of people decreases. Intercity trips increase because of WFH. E-commerce boosts logistic mobility.	Mobility conditions return to the way it was with the business district as the center point of mass transport users. E-commerce boosts logistic mobility.
New technology adoption	Mobility as a service (MaaS) is growing fast. IoT adoption helps the connection and provides a path to autonomous vehicles.	Digitalization of public transport services.	EV is quickly adopted by privileged society. Technology supports EV development.	Digitalization happens partially and is not synergized between transportation services.

and affect the decreasing level of air pollution. New start-ups which produce electric vehicles have also begun to appear, and it attracts investment institutions to invest in the most promising area in the electric vehicle industry. Nickel and copper are the primary materials of an EV battery. Considering that Indonesia is the biggest nickel producer and one of the biggest copper producers globally (Rijowan, 2021), the benefits can be enlarged should Indonesia's battery factories process nickel in batteries. Initially there was news Tesla, a multinational company, made an agreement with Indonesia for the establishment of a battery factory in Indonesia (Hamdani, 2021). But the one realized is a consortium of LG and Hyundai who are building a battery factory in Indonesia which will produce 10-Gigawatt hour (Gwh) worth of batteries in 2024 (CNN Indonesia, 2022).

The government still has to keep thinking of a way to unravel the congestion problem. At the same time, it continues to increase environmentally friendly energy sources, whether for private or public vehicles. Renewable sources for energizing the EVs need to be sought, including "sea-to-grid" technology (e.g., Musolino et al., 2019), considering the archipelagic nature of Indonesia. Moreover, the development of road infrastructure and public transportation facilities in the other cities, especially outside Java Island, is also one of the primary assignments that need to be done immediately.

Scenario 4: Social dilemma of public versus private transportation

Thus far, the COVID-19 pandemic has been able to be controlled well. One of the critical components of this success is the distribution of vaccines that has been done effectively. On the other hand, the economic impact of the pandemic is beyond prediction. Until 2030, the economic crisis is not predicted to be fully overcome yet. The government's effort to achieve the expected economic growth has to be done continuously, and the social disparity is still visible.

As a consequence, developments have faced a halt. The expansion of road infrastructure and development of integrated transportation facilities, expected to have finished by around 2020, is not yet completed. As a result, the government's goal of providing high-quality, seamless public transportation services that can give the best experience for its users has not come true. Moreover, some public transportation modes are not well maintained. Hence, the target to push the majority of people to shift to using public transportation has failed to be achieved.

Private vehicles are still the main choice for people's daily mobility. No wonder that traffic congestion, especially in capital city areas, has become more severe. The lack of road growth as the product of obstructed development causes the solution to solve traffic congestion to become an almost impossible thing to do. The absence of a fossil-fuel vehicle usage limitation policy contributes to the worsening situation. As a result, air pollution levels in urban areas are increasing. Environmentally friendly electric vehicles hoped to help reduce air pollution levels are still too expensive. The government has not yet implemented incentives to reduce the taxes on electric vehicles to make them more affordable for the general public. Hence, only a small portion of the privileged people and higher economic status can afford electric vehicles.

Scenario implications

This segment explains the implications of each scenario in several aspects such as traffic and the environment, social aspects, governance and regulations, and infrastructure development. These stakeholders are analyzed and combined, so that the implications can be produced for the stakeholders as a whole. Finally, the inputs from the interviewees for this research are categorized.

Implications on traffic and the environment

The scenarios involve the number of private vehicles, whether it will decrease due to the growing public transportation users or increase due to the growing usage of fossil-fuel-based private vehicles or electric vehicles. Furthermore, the number of private vehicles significantly affects traffic due to the congestion and environmental impacts from the emissions produced. Therefore, each scenario provides different implications towards the traffic and the environment.

Scenarios 1 and 2, which promote the usage of public transportation, will reduce congestion and pollution. However, the difference is that the congestion and pollution in Scenario 2 only occur in big cities due to the growing economy and inequity of the infrastructure in small cities. On the other hand, in Scenario 2, infrastructure development for both private and public transportation users is equal, with many incentives for EV and public transportation users.

The different sides are shown in Scenarios 3 and 4, in which both infrastructure and regulations are not sufficient to reduce the usage of private transportation, resulting in high congestion. However, due to the rise of EV producers and incentives, the pollution in Scenario 3 seems to decrease in 10 years, while it is still a major problem in Scenario 4.

Implications on society

The social impact differs from each of the scenarios. It is reflected in the community, the main player in this scenario development. Every obstacle and challenge is adjusted with the behavior and demand of the community. The behaviors shown in this segment are regarding the environment and transportation mode choice. Regarding the environment, the community's behavior differs in each scenario. Scenario 1 shows the highest level of environmental consciousness, followed by Scenarios 2 and 3, with the lowest in Scenario 4. The level is determined by the transportation environment that occurs in 2030 in each scenario.

Regarding the transportation mode choice, Scenarios 1 and 2 favor public transport due to the regulation and conditions that directly and indirectly encourage the community to use public transportation. The difference between Scenarios 1 and 2 lies in the application. Scenario 1 is mainly motivated by the ease and support of using public transportation using MaaS, while Scenario 2 is primarily motivated by the easy access to public transportation with housing patterns. On the other hand, Scenarios 3 and 4 favor private transportation since the regulations and conditions still support private vehicle usage. The acceptance toward a multimodal mobility system, like MaaS, will be influenced by users' freedom to choose their mobility chains and variety of transport means suitable for achieving their different goals (Spickermann et al., 2014). Hence, understanding the behavior of the users is essential.

The social impact also affects the industries such as the transportation industries and the supporting industries. The social behavior toward transportation affects the demand of the automotive industry and its complementary industries such as batteries, lubricants, oil, and gas. The high portion of public transportation in Scenario 1 makes the automotive industry players think about selling their products. The environmental sentiment resulted in product shifting from fossil-fuel-based vehicles to EVs altogether by the players. The EV trend also happens in Scenario 2; however, the EV is only limited to the upper socio-economic circles in the urban cities due to the gap of the economy with the small cities, in which higher demand for the fossil-fuel-based private vehicles occurs. In both Scenarios 1 and 2, the demand of the supporting industry related to EVs, such as batteries, will be much more rapid and higher to fulfill the demand of the EVs.

Lastly, in Scenarios 3 and 4, the behavior of the majority of the community is indifferent to the current condition, which is more focused on fossil-fuel private vehicles. Therefore, the battery industry will also emerge for the supporting industries to fulfill the limited demand of EVs, despite being lower than in Scenarios 1 and 2. In Scenarios 3 and 4, other supporting industries such as lubricant, oil, and gas, will still dominate the market due to the high level of fossil-fuel transportation.

Implications on governance and regulations

The organizational governance, both on the national and company scale, is developed differently. On the national scale, the government plays a significant role in scenario development since it contributes to

dealing with current and future challenges (Table 2). In this segment, government decisions and regulations are explained in each scenario. For example, in Scenarios 1 and 2, the government enacts regulations regarding the emission standards and encourages public transport usage by limiting the benefits of private vehicle ownership. The difference is that the infrastructure development in Scenario 2 is slower and only focuses on big cities, making it difficult to shape the public transportation culture in small cities while buying private vehicles due to their increase in income.

On the other hand, the government is still struggling with the ownership of private vehicles since the public transportation system is not yet integrated and intrigues people to use it. However, in Scenario 3, the government encourages eco-friendly activities by enacting regulations regarding the emission standards. It results in the shifting behavior of the high class due to their ability to buy the eco-friendly vehicles produced by the automotive industry.

On the company scale, some sectors' governance is affected by the impact of the scenarios. The first one is the public transportation segment. The effectiveness and efficiency of the public transportation system in Scenario 1 has resulted in the integration of the operators and services. The integration of this part is by sheltering the operators and the FM/LM services in one application. This integration, which involves physical and non-physical integrations, will create seamless services for users, such as the implementation of Mobility-as-a-Service (MaaS). In Scenario 2, the governance impact also affects the LRT and MRT, which are made and operated by the institutions respectively and parallel with the development of transit-oriented development established side-by-side with the public transport facilities. This is done to motivate people to use public transportation.

In Scenario 3, the EV producers are affected by the governance impact. The government incentives for the EV producers affect their governance to implement eco-friendly activities in the transportation industry by switching their fleets from non-renewable to more sustainable energy to meet the demand and comply with the regulations. However, the governance and regulations have not changed much in Scenario 4. Therefore, public transportation will remain the same due to Indonesia's situation in 2030. It occurs because the regulations have not changed significantly, and the operators have difficulties shifting people away from private vehicles.

Implications on infrastructure development

This part mainly discusses the infrastructure development to support the condition in each scenario. The utility and infrastructure developers will decide whether they need to innovate and invest in new products/services or focus on developing existing products/services. Scenario 1 pictures an environment with an integrated, seamless ecosystem and high awareness of eco-friendly activities. Property developers in Scenario 1 adapt to the scenario by establishing charging stations in many places to support the environment. The charging stations are divided based on the usage level in the area, such as ultra-capacity along the toll roads, medium-capacity on the public facilities, and home-charging capacity in housing, focusing on renewable energy to support the electricity supply. The difference in Scenario 2 is the charging stations are only available for public transportation with a medium capacity on public facilities. This condition happens because people's activities focus on public transportation and places. Infrastructure development is focused on rural areas to support the increased number of private vehicles. The charging stations are not made public in Scenario 3 due to the low number of EV users, causing the high price and low availability. To support that, the utility developer offers home-charging services to increase the electric power capacity in the household. On the other hand, the infrastructure development in Scenario 4 focuses on road capacity to fulfill the demand of private vehicle users.

Discussion

In describing the future mobility situation in the Jakarta Metropolitan Area (JMA), it is necessary to discuss some of the key issues that have contributed to influencing the previously identified scenarios. These issues are related to: (1) spatial and regional planning, (2) the certainty of related policies and their implications and derivative policies, (3) the transition of internal combustion-based vehicles to electric vehicles, and (4) the arrangement of road infrastructure and its supporting facilities.

The first issue regarding spatial and regional planning refers to a scenario that prioritizes transit-oriented development as a form of future mobility solution. JMA has experienced rapid urbanization and economic growth in recent decades, which has led to urban sprawl in its periphery. One of the main drivers of urban sprawl in Jakarta is highway expansion, which has improved accessibility to suburban areas but also induced more private car use and land development. Highway expansion has also contributed to social segregation between affluent gated communities and low-income informal settlements along the highways (Pratama et al., 2022). The next issue related to policies is the basis for looking at the behavior of commuters in the future, especially concerning the use of public transportation, which is expected to be more dominant than private vehicles. Next, the issue of switching from fossil-fuel vehicles to electric vehicles explains the potential for electrification of future transportation modes in Indonesia. Finally, the last issue regarding infrastructure arrangement is a challenge in realizing a picture of future mobility in transportation infrastructure funding that encourages sustainable and integrated development.

Based on these recommendations and the results of interviews with stakeholders, the following point of discussion will explain several fundamental issues related to the description of future mobility in JMA, which are divided into several topics, including: (1) efforts to support vehicle electrification; (2) supporting policies and infrastructure for limiting fossil-fuel vehicles and the use of public transportation; (3) mobility as a service as an effort to integrate and collaborate in transportation activities; (4) transit-oriented development as the main reference in linking mobility behavior with settlements; (5) efforts to change the behavior of commuters with push and pull policies; and (6) infrastructure funding as the main issue in providing mobility facilities.

Efforts to support vehicle electrification

To determine which scenario related to electrification the future mobility will reach, applying incentives for electric vehicle production and ownership is one of the key decisions. In Scenario 1, where the electric vehicle becomes affordable to any economic class of the society, the government will broadly implement these incentive policies. The government needs to apply incentives for the producers to reduce production costs and taxes for the customers to reduce vehicle prices. This study has concluded this statement based on the following answer from the stakeholders' interviews.

> *"The regulation support is important to make electric vehicles affordable for the Indonesian community…The government regulation support needed is incentives for environmentally friendly local products and support for new domestic mobility industries (start-ups)."*

AS, Automotive (Car) Manufacturer, Division Head, 13 years of experience in the industry.

> *"We must prepare the ecosystem for the electric-based vehicles within its B2B and B2C. The ecosystem includes the regulations, community awareness, and the prices of spare parts for its maintenance. In addition, the community must be given various types of comfortable, affordable, and fast transportation modes."*

DA, Automotive (Motorcycle) Manufacturer, Project Leader, 20 years of experience in the industry.

"Government coordination in issuing an integrated and appropriate policy on an electric vehicle is important."

DAR, Automotive Components Manufacturer, CEO, 25 years of experience in the industry.

According to Li et al. (2020), there are several incentives that the government can take to improve the number of electric vehicles in the future. The study identifies that incentives related to energy charging, driving the EV, vehicle registration, and purchasing are important from customers' points of view. Furthermore, the policies about incentives that help customers charge their EV batteries have been perceived as the most important one based on the study. In Beijing, Huang and Ge (2019) also found that monetary incentive policies significantly and positively impact EV purchase intention. In contrast, they also encountered that non-monetary incentive policies have no significant effect on the purchase intention. In conclusion, it is pertinent to focus on delivering a supportive infrastructure for EV users, especially those related to charging activities, using the incentives to minimize the cost on the customers' side. The findings align with the concern from one of the stakeholders in the following statement.

"Facilitating the permit and making it free of charge for an electric vehicle is important. Also, tax incentives should be given for the companies which support electric vehicle manufacturing."

FS, IT and Communication Provider, Commissioner, 30 years of experience in the industry.

Supporting the limitation of Fossil-Fuel vehicles and broader use of public transportation

The government should respond by implementing a limitation policy on fossil-fuel vehicles to reduce private vehicle users. This response is one of the indicators for completing Scenarios 1 and 2, which also promotes growth for mass transportation vehicle manufacturers. However, the authorities will not apply this in Scenarios 3 and 4. The statement is supported by the stakeholders' answers in the interviews, as described by the following words.

"Increase the budgeting for public transportation quality improvement… and regulations to control the volume of private vehicles on the roads…"

HKDA, Freight Transport Provider, Country Director, and 18 years of experience in the industry.

"The increasing fossil fuel import tariff for Indonesia…will be the determining economic factors that shape future Indonesian mobility."

SW, Venture Capital, COO, 16 years of experience in the industry.

In the context of fossil fuel usage reduction, a study from Rinscheid, Pianta, and Weber (2020) revealed that subsidies for alternative energy are preferred over taxes and bans. Hence, the policy should consider limiting the internal combustion vehicles by increasing the taxes of the car type and reducing the cost of an alternative type of vehicle that is more environmentally friendly. However, the tax strategy is not necessarily becoming unimportant. For example, a study from Barbieri (2016) concluded that tax-inclusive fuel prices effectively change people's behavior from using non-eco-friendly technologies to eco-friendly ones. Therefore, the government needs to focus on both strategies, whether to increase the carbon tax policy and subsidies for using public transportation or any transport mode that has proven to be less damaging to the environment.

MaaS as an effort to integrate and collaborate in transportation activities

Everything should be connected, including mobility. The mobile phone will lead to how people move from their houses to the office in the future. Information about how long the transportation mode will drive you to the destination will become the most impactful aspect in people's journeys. The way we communicate will connect every service related to mobility. It will be more connected, integrated, and shared between one service and others. Hence, the term MaaS is broadly implemented. There is no more conflict between mass transportation and shared mobility providers. On the contrary, they will tend to collaborate. The necessity of MaaS has been revealed through several statements from different stakeholders in the following citations.

"Cooperate with ride-sharing services in Indonesia to prepare the fleets and after-sales service."

AS, Automotive (Car) Manufacturer, Division Head, 13 years of experience in the industry, when we asked him about his company's contribution to increase people's and logistic mobility.

"The widespread usage of MaaS."

AD, Public Transport Service (road-based), Director, 17 years of experience in the industry, when we asked his opinion on the future of people's and logistic mobility in Indonesia.

"The future of transportation: seamless public transportation through an integration concept."

PBP, Government (national transportation agency), 11 years of experience in the industry, when we asked her opinion on the future of people's and logistic mobility in Indonesia.

From three different stakeholders from a public transport provider, an automobile manufacturer, and the government, we have seen that they all have a similar perspective: sharing and integration are the main parts of future mobility. The first and the last statement mentioned integration and cooperation in mobility. Meanwhile, the statement of the director of the public transport service provider explicitly mentioned MaaS or Mobility as a Service. In terms of integration in transportation to be a success, five main attributes are important to be integrated: 1. network integration; 2. fare integration; 3. information integration; 4. physical integration of stations; and 5. a coordinated schedule (Chowdhury et al., 2018; Barreto et al., 2018). On the other hand, a study from Casadó et al. (2020) also identified barriers for integration in mobility to be well implemented. The barriers are unclear information of a multimodal journey; a lack of interoperability of trips among different providers; the need to acquire physical tickets for several segments of the trip; inconsistency of payment methods; and unclear notifications of available parking areas, including for bikes. These attributes and barriers must be considered to successfully implement the MaaS.

TOD as the main reference in linking mobility behavior with settlements

The location of the residential area is closer to the point where the mass transportation stops. People tend to live near stations because they think that commuting is one of the most frequent activities in their lives. Thus, the trend of infrastructure development related to property is changing. It will be connected with mass transportation, known as transit-oriented development or TOD**.** Moreover, the development of the metropolitan areas will focus on the connectivity between mass transportation, residential areas, and smart city development.

Furthermore, the development of the urban areas will focus on the connectivity between mass transportation, residential areas, and smart city development. As a result, people in the future will live in neighborhoods where mobility is one of the most meaningful activities in their lives. The following statements led to this discussion.

"People's awareness of using public transportation will be higher… In addition, a cheap residential development near the public transport corridor will motivate the commuters to have houses near their workplaces."

YA, Public Transport Provider (road-based), Director, 20 years of experience in the industry.

"Smart cities will affect public transportation."

RA, Utility Company, Supervisor, 19 years of experience in the industry, when we asked his opinion on the future of people's and logistic mobility.

Furthermore, Malavenda et al. (2020) assumed the attributes that determine community residential location decisions into four categories: socio-economic and mobility attributes of a residential area and/or their components; land-use; the real-estate market; and the transport system. Moreover, Pengjun and Shengxiao (2018) highlighted that when a mass transport station or stop is situated far away from the city center, a commuter has a higher chance of residing in the area. In the end, Loo and du Verle (2017) concluded that a seamless intermodal change and integrated public transportation with residential areas should be developed in future cities. Hence, the development of residential areas will be integrated with mass transportation stations to fulfill commuters' demands. However, socio-economic factors will determine how far the communities' houses are from the nearest station. Pengjun and Shengxiao (2018) revealed that low-income commuters might have to live further away while high and middle-income commuters choose to live nearer. Thus, the development of feeder buses is also important for low-income commuters to reach their working or main activity places using mass transportation. This finding can be concluded from the following statement.

"It facilitates connectivity between residential and public transportation stops, especially buses. One of the examples is the availability of the feeder buses."

HKDA, Freight Transport Provider, Country Director, 18 years of experience in the industry, when we asked his opinion about the challenges to improve the quality of public transportation.

Efforts to change the behavior of commuters with push and pull policies

The transition of private vehicle users to public transportation requires improving the quality and accessibility of public transportation services and push and pull policies that limit the use of fossil-fuel private vehicles. In addition, the behavior of commuters to choose healthier and environmentally friendly transportation modes needs to be a concern of policymakers. Safe and comfortable road access for cyclists is expected to support the use of public transportation in the future. All these strategies are expected to change the behavior of commuters to be more concerned about the environment and be able to reduce congestion in urban areas. In the future, public transportation could become the preferred mode of transportation for commuters if the issues described previously are implemented properly and optimally. This study emphasizes the point of discussion based on the following statements from interviews.

"The increase of the private vehicle users is because of the inability of the government to provide sufficient public transport service. Ineffective road space usage because of the number of the low-occupied private vehicles causes an increase in the traveling time and reduces the speed."

SP, Transportation Analyst, Solution Specialist, 16 years in the industry.

"In-city public transportation has been better, but the traffic still exists. In addition, facilities for pedestrians and cyclists are limited."

AD, Venture Capital, Associate Consultant, 3 years in the industry.

"It will be hard to persuade people to use public transportation if the cost is high because Indonesian incomes are not yet categorized as high incomes."

IB, Online Media Provider, Division Head, 16 years in the industry.

These findings align with Wang et al. (2020) study, which found that push factors, including perceived environmental threats and inconvenience, affect an individual's mode-change away from private vehicles. In contrast, the pull factors, including eco-friendly transportation policies, campaigns, and transport systems, attract individuals' mode-shift to eco-friendly transportation. Therefore, this study proposes to combine the push and pull factors, increasing the cost for private vehicles while also developing a better quality of mass transportation to promote changing modes from private to public transport modes. Furthermore, another study from Keizer et al. (2019) stated that policy acceptance is also related to the personal norms of commuters about the right things to do. Moreover, the study surmised that personal norms correctly predict when the push strategy is associated with personal costs. Hence, the push strategy should increase the personal costs for private vehicle users to transform their behavior in using public transportation.

Infrastructure funding as one of the main issues in providing mobility facilities

Funding is the most important part of accelerating infrastructure development in Indonesia, including future mobility facilities. The government has made various efforts to obtain funding from the state budget and collaborate with the private sector. To support this, the government has developed several strategies by providing a state-owned company that focuses on collecting investor funding for infrastructure development. In addition, various collaborations between the government and private companies have been initiated and run well to provide better infrastructure. However, attracting private investors to invest in infrastructure needs several government interventions to provide bankable infrastructure, especially in transportation and mobility. This study discusses this issue based on the following statement from one respondent who works as a division head of the aforementioned state-owned enterprise.

"… (the name of the company) is a special state-owned enterprise that has a mandate in the national infrastructure development acceleration. Our company's strategic role is to increase the infrastructure projects, such as transportation, by giving funding that suits the project characteristics (structured financing) and how to motivate private investments in transport infrastructure as much as possible."

S, Infrastructure Investment Company (state-owned company), Division Head, 10 years of experience in the industry.

The collaboration between the government and the private sector in funding infrastructure schemes has been known as public–private partnerships. This scheme has benefited from the lack of a government budget to develop better infrastructure, including transportation. However, a study from Soomro and Zhang (2015) highlighted several cases of failure during the collaboration, especially as the effect of inappropriate decisions and actions from private-sector partners. Therefore, this study proposes that the government should make a good relationship and effective control in collaborating with private-sector partners to fund the infrastructure projects. On the other hand, another study also discovered that public–private partnerships not only help the government to build infrastructure but also to support policies such as road-pricing strategies (Rouhani et al., 2016). However, this study notes that the discussion on revenue allocation should be well discussed, especially if the policy is also related to the distribution of social welfare or other infrastructure development. Hence, the policy and infrastructure funding scheme should discuss how the revenue will be allocated to provide better transportation services. In conclusion, clear rules on revenue allocation and control function of the government are essential to attract investors to fund transportation infrastructure and for policy development.

Conclusion

Transportation development is essential to increase the effectiveness of moving people and objects from one place to another. However, more civilized transportation also creates more complex problems in the future, such as land use, car dependence, environmental, congestion, and other issues. Many ideas have been proposed to overcome these problems, yet they may also cause consequences in the future, as the cycle continues. These conditions occur when uncertainties have important impacts. Many factors will be taken into account in future developments. In preparing for an uncertain future, every stakeholder needs to identify what efforts they need to consider. Scenario planning is a method capable of forecasting plausible futures and developing options as the consequences of the implications in every scenario.

With the significant improvement in transportation and mobility to accommodate a potential denser population, it is considered important to use scenario planning to solve the future issues. Therefore, this paper presented the development of the possible futures of mobility of JMA in 2030 by looking at the current condition and observing the future obstacles from the stakeholders in transportation and related industries. Complemented with the DEMATEL and CLD methods, scenario planning, and steps adapted from previous literature, four possible futures of mobility in 2030 were identified as: 1) a one seamless ecosystem, 2) the culture of public transportation, 3) an exclusive green community, and 4) the social dilemma of public versus private transportation.

The elements that describe every scenario consist of socio-economic factors, infrastructure development, governance, mass transportation development, eco-friendly policies, consumer behavior, an investment climate and scheme, the impact of the pandemic, and technology adoption. With the unique elements found in every scenario, four implications were identified based on the traffic and environment, society, governance and regulations, and infrastructure development. However, the scenario planning approach is a method that focuses on the long-time horizons. Thus, sustainable efforts are needed to direct Indonesia's future mobility to the desired future. Six main efforts were described and supported by the stakeholders' arguments to be continuously monitored in the next 10 years. The efforts are related to vehicle electrification, the limitation of fossil-fuel vehicles and the broader use of public transportation, the implementation of MaaS and TOD, commuters' behavior changes with push and pull policies, and encouraging funding regarding mobility facilities. Not to mention many stakeholders' role to achieve the desired future, the role of government is vital as a key stakeholder in terms of budgeting, policy making, and providing necessary regulation. As a result, they can minimize the negative implications and maximize the potentials from the positive implications. Therefore, the stakeholders need to be aware of all the possibilities and decide which options can produce the greater good for Jakarta Metropolitan Area's mobility in 2030.

A couple limitations were identified from this study, which can be followed up in further research. Firstly, the study focuses on the development of scenarios and highlighting some implications and options that can be done by stakeholders. The scenario is a transformative one hence in order to achieve the desired scenarios, all stakeholders shall contribute to realize the efforts highlighted in the study. The steps to be taken by each stakeholder and the timeline is out of the scope of study, which can be done in further research. Secondly, the scenarios are qualitative ones, providing a narrative of plausible scenarios of the future of mobility. A follow up study by quantifying each scenario using modelling & simulation (e.g., systems dynamic) can provide projections of the situation in each scenario quantitatively.

CRediT authorship contribution statement

Yos Sunitiyoso: Funding acquisition, Conceptualization, Methodology, Investigation, Supervision, Writing – original draft, Writing – review & editing. **Agung Wicaksono:** Conceptualization, Methodology, Validation, Supervision. **Noorhan Firdaus Pambudi:** Conceptualization, Resources, Investigation, Visualization, Writing – original draft. **Wulan Asti Rahayu:** Conceptualization, Methodology, Investigation, Writing – original draft. **Ilham Fadhil Nurdayat:** Conceptualization, Software, Investigation, Writing – original draft. **Fikri Hadiansyah:** Conceptualization, Data curation, Investigation, Writing – original draft. **Shimaditya Nuraeni:** Conceptualization, Investigation, Project administration, Writing – original draft. **Adhimas Aulia Muhammad:** Conceptualization, Investigation, Data curation, Writing – original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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Appendix A. Supplementary data

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