

# **Spatial Decision Support System for resource location allocation towards equitable accessibility**

Case study: Java Island, Indonesia

DWI RINI HARTATI

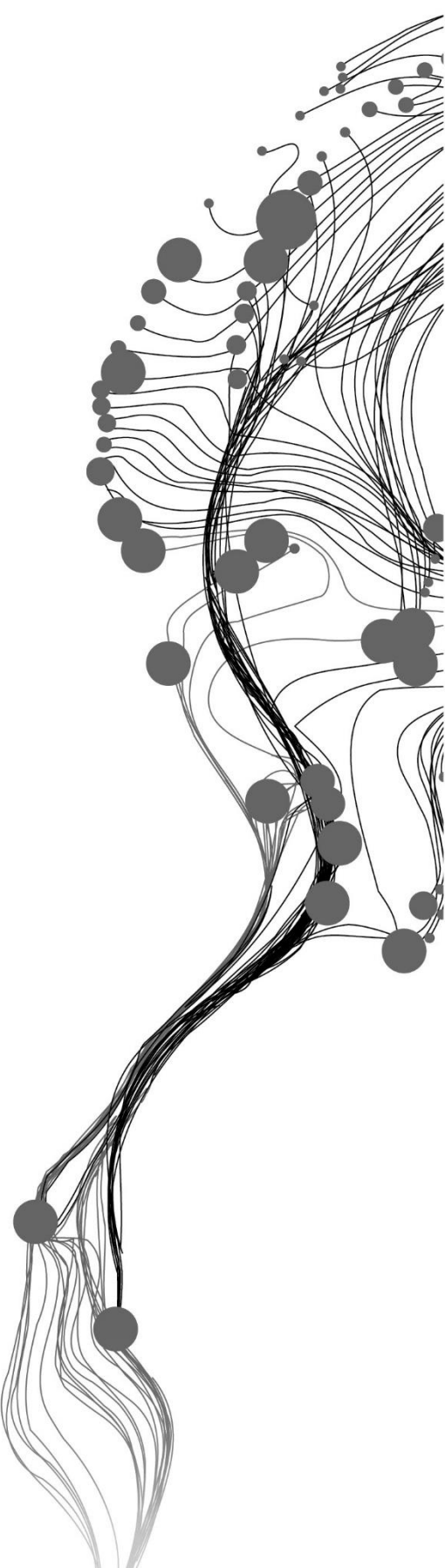
February, 2018

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Dr. J. (Johannes) Flacke





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Enschede, The Netherlands, February, 2018

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## ABSTRACT

The inequity of resource allocation in road development planning leads to inequitable accessibility, which is a trigger to disparity. Appropriate decision making (DM) should be conducted to ensure resource allocation in road development can improve the equitable accessibility. However, the DM for resource allocation of road development is problematic, as it usually involves structured and unstructured decision problems, significant money investment, long period of time and a number of stakeholders with various interests. Hence, a tool that can automate the structure part and assist collaboration of different stakeholder can be used to support the DM to bridge the communication between stakeholders.

This research aimed to develop a prototype of Spatial Decision Support System (SDSS) that can be used to assist collaborative planning in achieving more equitable accessibility. The development of the SDSS prototype adopted the software development steps accommodating 4 SDSS components which consist of model management component (MMC), database management component (DBMC), dialogue management component (DMC) and stakeholder component (SC). A literature study was used to understand the current DM process in the study area. The equitable accessibility was evaluated using contour measures for the accessibility calculation and coefficient of variation (CV), Global Moran's I and Local Indicator for Spatial Association (LISA) for the equity measures. The prototype was developed in the network analyst, the spatial analyst and the CommunityViz Planning Support System (PSS) as part of the ArcGIS platform, and was evaluated through DM simulation workshops and usability questionnaires.

The prototype user interface is presented in interactive accessibility map and LISA map of accessibility. The accessibility map shows the accessibility level as a cumulative regional Gross Domestic Product (RGDP) of the economic opportunity. Overlay of LISA map and population shows the similarity and dissimilarity cluster of accessibility that demonstrates the under-provided (low accessibility cluster with high population) and over provided area (high accessibility cluster with low population). The overview of equity indicators is displayed in LISA map and supported by CV and Global Moran's I interactive graphs. The interactive graph is also used to show the benefit (accessibility) and the cost (resource required) trade-off and the estimation of resource requirement. This prototype is capable of providing interactive functions to simulate road development and road upgrading impact to the accessibility and equity for collaborative road development planning.

The workshop evaluation results show that this prototype succeeded to involve the workshop participants to interact and exchange ideas during the simulation workshop. However, despite deemed sufficient by the participants to assist collaboration, more developments are required for implementation of the prototype to the real DM process to improve its user-friendliness. Finally, the usability questionnaire showed that the participants perceived this prototype as usable based on the usability indicators (appropriateness recognisability, learnability, operability, user error protection, user interface and accessibility). However, they still needed assistance to operate the prototype during the workshops.

**Keywords:** Accessibility, Equity, Collaborative planning, PSS, Road development, Spatial Decision Support System

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# 1. INTRODUCTION

## 1.1. Background and justification

### 1.1.1. Background

The desired impact of Infrastructure development is not only to boost economic growth but also to induce better well-being and reduce inequality (Asian Development Bank, 2017). The infrastructure performance influences business productivity and growth. Therefore, different resource allocations of infrastructure development between regions cause inequality (Snieska & Simkunaite, 2009), as it leads to different performance quality. Since the distribution of commodities and information trigger economic growth and increase welfare (Baradaran & Ramjerdi, 2001), inequitable access to them induce inequitable economic development. This was confirmed by Hochard & Barbier (2017), who argued that economic production increase as the decrease of distance to access market. Hence, better accessibility leads to better economic development.

Transportation is the main infrastructure that forms accessibility component (Geurs & van Wee, 2004). Sufficient and efficient transportation networks ensure better accessibility and, subsequently, provide economic and social opportunities that benefit to the economy (Rodrigue, Comtois, & Slack, 2013). Since the transport infrastructure quality influences accessibility, it is essential to ensure the transportation infrastructure performance. Resource allocation for transport infrastructure development should be justifiable to establish equitable economic development.

Moreover, inequitable access to economic opportunity also leads to inequitable economic development across regions, and thus, regional disparity is inevitable. According to Aritenang (2010), Indonesia is still suffering from disparity that occurs not only within the region but also between region. Thus, appropriate decision making (DM) should be conducted to ensure that transport infrastructure development will promote equitable accessibility to reduce disparity. Ensuring that the resource allocation will lead to equitable accessibility is challenging for planners and decision maker. Thus, this matter should be considered in the planning and DM process.

DM for transportation planning is the process of making choices amongst alternatives of transport intervention that best addresses the desired outcome of the decision (Yoon, Hastak, & Cho, 2017). In this process, planners and decision makers should guarantee that the transport infrastructure planning not only be able to meet the needs of the community, but also develop equitable benefit. They should provide sufficient allocation of investment for transport infrastructure in order to attain the planning targets. Resource for infrastructure development should be allocated in the most desired part of transport infrastructure to achieve expected outcome.

### 1.1.2. Justification

DM process to prioritise location for resource allocation is problematic as it is usually costly, long-term period and involving stakeholders with different interest (Coutinho-Rodrigues, Simão, & Antunes, 2011). Furthermore, the complex transportation networks and their characteristics will also complicate the resource allocation process of transport infrastructure management. Regardless of the complexity, DM process should be scientific, use well-defined criteria and facilitate the interests of stakeholders (ibid).

Collaborative DM facilitates the involvement of various stakeholders with different interests in the DM process. The complexity of problems and diverse stakeholders' interests should be brought together in a

collaborative process to achieve the most desirable decision. However, collaborative DM requires a planning support system (PSS) that is able to aid the DM process by systematising the structured part of DM process and able to facilitate harmonisation of ideas among stakeholders. PSS is able to support the planning process by bridging the overview of different actors and facilitating integrated learning process (Peter Pelzer & Geertman, 2017). This system capable to support the process with spatial information, modelling, visualisations and other function (Peter Pelzer & Goodspeed, 2015).

Spatial Decision Support System is a PSS that has been developed to support DM process. This tool is a communication tool of spatial information, an analysis tool for spatial evaluation and an interactive tool for decision support (Arciniegas & Janssen, 2012). This system can be generated as a GIS-based system that integrates spatial information for DM process to achieve better performance and provides a user-friendly computerised platform (Maniezzo, Mendes, & Paruccini, 1998). This system has functions that allow stakeholders to be involved in the process, either in its development or in its application.

## **1.2. Research problem**

Java is the centre of economic development in Indonesia, contributing as much as 50% of the national gross domestic product. More than 50% of the total population and economic activities are concentrated in this island (Wandani, Siti, Yamamoto, & Yoshida, 2016). Moreover, Java island has been facilitated with a sufficient road infrastructure compared to the other island (Simanjuntak et al., 2017). However, the regional disparity within the island itself, especially in the southern and the northern parts of this island is still an issue (ibid). Bappenas (2012) reported the disparity index between province in Java island is still high. The road infrastructure provision analysis indicates disparity of road density and road quality. Different road infrastructure conditions between these two parts of the island cause inequitable accessibility and lead to the spatial inequity of economic development. Road infrastructure in the northern part of the island can elevate its economic development and mobility, whilst limited road infrastructure condition in the southern part is hindering the economic development of isolated areas (ibid).

Indonesian government through Ministry of Public Works developed a regional strategic development approach to improve accessibility and overcome the disparity issue, as one of the national planning objective. This approach is documented and applied in the planning and resource allocation program of road development. The implementation of the program generally involves various stakeholders with different perspectives related to their own responsibility. Obviously, the conflict of interest complicates the DM process, making consensus difficult to achieve.

Currently, there is a lack of proper decision support that can help stakeholders to evaluate the impact of resource allocation of road infrastructure development in spatial point of view. The system that is currently used, Indonesian Integrated Road Management System (IRMS) database, prioritises road development based on its condition (Kairupan, Sompie, & Timboeleng, 2012). However, it does not take into account the impact of the development on the spatial equity of accessibility. Moreover, the current system does not facilitate collaborative planning for achieving consensus.

To fill the gap, this research is intended to develop a Spatial Decision Support System (SDSS) prototype that can be used to support the collaborative road development planning. It assists the communication between stakeholders by generating interactive spatial simulation of resource location allocation impact to the equitable accessibility in one integrated platform. The result will contribute to the development of SDSS framework which can assist collaborative DM process of road development towards equitable accessibility.

As this research considers regional accessibility, it focuses on the national level road which is part of the responsibility of the Ministry of Public Works and Housings (Ministry of PUPR). The national level road (national highway and toll-road) has significant functions as a major road for freight and passenger transport

between regions. According to Baum-snow, Turner, Henderson, Zhang, and Brandt (2016), highway promotes economic growth by improving connectivity to the export nodes and economic activities at the regional level. In Java island, these types of road connect the economic hubs and major cities.

This study, subsequently, is an endeavour to fill the gap in previous studies on a similar issue. A research conducted by Eissa (2013) provided a Spatial Decision Support System (SDSS) framework for resource allocation in Yogyakarta region. While Wismadi et al. (2012) analysed infrastructure interdependency between villages and its relation to economic opportunity in the same location. However, these previous researches did not consider accessibility as a driver to economic development. Their focus is on the effect of alternative intervention or decisions in the resource allocation to improve accessibility to economic opportunity and reduce disparity. Alternatively, this research considers equitable accessibility as a key factor to economic opportunity.

### **1.3. Research objectives**

The main objective of this research is to develop a prototype of SDSS for road infrastructure resource location allocation towards the improvement of equitable accessibility to the economic opportunity. For achieving this objective, several sub-objectives are generated

1. To evaluate the existing condition of accessibility to economic opportunity in the study area
2. To develop an SDSS framework in resource location allocation process for road management
3. To implement the SDSS framework for improving accessibility in the study area

### **1.4. Research questions**

To achieve the objectives of this research, following research questions are developed:

1. To evaluate the existing condition of accessibility to economic opportunity in the study area
  - a. How is the level of accessibility for each region to economic opportunity in Java Island
  - b. How is the equity condition of accessibility in Java island
2. To develop an SDSS framework in resource location allocation process for road management
  - a. What is the current DM process for resource location allocation in Indonesia
  - b. What is the current road development plan that will be implemented in the study area
  - c. Which stakeholders are involved in the DM process for resource location allocation for road development
  - d. In what stage of the DM process of resource location allocation this SDSS prototype will contribute
  - e. What is the design of the SDSS framework and prototype
3. To implement the SDSS framework for improving accessibility in the study area
  - a. Which plan or decision will satisfactory contribute to the equitable accessibility
  - b. What's the usability of the SDSS prototype to improve the DM process

### 1.5. Conceptual framework

Figure 1 below shows the conceptual framework of the research that explains the relation between accessibility concept and equity concept, which explain the equitable accessibility.

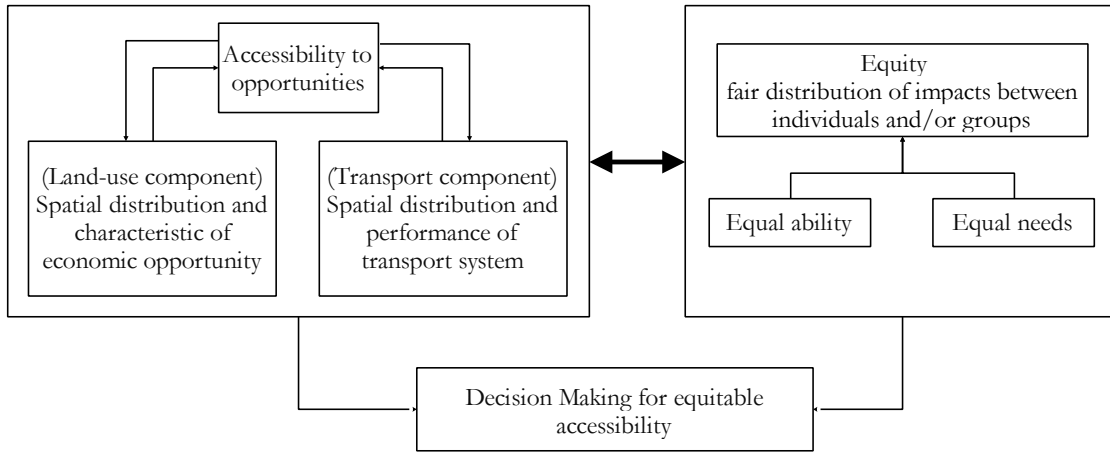


Figure 1. Conceptual framework  
Source : modified Litman, (2005) and Geurs & van Wee (2004)

This research is expected to fill the gap of the current DM process in achieving equitable accessibility as one of the national planning objectives. Hence, the concept of equitable accessibility is used in this research. Accessibility is a potential opportunity for interaction, how the interaction between people to the economic opportunity in a certain location with a particular size of activity defines accessibility to economic opportunity (Hansen, 1959). Accessibility characterizes the interaction between land use as the spatial location of the destination with the transport system that allows groups of people to reach activities as their destination. In this research, economic activity defines economic opportunity.

Equitable accessibility between regions in Java is the expected goal of the DM for resource location-allocation, hence the resource should be allocated to the most desired location to achieve equitable accessibility. The equitable accessibility in this research adopts the concept of horizontal equity concept in Litman (2005), which is a fair distribution of accessibility among regions that have equal ability and equal need. In other word, regions in the study area which are assumed to have equal resources and needs should receive equal treatment.

### 1.6. Research framework

This research is a modelling type of research that generates a prototype of a SDSS for road infrastructure resource location allocation. Quantitative and qualitative approaches are used to collect and analyse data as part of the prototype development. Methodology to achieve the objectives is explained in Figure 2 below

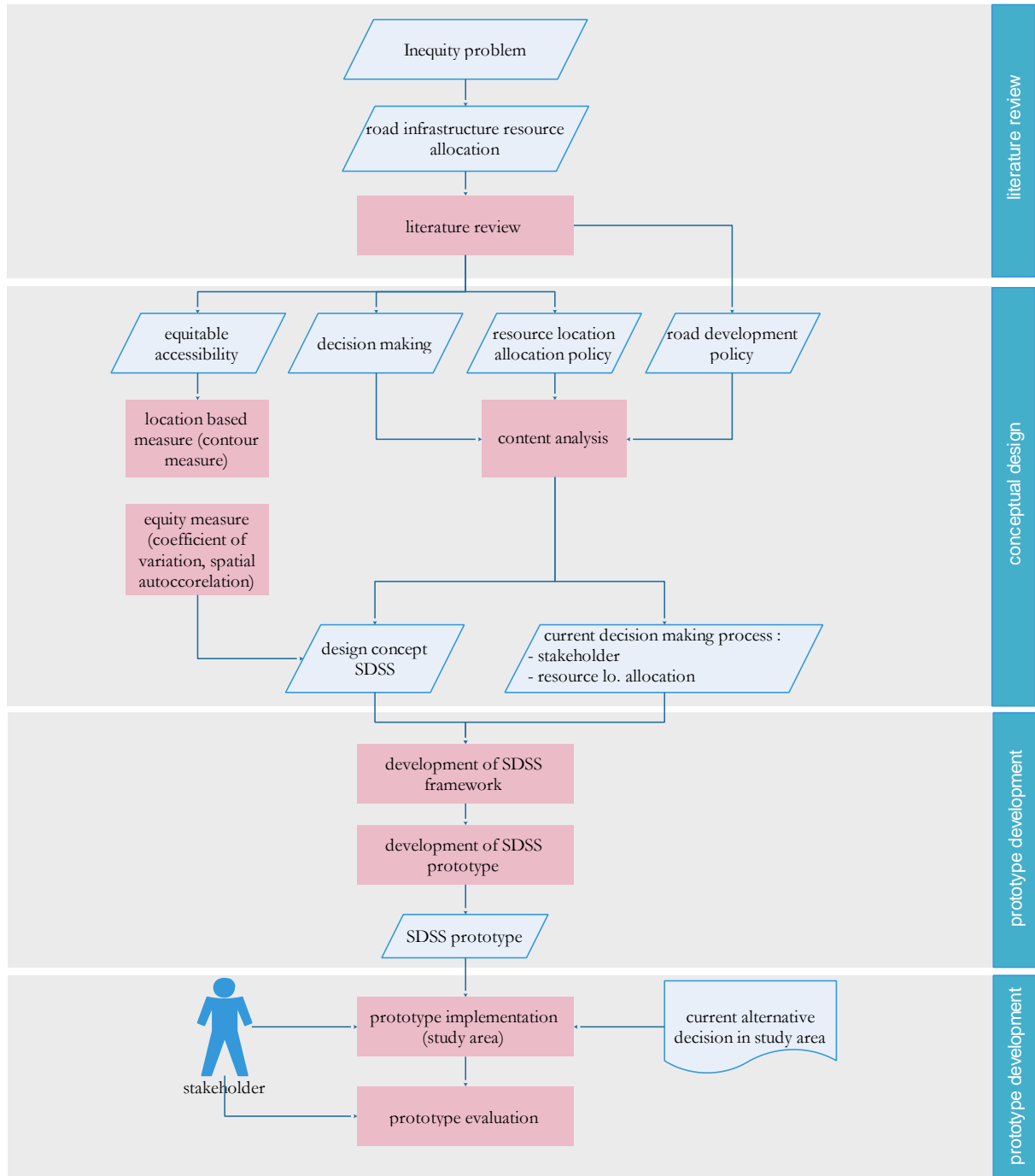


Figure 2. Research framework

This research was conducted in four general steps which are, literature review, conceptual design, the development of the prototype and evaluation.

### 1.7. Thesis structure

This thesis consists of 7 (seven) sections, which structured as follow

- *Chapter 1 : Introduction.*  
This chapter explains the background and justification of the research, research problem, research objectives, research question and research framework.
- *Chapter 2 : Literature review.*  
This section explains literature review of concept and methodology used in the research. It describes the concept of infrastructure planning and resource location allocation in Indonesia, spatial equity, accessibility, and SDSS for collaborative DM.
- *Chapter 3 : Methodology.*  
This section explains the methodology including data collection and analysis method. It covers the methodology of prototype development and evaluation.
- *Chapter 4 : Case study area*  
This chapter is the first part of the results. It explains the current situation of the study area, includes the current accessibility situation, the current DM process and mechanism and the stakeholder involved in the DM.
- *Chapter 5 : System design and prototype development*  
This chapter is the second part of the result that describes the development of SDSS prototype. It explains the general problem definition, the aims of the prototype, the SDSS frameworks and operationalization.
- *Chapter 6 : Analysis and evaluation*  
This chapter explains the evaluation of the SDSS prototype. The first part demonstrates the simulations of interventions based on the national development plan. The second section defines the usability evaluation workshop process and results. It covers the workshop observation and usability questionnaire.
- *Chapter 7 : Conclusions and Recommendations.*  
This section expresses the discussion and conclusion of the research, including limitations and recommendations for future research and further development of the prototype.



## 2. LITERATURE REVIEW

This chapter presents a review of the literature related to the study. This chapter is divided into four sections. The first section provides a brief overview of the conceptual of infrastructure planning and resource allocation in general and in Indonesia particularly. Next, the second section describes the concept of accessibility and equity. The third section is an account of the concept of spatial decision support system, and finally, the last section discusses the role of SDSS in collaborative planning.

### 2.1. Transportation infrastructure planning and resource location allocation

In this section, the general concept of infrastructure planning will be explained. Specifically, this section provides an account on current issues on infrastructure planning and resource allocation practice in Indonesia.

#### 2.1.1. Infrastructure planning and resource location allocation in Indonesia

This sub section will explain a more general mechanism of road development planning in Indonesia, starting with the national development agenda. Indonesia uses decentralisation approach for planning and budgeting system (Kusuma, 2016; Wismadi et al., 2012). The central government gives the authority of planning and budgeting to the local government (Kusuma, 2016). Based on Indonesian Government Regulation of Road number 34 (2006), transport infrastructure planning, particularly road management, is also conducted based on decentralisation mechanism. Thus, there is a role sharing mechanism, in which the central government responsible for managing national level road, whilst local government responsible to local level road.

The implementation of planning and budgeting for central government is mainly conducted based on a top-down approach. It started with the national policy that is translated to National Long-Term Development Plan (RPJPN), National Medium-Term Development Plan (RPJMN) and it will be translated into strategic planning document at the ministry level. This strategic planning document is developed based on the strategic issue in the national planning document in ministry level and will be detailed into department level afterwards.

To implement the infrastructure development, the Ministry of PUPR developed a policy of infrastructure planning based on a regional development approach. This policy prioritises the infrastructure development into 35 strategic development regions called prioritised regions or *Wilayah Pengembangan Strategis* (WPS). The planning and budgeting focus on central economic growth regions that can drive the economic growth of their surrounding regions (Simanjuntak et al., 2017). This policy will be adopted in the development of department level strategic planning to implement the resource allocation.

Infrastructure planning process in Indonesia is conducted based on RPJMN 2015-2019. The road development policy in this document focuses on improving competitiveness through connectivity and accessibility to reduce disparity. Divided into 9 WPS, the infrastructure development goal of Java to Bali island is to improve connectivity and reduce disparity of regional development between northern and southern parts of Java (Simanjuntak et al., 2017). The strategic planning of road development consists of: 1) development of Trans Java road toll, and 2) development and improvement of southern Java roads, usually called *Jalan Lintas Pantai Selatan Jawa or Pansela*. This development aims to improve connectivity, reduce disparity and improve domestic integration of human and freight movement (ibid). This planning will be translated into the priority program of road development, which will be the responsibility of Highway department, the Ministry of PUPR.

Besides handling the implementation of the priority program, the ministry is also responsible for the national road maintenance routine. To prioritise the location of maintenance, a minimum service standard is used to

decide the locations. IIRMS database has been used by the Indonesian government to prioritise programming and budgeting for road maintenance (Kairupan et al., 2012). This mechanism emphasises on the quality of the road itself without considering the impact to the accessibility level. Regardless of this issue, the mechanism is well-established. Yet, there is no mechanism to measure whether the road development and maintenance promote equitable accessibility amongst regions.

## **2.2. Spatial equity and accessibility**

### **2.2.1. Accessibility**

Beside the popularity of mobility as an indicator in transport planning, the number of research on the utilization of accessibility to evaluate the performance of transport infrastructure is increasing recently (Bocarejo S. & Oviedo H., 2012; Boisjoly & El-Geneidy, 2017; Curl, Nelson, & Anable, 2011; Lucas, van Wee, & Maat, 2016; Silva, Bertolini, te Brömmelstroet, Milakis, & Papa, 2017). While mobility provides information about the ability to move from one place to another, accessibility measures the interaction between transportation system and land use, and informs the social aspect of transport planning (Boisjoly & El-Geneidy, 2017). However, there are still various interpretations about the accessibility concept, its indicator and the most proper method to apply it for planning practice (Curl et al., 2011).

Boisjoly and El-Geneidy (2017) analysed transport plans from several counties to assess the integration of accessibility concept as a performance indicator of transport system to assist DM process. They found that, although the target of accessibility is incorporated in transport plan, there are few plans that applied accessibility indicator to support the DM processes. Furthermore, they also discovered that there is an inconsistency between goal of accessibility in the planning document and the indicator used. Conversely, Curl et al., (2011) asserted that the application of accessibility measure in planning process still has some shortcomings. It is not easy to translate the accessibility measure into the expected benefits by the decision maker, which are to improve accessibility and reduce transport disadvantage.

However, apart from the shortcomings of accessibility concept integration to the DM process, accessibility has the capability as an instrument to evaluate the quality of transport infrastructure. Some researchers integrate accessibility measure to develop a decision support tool to assist DM in a transport planning process. Burdziej (2012) built a concept of SDSS using network analysis and spatial analysis in an interactive Web-based platform. This system evaluates the spatial variation of accessibility to services within a city and is intended to be used by the decision makers and citizens to support their spatial decision of transportation planning. In addition, Karou & Hull (2014) developed a GIS-based accessibility model to identify the gaps of public transport provision and the efficiency in spatial distribution of urban services. This research is intended to develop SDSS, by the application of accessibility and equity analysis to identify the most desired location for road development to reduce disparity.

Accessibility is described as a potential opportunity for interaction (Hansen, 1959). While Cascetta, Carteni, and Montanino (2013) defined accessibility as “the ease in meeting one’s needs in locations distributed over space for a subject located in an area”. Furthermore, Geurs & van Wee (2004) defined it as how land-use and transport system enables people to reach and participate in activities within their destination locations using a combination of transport mode. Related to the common definitions, this research uses the accessibility concept to evaluate the ease of interaction between people in every district to the economic activity locations over the national highway and toll road. The level of accessibility will describe the ability of the road networks to link the districts to the economic activity locations, and, consequently, improve the economic opportunity. Travel time is used to measure the accessibility, as the value is flexible based on the quality of the transportation system (Rodrigue et al., 2013).

Geurs and van Wee (2004) define four components of accessibility as the following: 1) land-use component that reflects the characteristic of opportunity in the destination location and the characteristic of demand in the origin location; 2) transportation component is a transport system that explains the disutility of individual or groups in their travel from origin location to reach the destination that can be expressed by travel time, distance or cost. 3) Time component explains time characteristic of the demand and the opportunities, i.e. the availability of the opportunity at a different time; 4) individual component explains the needs of the traveller based on their characteristic such as age, gender education level, etc. As this research evaluates the accessibility between regions in macro level, the time component and travel characteristic of individual traveller are not taken into account. The availability of opportunity and the time availability of travellers are considered as unchanged. Moreover, the level of individual to access the transport mode are also treated as constant.

There are several approaches to evaluate accessibility. Geurs and van Wee (2004) defined four basic perspectives in measuring accessibility, whilst Baradaran and Ramjerdi (2001) explain five types of accessibility measure, as described below:

- *Infrastructure Based Measure* (Geurs & van Wee, 2004) or travel-cost approach (Baradaran & Ramjerdi, 2001) measures the travel impedance between origin and destination, such as travel time, congestion, and operating speed of the transport network. This measure does not consider the quality of the location, value of time and behaviour aspect of the travellers (Baradaran & Ramjerdi, 2001).
- *Location based measure* calculates accessibility to spatial distributed of economic activities (Geurs & van Wee, 2004), for example the number of opportunity within certain minutes travel time. The capacity of the opportunity can also be considered in location-based measure. Thus, it yields a more complex accessibility measure.

The first mentioned location-based accessibility measure is *contour based measure, cumulative opportunities or daily accessibility*. It calculates the number of opportunities that can be reached from an observation point within a certain cost (travel time or distance). This measure is easy to be operationalized, interpreted and communicated, especially by researcher and policy makers. It also requires less data. However, it still has several shortcomings, as follows: 1) even though it includes the land use and transport components, it cannot explain the combination of both components, 2) it does not take into account the competition effect, 3) it ignores the traveller's preferences of opportunities and transport mode. Hence, this measure cannot provide advantageous overview of accessibility for the social and economic evaluations of land-use and transport changes (Geurs & van Wee, 2004)

*Potential Accessibility Measure*, also called gravity model, calculates accessibility from origin to the opportunities in the destinations, taking into account the degree of the attractiveness and smaller or greater distance which provide diminishing influence (Geurs & van Wee, 2004; Hansen, 1959). This approach is widely used in planning and geographical studies, and it answers the shortcoming of the contour measure mentioned in previous paragraph (ibid). It does not only evaluate the combined effect of land-use and transport, but also considers travel behaviour using distance decay function. This measure can be used as an input for the infrastructure based measure and spatial economic evaluation of transportation project (Geurs & van Wee, 2004).

- *Person Based Measure* captures accessibility based on the viewpoint of individuals and integrates spatial and temporal aspect (Geurs & van Wee, 2004), it is also called time-space measure (Bhat et al., 2000; Scheurer & Curtis, 2007). This measure evaluates individual behaviour of travel as they only have limited time to do a certain activity (Bhat et al., 2000). While this measure meets the almost all theoretical criteria, it is difficult to aggregate to evaluate in groups or higher geographical scale (ibid).

- *Utility Measure.* Utility measure is calculated based on how individuals perceive utility for different travel choice (Bhat et al., 2000). It is interpreted as the outcome of transport choice. This measure satisfies the theoretical criteria except for temporal aspect. However, it is data demanding and difficult to be interpreted.

This research uses location based measure as it is the most used method in urban planning studies (Geurs & van Wee, 2004). In order to provide better accessibility measure for spatial-economic evaluation of road development planning, potential measure is the most appropriate measure to use. However, because the accessibility evaluation is intended to be interpreted by decision makers with diverse backgrounds, it needs a measure which is easy to be interpreted and communicated. Hence, the goal of the SDSS prototype to communicate accessibility evaluation to assist the DM process can be achieved. Therefore, contour-based measure is used in this research. Moreover, as this research are intended to assess the accessibility among regions, the determination of distance decay is rather difficult due to the data limitation.

### **2.2.2. Equity**

Equity in transportation aspect is an important concept to be adopted in a planning and DM process. Service provision should be distributed fairly amongst regions to reduce uneven regional development and improve the equitable welfare, as the goal of the government development program. However, the application of this concept in planning process is not an easy task, because of the many types of equity measures, various ways to measure the impact and to categorize the people for the equity analysis and many impacts to be consider (Litman, 2005).

Disparity and inequity of road infrastructure provision are still an issue in Java, as explained in chapter 1.1. To overcome this issue, the 6th agenda of the national policy and target stated one of the sub-agendas, which is “to develop national connectivity to achieve equitable development”. The strategic planning of Directorate General of Highways emphasised that the road development is intended to improve connectivity for strengthening competitiveness. However, due to the difficulty of applying the equity concept, there is no mechanism to measure equity in the planning and budgeting process.

Equity is related with a distributive justice or fairness (Litman, 2005; Lucy, 1981). It can be described as fair distribution of effects, fair sharing of cost or resources (Camporeale, Caggiani, Fonzone, & Ottomanelli, 2017). While Obrist et al. (2007) described equity as equal access to services for people who have equal needs to opportunity. Equity in transportation practice is classified into two concepts: horizontal and vertical equities. Horizontal equity, which is usually called as egalitarianism emphasises in the even distribution of benefit and cost to groups which has equal capacity and needs (Caggiani, Camporeale, Binetti, & Ottomanelli, 2017; Camporeale et al., 2017; Jang, An, Yi, & Lee, 2017; Litman, 2005). It explains that equal groups should be threaten equally in term of transportation infrastructure provision (ibid). It puts emphasis on the spatial distribution of transportation services and opportunities (Murray & Davis, 2001). The second concept is vertical equity, which can also be called social justice, environmental justice, and social inclusion. This concept is explained as the distribution of benefits among groups with different abilities and needs. It emphasises on the transportation infrastructure provision to economically and socially disadvantages group (Caggiani et al., 2017; Camporeale et al., 2017; Jang et al., 2017; Litman, 2005).

As one the objectives of the transportation infrastructure development in Indonesia is to improve the connectivity for strengthening competitiveness among regions, the equity context is mainly related to equitable accessibility. In addition, because this research does not take into account the social condition of individual traveller, but instead focuses on the physical condition of the road network, the concept of horizontal equity is used to evaluate the distribution of accessibility unevenness among regions in the study area.

The equity impact of transport infrastructure provision can be measured based on the change of accessibility distribution among region (Kim & Sultana, 2015; Monzón, Ortega, & López, 2013). There are several mathematical approaches in assessing spatial equity of accessibility. Some approaches already implemented by researchers are; spatial autocorrelation including global and local indicators of spatial association (LISA) (Rahman & Neema, 2015; Talen & Anselin, 1998; Tsou, Hung, & Chang, 2005; X. Wang, Huang, & Zou, 2016; Wismadi, Brussel, Zuidgeest, & van Maarseveen, 2015; Xiao, Wang, Li, & Tang, 2017), integrated equity indices (IEI) (Tsou et al., 2005), spatial autoregression (C. H. Wang & Chen, 2015), coefficient of variation and (Kim & Sultana, 2015; Monzón et al., 2013). Gini coefficient and Lorenz curve of accessibility (Jang et al., 2017; Lucas et al., 2016).

The above-mentioned methods are statistical approaches that evaluate the spatial distribution of accessibility, commonly used to determine equity. However, there is no ideal method to measure equity (Bröcker et al., 2006; Monzón et al., 2013). To explain the equity effect, this research performs the concept of coefficient of variation (CV) and spatial autocorrelation, which is measured by Global Moran's I and LISA.

CV calculates the degree of variability in relation to the mean value (Irawan, 2014). It is a statistical measure to evaluate the spatial distribution of accessibility that is applicable for general purpose (López, Gutiérrez, & Gómez, 2008). This measure describes the equity indication based on the level of variability of the accessibility around its mean. The less variation denotes a more balanced distribution of accessibility, and vice versa (López et al., 2008; Monzón et al., 2013). Less CV explains more variability in the data distribution, and vice versa.

Spatial autocorrelation provides an overview of the spatial distribution pattern of accessibility in the study area, whether it is clustered, disperse or random. According to (Rahman & Neema, 2015), spatial autocorrelation can be used to explain the characteristic of spatial equity. Areas which are clustered in high accessibility level imply that those areas are located in an advantageous location and are provided with more sufficient transport infrastructure than other location. In contrast, those which are clustered in low accessibility indicate under-provided areas. Hence it assists the decision makers in setting the priorities for the road development services to the most disadvantaged areas.

Global Moran's I calculates the spatial distribution pattern of accessibility throughout the study area. It explains a cluster, disperse or random pattern. A positive Moran's I suggests spatial cluster behaviour of accessibility value while Moran's I = 1 is the perfect cluster behaviour. Alternatively, negative Moran's I index suggests disperse behaviour (Wismadi et al., 2015)

In addition, Anselin local Moran's I or LISA is used to obtain an overview of the accessibility distribution in local level. It is a local spatial statistic that measures the local spatial autocorrelation (Rahman & Neema, 2015), which indicates the similarity of accessibility value of an observation unit to its neighbour (Anselin, 1995). LISA measure is presented in LISA map that shows the high-high accessibility cluster, low-low accessibility cluster and outliers which is expected to give an overview of under-provided and over-provided area.

## **2.3. The concept of Spatial Decision Support Systems (SDSS)**

### **2.3.1. Decision making**

DM is the process to find the best actions or alternatives to change the current condition to the desired situation (Sugumaran & Degroote, 2010). However, it is not only about the best decision as the final goal, but also about the whole process of decision. Hence this term is similar with "managing" (Simon, 1960). According to Simon (1960), DM is structured in three principle phases, namely intelligence, design, and

choice. Intelligence means the analysis of a certain issue or problem formulation that calling for decisions. The design phase includes inventing, developing, and analysing data and information for the action. Finally, the choice phase is the selection of the alternatives.

Simon (1960) distinguished decisions into two categories, programmed (structured) and non-programmed (unstructured) decision. Decisions will be considered as programmed if they are repetitive and routine, in addition to having a procedure to handle it. Whilst it is non-programmed when it novel and unstructured, it refers to problems that never emerged before, and thus it needs special treatment. Gory and Scott Morton introduce semi-structured decision wherein some or one of the decision phases are structured (Turban, Aronson, & Liang, 2005).

DM can be supported by tools that work through model the decision phase called decision support system (DSS). However, DSS can only model the structure part of the DM (Turban et al., 2005). This system is usually supported by computer-based information system technology (ibid). The DM process of road development can be categorized as semi structure. Essentially, the government has developed a system that is applied annually for road development planning. However, the emergence of some major issues and unprecedented cases are inevitable. These cases are usually unstructured and require specific treatment.

To assist the complex DM process, the utilization of technology is commonly used, particularly to automate the DM process using computer and information technology to make it more efficient. However, computer and information technology can only be used to automate the structured part of the DM process. Furthermore, communication constrain among the stakeholders and the conflict of interest hindering the achievement of consensus. A technology-based tool can also be used to assist the collaboration among stakeholders to exchange ideas and achieve agreement in DM process.

### **2.3.2. Spatial Decision Support System**

SDSS is a computerised tool to support DM which involves geographic component in the decision process (Keenan, 2003). The support system is defined as the analytical process of handling unstructured and complex problem. Hence Sugumaran and Degroote, (2010, p. 14) mention that “*SDSS is an integrated computer systems that support decision makers in addressing semi-structured or unstructured spatial problems in an interactive and iterative way with functionality for handling spatial and non-spatial databases, analytical modelling capabilities, decision support utilities such as scenario analysis, and effective data and information presentation utilities*”.

As DM is a complex process, it is impossible for human brain to memorise and analyse without assistance. Furthermore, spatial DM typically deals with big data, hence computerize system is needed (Sugumaran & Degroote, 2010). According to Kemp (2008), SDSS combines analytical tools and function that are available in GIS and DSS model to evaluate various alternatives decision. It functions to support the solving of structured problems. SDSS has the ability to combine data, analyse them, and evaluate the most desired alternatives. It is also supported by a user-friendly interface to assist the interaction between users and the system.

SDSS can be implemented to support location allocation DM, as it has a spatial aspect of solving “location” problem. It is used to assess the most appropriate location of services and to generate alternatives to achieve the most desired equitable spatial distribution (Buzai, 2013). The use of this system aims to improve spatial efficiency and spatial equity of the distribution.

SDSS basically has four major components, namely database management (DBMC), model management (MMC), dialogue management (DMC) and stakeholder (SC) (Sugumaran & Degroote, 2010). DBMC contains the relational database, while MMC provides analytical capabilities that explain location, attribute and relation. DMC provides user interface of the system and SC explains the role of stakeholder and the decision makers. GIS usually covers the role of DBMC and DMC.

### **2.3.3. Group Spatial Decision Support System**

Recently, the needs of spatial support system entail not only facilitating participatory GIS, but also assisting group DM process. Hence, the development of SDSS to support group decision making is necessary. As mentioned by (Borouhaki & Malczewski, 2010), group SDSS provide tools to compromise among stakeholders, to identify conflict and to support stakeholders to exchange information and idea interactively.

SDSS, as a spatial based tool, incorporates the usage of maps for the communication approach. The functions of SDSS to support collaborative planning process can be compared with the usage of maps. According to (Arciniegas & Janssen, 2012), map can be used to support the collaborative planning process in three stages, namely: 1) to communicate the spatial information to the users, 2) as a spatial evaluation tool and 3) as an interactive decision support.





### 3. METHODOLOGY

This chapter describes the methodology of the research process. The first section describes the data collection method and process. It explains the primary and secondary data collections. Subsequently, the second section explains the methodology of the prototype development. This development process adopts a software development framework that have been adapted with the study case. Finally, the third section explains the accessibility and equity principle. To achieve the goals of the prototype development which is to assist collaborative planning in road development DM towards equitable accessibility, these two measures were implemented.

#### 3.1. Data collection method

This section describes the primary and secondary data collection method. Primary data were collected through interview, workshop observation and questionnaire, while the secondary data were gained from various agencies in Indonesia.

##### 3.1.1. Primary data collection

###### 3.1.1.1. Key informant unstructured interview

The interview was conducted to obtain the overview of the DM process in the study area. I used unstructured interview to get a broader overview of each respondents about the DM process in the study area. The questions were based on 5 main themes, which are: 1) how is the current DM mechanism of road development, 2) what aspect is considered in the DM process for resource allocation, 3) is collaborative planning mechanism used, 4) which stakeholders are involved in the DM process, and 5) what is the current planning of road development

The respondents were selected through snowball approach. It started with the person who was in charge of providing data and information for the DM process, and led to other respondents who were in charge in road development planning. Four respondents were finally interviewed during the data collection, two respondents from sub directorate of network planning and system integration, one respondent from sub directorate of data analysis and system development, and one respondent from toll road management agency. The selection was finished when there was no further information required and most of the respondents explained similar information.

###### 3.1.1.2. Workshop observation

The workshop was conducted to assess the usability of the prototype. To evaluate the workshop process, direct observation method was used to understand the behaviour, process and unfolding events during the workshop (Taylor-powell & Steele, 1996).

The workshop was set to imitate the collaborative planning process. The main task was to build the most desired location of road development plan as an intervention. Each stakeholder proposed a set of intervention based on their own perspective and based on the information provided by the prototype. The prototype was used to investigate the impact of the intervention to the accessibility. The workshop was observed to evaluate the behaviour of stakeholders in a collaborative planning environment, and how they perceive the prototype as the supported tool. Some aspects were observed, such as how they used the provided tools to decide the interventions, whether the tools helped or hindered the process, how they interact with each other, how they use the prototype, whether difficulties occurred during the prototype operationalization, and how they utilized the provided information in the prototype. Some inputs during the discussion session were recorded to be considered in the improvement of the prototype. This process

can also be considered as an iterative process of the prototype development. It was used to obtain feedback from user for further development.

#### *Workshops setting*

The workshops were conducted in three phases, phase one took place in Yogyakarta on 13 November 2017, and phase two in Jakarta on 17 November 2017, Indonesia. Finally, phase three was held in UPM department, ITC Enschede on 19 December 2017. The workshops were used to evaluate the usability of the prototype. Since the SDSS prototype development is an iterative process, the recommendation result of each workshop was then used as input to the improvement of the prototype.

The first workshop was attended by stakeholders from local government representation and the university. It was attended by 18 people from *Gadjah Mada* University, province and district level development planning agency (BAPPEDA), province level public works and housings department (*dinas PUPR*) and province level environmental department (*Dinas Lingkungan Hidup*). The second workshop was conducted with the national government that was responsible for national level road development implementation. The attendance included 4 people from planning board department of highway and regional development researcher, the ministry of public works and housing. While participants in the third workshop were 20 MSc students of urban planning and management department.

Participants in the first workshop were expected to represent the opinion of local government and academics. The participants had sufficient knowledge about DM process and its dynamics in the local government. The common conflicts between governments institution in local level developed their local understanding of the DM problems. This knowledge was expected to enrich their viewpoint of the SDSS roles to support the DM process, hence leading to comprehensive input for the prototype improvement.

The second workshops were attended by the decision makers of national road development in Indonesia, who worked in the planning board of the highway department of the ministry of public works and housing. Their inputs were expected could represent the real needs of SDSS of road development planning process, additionally they have knowledge about the positioning of this prototype in the current DM process. Hence, more applicable inputs were expected. The third workshop was an additional workshop to test how students who had no understanding about the study area and the DM process in Indonesia perceive the usability of this prototype. Their overview about this concept could enhance the analysis of the applicability of this prototype to support participants from various background.

#### **3.1.1.3. Questionnaire**

Perceived usability data collection was conducted using usability questionnaire. This questionnaire aimed to get the perception of users whether the prototype could be implemented. The usability indicator was developed based on product quality model of ISO 25010:2011 that is used to evaluate the degree to which the prototype satisfies the requirement of stakeholders and if it can provide additional value in the DM practice. According to ISO/IEC 25010 (2011), a product quality can be evaluated based on eight aspects, namely functional suitability, performance efficiency, compatibility, usability, reliability, security, maintainability and portability. Since the evaluation of the prototype focused on perceive usability, the indicator was developed based on the usability characteristics.

The usability characteristics were used to evaluate the degree to which the prototype can be used to achieve the DM goals with effectivity, efficiency and satisfaction to achieve agreement of various stakeholder in the DM process. Usability characteristics were detailed into 6 (six) sub characteristics used to develop the questions, as follows:

1. Appropriateness recognisability, explains whether the prototype is appropriate to fulfil user needs
2. Learnability, the degree to which a prototype enable user to learn how to use it in any situation

3. Operability, how easy the prototype is operated and used
4. User error protection, the degree to which the system provides sufficient alert in user error
5. User interface, how the user interface satisfies user in using the system
6. Accessibility, how the system can be used by people from various backgrounds and abilities

In addition to the prototype usability, the questionnaire also measured how users perceive the advantage of the collaborative planning workshop, and whether this prototype supports stakeholder learning process of collaborative DM. To measure the degree of usability based on user's opinion towards the prototype, the questionnaire was developed using Likert scale. Respondents answer the questions in 5 scales from strongly disagree to strongly agree to measure their agreement of each question.

This questionnaire was asked to the workshop participants (which were threatened as users), with the total number of respondents as many as 41, consisting of eighteen respondents from Yogyakarta workshop, 4 respondents from Jakarta workshop and 19 respondents from Enschede workshop.

### 3.1.2. Secondary data collection

Secondary data were collected from Ministry of PUPR, Indonesian statistical board and Indonesian geospatial information board. Table 1 below provides a list of collected and used data to develop the system

Table 1. Secondary data requirement

Data	Data source
National level road networks	Indonesian Ministry of PUPR ( <i>Kementerian PUPR</i> )
Province-district level road networks	
District map	
Local level road network	Indonesian Geospatial Board ( <i>Badan informasi geospasial BIG</i> )
National economic hub location (urban cities)	Indonesian Government Regulation of National Spatial Planning
Regional Gross Domestic Product (district level)	Indonesian Statistical Board ( <i>Badan Pusat Statistik BPS</i> )

#### *Road network*

The road network consists of 4 road classes road based on Indonesian road act no 38, 2004 . National (toll and non-toll road) and province road network data are provided by the Indonesian Ministry of Public Works and Housings and PUSTRAL UGM, while local road data was provided by the Indonesian Geospatial Information Board. Travel time was used as the main indicator for the accessibility analysis, hence average vehicle speed was required. Additionally, national road network is completed with field survey speed that provided by PUSTRAL UGM. Incidentally, although toll-road speed was provided by the Ministry of PUPR, it did not explain the speed for each segment. Thus, google typical speed was used to determine toll speed for each toll road segment. Finally, design speed based on Indonesian highway capacity manual was used to determine speed for province and local road.

#### *Economic opportunity*

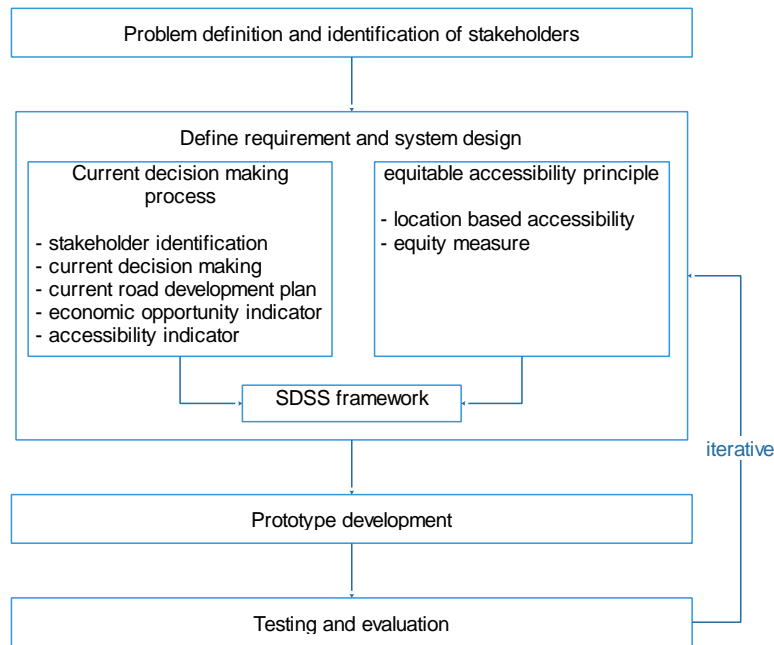
The economic opportunity was measured by the locations of urban cities and districts (rural and urban) with population more than one million people. The location and regional Gross Domestic Product (RGDP) that was used as the indicator for its attractiveness, was downloaded from Indonesian Statistical Board (BPS) website.

#### *Administrative data*

To define point of observation for the accessibility measure, administrative data that explain administrative boundary of Java island was used. To achieve more detailed observation, 5x5 km<sup>2</sup> hexagon tessellation was developed as the unit of observation in the accessibility and equity measures. I obtained the administrative data from the Indonesian geospatial board.

### 3.2. Analysis method

This section discusses the general methodology used to develop SDSS for equitable accessibility. The design of the prototype follows software development steps introduced by Sugumaran and Degroote (2010). The steps started with 1) definition of problems and stakeholders, 2) definition of the requirement, 3) design of the system, 4) development of the prototype and 5) test and implementation.



Source : adopted from Sugumaran & Degroote (2010)

Figure 3. SDSS development process

#### 3.2.1. Problem definition and identification of stakeholder

The preliminary step of the prototype development was problem definition and identification of stakeholder. This step aimed to identify the current problem that would benefit from the development of the SDSS and the stakeholder involvement in the DM process. Literature study was used to define problem and stakeholder involvement mechanism. In addition, stakeholder interview provided more overview of the current condition and stakeholder involvement.

The stakeholder analysis was conducted using Atlas-ti software. This software was used to identify the relation between stakeholders and their responsibility related to the road development planning process. Codes were assigned to the interview result to identify the involved stakeholders and their responsibility based on respondent's information. Relationship between stakeholders was identified and illustrated using "links" tool in the software. Afterwards, the network tools in the software were used to plot the map of the relation between stakeholder. The stakeholders map is presented in section 4.5.

#### 3.2.2. Defining requirement and system design

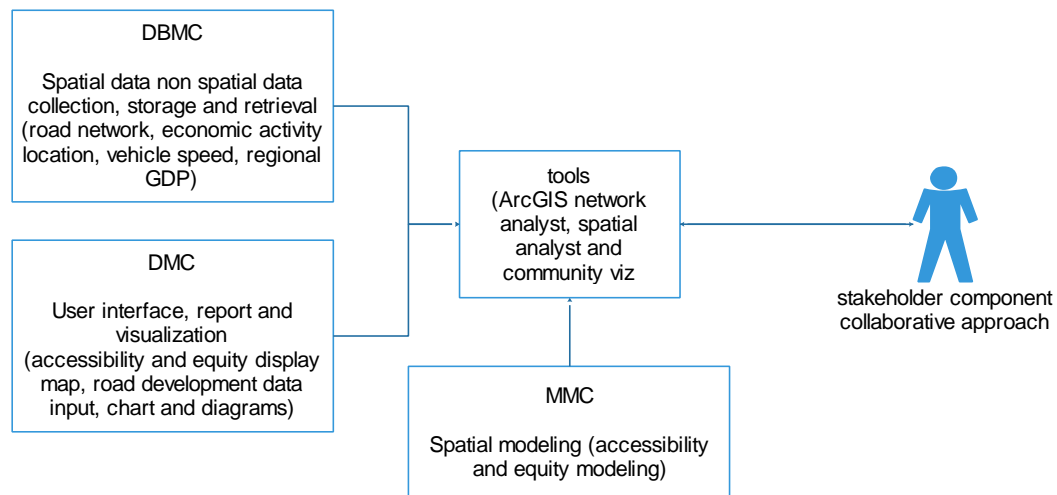
To obtain a comprehensive overview of the requirement, understanding of the current DM process is required. Literature study was used to gain the picture of the current DM process and resource allocation practice in the study area. To enrich and confirm the literature review findings, key informant interview was conducted.

This system proposed the concept of accessibility as the indicator. The development of this prototype adopted the concept of equitable accessibility as the goal of the DM process. Although the purpose of the decision making is related with various aspect, especially the economic development, the main goal of this

research was the equitable accessibility to the economic opportunity. Hence the principle of accessibility and equity were used in the system design.

### 3.2.3. Prototype development

This prototype was developed using DSS tools and generator available in ArcGIS package. It utilized the functions of network analysis for the accessibility evaluation, spatial statistic for the equity measure and CommunityViz for the user interface that also functions as the user-system interaction platform. The prototype consists of 4 core components of SDSS mentioned in section 2.3.2 namely model management component (MMC), database management component (DBMC), dialog management component (DMC) and stakeholder component (SC). The stakeholder component is the involvement of users in the utilization of the prototype, hence it will not be explained in this section.



Source : adopted from Sugumaran & Degroote, 2010

Figure 4. SDSS component

#### 3.2.3.1. Database management component development

The DBMC stored road networks map and its attributes such as speed for each segment used in network analysts for accessibility calculation. It also stored economic activity locations data and the attributes (RGDP as the indicator for the opportunity). These data were used in the accessibility analysis conducted in model management component.

##### *Network dataset preparation*

The accessibility analysis was conducted using networks analysis tools. These tools required the road feature data to be converted to network dataset which stored simple feature (points and lines) and turns. It also stored the connectivity information of the road network data (ArcGIS, 2016d). The road feature data was classified into existing road data and planned road data. The existing road data represented the road network data that have already built in the real world whereas the planned road data was road segments which are planned by the government and/or proposed by a scientific study. While the segments have yet to be built and operated yet in the real world, these planned road data will be used as the simulation of the intervention in the prototype.

The source layer for network building consists of two feature types, points and lines. The existing road data covers: 1) national toll-road line feature, 2) national non-toll line feature, 3) province line feature 4) local line feature, and 5) point link of toll-road to regular road. Conversely, the planned road data covers: 1) new toll road plan, 2) new national road plan and 3) road upgrading plan.

The impedance of the road segments is travel time, which calculated based on speed data and length of the segment. The speed data was obtained from the Ministry of PUPR, Pustral UGM and google map typical speed data. More explanation about the speed is discussed in section 3.1.2. During the building network process, the planned segment was assumed to have 0 (zero) speed, hence it will not be incorporated in the current condition of accessibility calculation. Assignment of speed for these planned segments will be done during the intervention simulation.

#### *Tessellation as unit of observation*

Ideally, the analysis should be conducted in official administrative units. However, there is a significant difference of area sizes between one region and the other which might affect the accessibility calculation. To overcome this shortage, 5x5 km tessellation was used. Java island was divided into 5x5 km hexagons as the smallest unit of observation. These hexagons will be the origin for accessibility measurement.

#### *Point feature extraction for the economic opportunity location*

According to Gutierrez & Urbano (1996), urban agglomeration is considered as the main centre of economic activities and an attractors for transport flows. This research used the urban cities and districts (both rural and urban) which have population more than one million people as the indicator of economic opportunity, it was used as a proxy of the economic activity. The better access to these regions leads other regions to access better markets, employment, services and other economic activities that induce to better economic development.

This data was stored as points feature, which was derived from the centroid of the cities and districts. To obtain the RGDP that will be used as the value of the destination, table of RGDP from BPS was joined to the point features.

### **3.2.3.2. Model management component development**

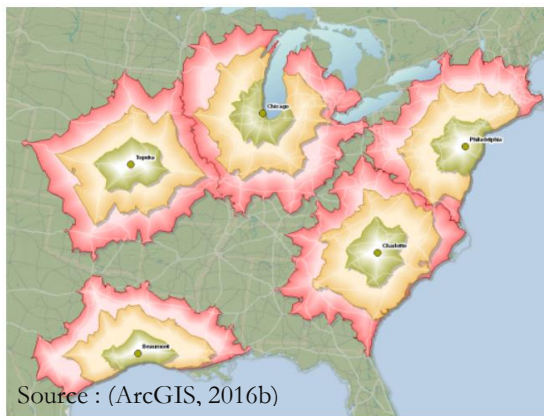


Figure 5. Service area illustration

#### *Model for accessibility measurement*

Accessibility and equity calculation are parts of this component. The MMC was developed using model builder in ArcGIS software. Network analysis-service area tool was used to calculate the accessibility. It built polygons that covers all accessible road networks which were determined by certain travel time from the origin points. Figure 5 shows the illustration of polygons formed by the service area tool. All economic opportunity points coincide with the polygon of each origin, will be accumulated as the accessibility value. The concept of accessibility measure is described in section 3.3.1.

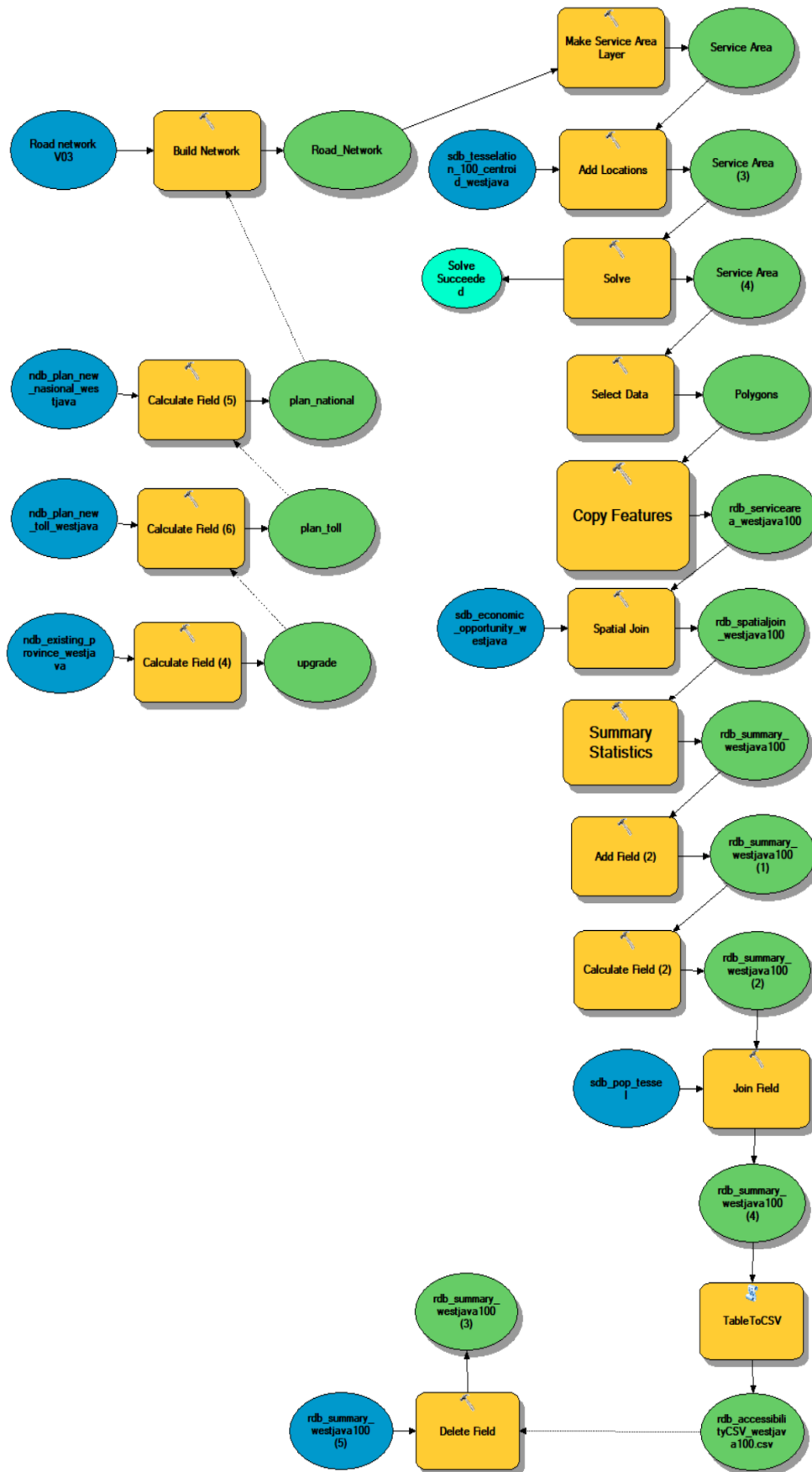


Figure 6 shows the model builder for contour measure accessibility calculation. The network dataset, point feature of the economic opportunity and the hexagons that have been explain in section 3.1.1.1 were used as the input data. The result of this model was the accessibility value as a cumulative RGDP which coincided with the service area polygon of each hexagon. It was stored in a table format to be integrated to the CommunityViz for the display purpose.





### Model for equity measurement

The equity measure was represented by LISA map, Global Moran's I and CV, while the concepts of the measures is described in section 3.3.2. The LISA map was developed based on the accessibility value using spatial analysis tool in ArcGIS, whereas the global Moran's I index was calculated as the aggregated value of the local Moran's I index in LISA map. This process was conducted using formula editor in CommunityViz. In order to make the model applicable for the prototype, the calculation was modelled using model builder. Figure 7 shows the model builder for LISA map generation. The accessibility model and equity model then were linked to the scenario 360 CommunityViz extension for the layout and the development of DMC. The calculation of CV was conducted using the formula editor tool in CommunityViz.

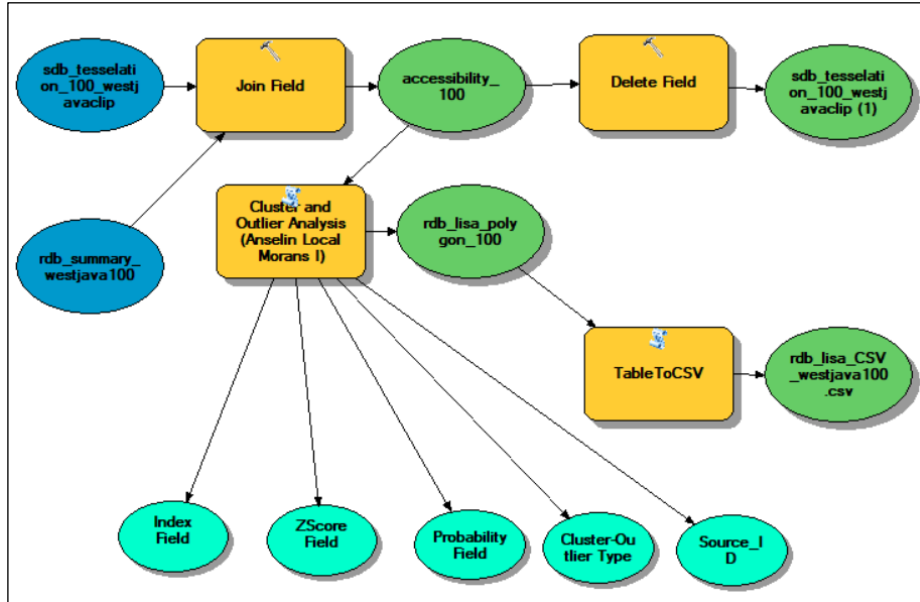


Figure 7. Model builder for LISA map generator

### 3.2.3.3. Dialog management component development

The dialog management component is a platform for the communication between the system with users, usually termed as the user interface of the SDSS. The user interface of this prototype was designed as a game-like system for collaborative planning tools. This prototype allows users or stakeholders to input their alternative decisions data to the system. Afterwards, the system generates a simulation of the accessibility and equity level on the table simultaneously.

The planned road data (mentioned in section 3.2.3.1) was used as the data input platform. To simulate the road development intervention, user updates the status of planned road to build road or upgrade road (according to the set of intervention provided). The system will automatically update the speed of planned road data (which were previously set as zero to prevent it from being considered in the accessibility calculation) once it is updated to build road/upgraded road. Thus, it will be considered in the accessibility calculation. Finally, the accessibility map display will be updated based on the data input.

The display of the user interface includes the interactive accessibility and equity (LISA) map. The other equity indicator and information of resource requirement are displayed as an interactive graph. The LISA map explains the cluster of high and low accessibility location, which can be used as an indication of equity level. The graphs explain the increase/decrease of the equity indicators (CV and Global Moran's I), while the resource requirement graph explain the approximation of resource required to implement the intervention. The DMC component was established using scenario 360 CommunityViz PSS extension in ArcGIS platform.

### **3.2.4. Testing and evaluation**

Testing and evaluation were the final step of the SDSS development process. The aim of this step is to evaluate the sufficiency and usability of the prototype. It was conducted through usability test workshop. This workshop was set to resemble collaborative DM process, and ended with usability questionnaire. Usability analysis was used to evaluate if the prototype was usable according to the stakeholder perspective and if this prototype could improve or provide added value to the current DM process. The process is explained in section 3.1

Stakeholders of road development DM were involved in this workshop. During the workshop, the researcher observed the dynamic and behaviour on how the stakeholder used the system to evaluate if this prototype is sufficient to support collaborative planning (see section 3.1.1.2). The usability was analysed in two methods, qualitative analysis for the workshop observation and descriptive statistics for the usability questionnaire.

#### **3.2.4.1. Qualitative analysis of the usability workshop**

Qualitative descriptive explain the observation and discussion result. The observer analysed the following aspects:

- How the workshop participants used the display map to understand the problems
- Are the provided indicators sufficient as a consideration for decision making (selecting the intervention)?
- How the participants used the provided functions in the prototype. Is it considered as easy to use? What kind of improvement is required?
- Are the participants comfortable with the user interface?
- Is the tools helpful for the simulation of DM process?

The dynamic of the workshops was observed and analysed to evaluate the participants' perception of the usability. Atlas-ti software was used to classify the participants' inputs and opinions during the discussion and the result was analysed using descriptive analysis.

#### **3.2.4.2. Descriptive statistic of the usability questionnaire**

The questionnaire was developed using the Likert scale (the explanation of questionnaire data collection is described in section 3.1.1.3). Scale 1 expressed the strongest disagreement to the question and scale 5 represented the strongest agreement. Descriptive statistics (mean, median, frequency and interquartile range) were used to analyse the questionnaire.

### **3.3. Accessibility and equity measure**

#### **3.3.1. Accessibility measure**

Accessibility was used in transport planning because a reliable indicator in evaluating the relation between land-use and transportation performance (Boisjoly & El-Geneidy, 2016). Specifically, Martens, Golub, & Robinson (2012) mentioned that accessibility can be used to promote equitable transport system. Because one of the objective of road network development planning in Indonesia is to achieve improvement in accessibility and to reduce disparity, hence equitable accessibility can be the intermediate output to achieve those objectives. Decision makers can use this concept as a benchmark in the planning process.

Location based measure was used to describe the level of accessibility to spatially distributed activities (Geurs & van Wee, 2004). Amongst many indicators of accessibility measures that have been explained in section 2.2.1, contour measure or daily accessibility indicator was used to calculate the accessibility. As explained in section 2.2.1, this method was selected for easier communication and interpretation by the decision maker. The SDSS prototype was expected to assist stakeholders in road development decision making process who

came from diverse backgrounds. Thus, it should provide accessibility measure which is easy to interpret and understand. Contour measure is explained by value in meaningful units (travel time and RGDP), hence the accessibility level is easier to be interpreted (Gutiérrez, 2001).

The accessibility measure considered two components of accessibility, namely transport component and land use component. The transport component was represented by the time travel or cost between activity location, therefore road network was modelled in the system. This prototype was developed with a focus on road network since it was expected to be used as a DM support for road development. The land use component explained the location of the origin and the destination. The measure was represented by the accessibility level of each unit of observation that defined the origin (centroid of the hexagon tessellation). The destination was defined by the location of the economic activity centre throughout the study location, which was also represented by node with RGDP as the attribute of each node.

In the road network modelling, province level and national level road network were taken into account. To improve the accuracy, non-detail local roads were used. The national road network consists of non-toll and toll road network, while toll gates were considered as nodes. For each type of road, travel speeds were registered.

This prototype defined the accessibility as the cumulative RGDP of the economic activity that can be reached within 2 hours travel time threshold along the road network from the origin. This threshold was defined based on the common willingness of travellers to do return travel within one day to visit the destination and do an activity Gutiérrez (2001). As this research did not take into account the individual component of accessibility, it treated any trip as the same.

The operationalisation of accessibility in this research used centre of economic activity as the destination. Urban cities and districts (including rural districts) with population more than 1 million people were used as a proxy to define the economic activity location or the economic opportunity. The size of attractiveness or capacity of the economic activity is represented by RGDP (Cao, Liu, Wang, & Li, 2013; Keeble, Owens, & Thompson, 1982; Monzón et al., 2013). The formula below explains the accessibility measure, adopted from (Martín, Gutiérrez, & Román, 2004)

$$A_i \sum_{j=1}^n P_j \delta_{ij} \quad (1)$$

$A_i$  is the accessibility of node  $i$ ,  $P_j$  represents the RGDP of economic opportunity  $j$  and  $\delta_{ij}$  is the travel time threshold, it values 1 if the travel time threshold  $< 2$  hours and 0 if  $> 2$  hours.

The analysis did not take into account different transport modes, hence the indicator to evaluate accessibility was generalized as the time travel of automobile. This calculation was used to evaluate macro level accessibility that only considered node-to-node travel time and beyond regional boundary. It is aligned with findings from Wandani, Siti, Yamamoto, & Yoshida (2016), who discovered that motorcycle trips are usually local, but automobile trips extend beyond the city boundary. Hence, automobile travel characteristic is appropriate to be the case study. Moreover, regional travel characteristics data fluctuates from one district to the others and often unavailable (Cao et al., 2013).

### 3.3.2. Equity measure

As explained in section 2.2.2, this research adopted CV and spatial autocorrelation method to determine the equity effect. This section explains the methodology to calculate the equity indices and its operationalisation

#### 3.3.2.1. Coefficient of variation

This method was used to measure spatial distribution of accessibility based on its changes due to project intervention. It indicated equity based on variability of accessibility in the whole study area. In the

measurement, it took into consideration the population as the weight that explains the size of each region. According to Monzón et al. (2013) the equity measure is formulated as follows:

$$CV = \frac{\sigma^{p*}}{\frac{\sum A_i^* P_i}{\sum P_i}} \quad (2)$$

Where  $CV^*$  is the coefficient of variation,  $\sigma^{p*}$  is standard deviation of the accessibility, while  $A_i$  is the accessibility and  $P_i$  is the population weight.

CV explains the level distribution of the accessibility level around its means. From the value of CV, we can conclude the level of accessibility variation. However, there is no standard CV value for the equity level, hence we can only measure the difference CV value between current condition and the condition after the intervention to calculate the increase or decrease. The increased CV demonstrates a rise of variation in accessibility distribution amongst region. In the other hand, the decrease CV value demonstrates more balanced spatial distribution of accessibility, while the zero value of CV is assumed to represent perfect equity scenario (Kim & Sultana, 2015; Monzón et al., 2013). However, as this measure only explains the variability of accessibility and cannot explain its pattern spatially, I applied spatial autocorrelation method to describe the spatial pattern.

### 3.3.2.2. Spatial autocorrelation

Local Indicator for Spatial Association (LISA) or local Moran's I and global Moran's I index were used to explain the spatial pattern of accessibility distribution in the study area. LISA map shows spatial cluster of similar value around each location in local level, and spatial outlier. The cumulative value of LISA represents the value of global indicator of spatial association (Anselin, 1995) or global Moran's I. Whereas global Moran's I explains whether the data distribution is clustered, dispersed or random spatially over the whole datasets.

According to (Anselin, 1995), LISA is represented by I, define as

$$I_i = z_i \sum_j w_{ij} z_j, \quad (3)$$

where  $z_i$  and  $z_j$  are the deviation from the mean and the summation over  $j$  explain that only neighbouring value of  $j$  is calculated, and  $w$  is the spatial weight between  $i$  and  $j$ . As the summation of local Moran's I represent global Moran's I, it is described as

$$\sum_i I_i = \sum_i z_i \sum_j w_{ij} z_j \quad (4)$$

As explained in section 2.2.2, the positive value of  $I$  indicates that a feature has neighbour feature with similar value (cluster distribution), which interpreted as spatial equity by Wismadi et al. (2015), where value  $I = 1$  is a perfect cluster. Conversely, negative value of  $I$  indicates dissimilarity of a feature to its neighbouring feature (disperse distribution) that is interpreted as spatial inequity (ibid).

The spatial equity was displayed on LISA map that shows the similarity and dissimilarity cluster. The LISA map shows the spatial cluster of accessibility in four (4) concepts First, high-high (HH) cluster explains cluster of high accessibility value that surrounded by similarly high accessibility value. Second, low-low (LL) cluster explains cluster of low accessibility value surrounded by similarly low accessibility value. The other two concepts show the dissimilarity pattern. High-low (HL) outlier indicates high accessibility value which is surrounded by low accessibility value. Finally, low-high (LH) outlier explains the low accessibility value which is surrounded by high accessibility value. This measure helps the decision makers decide an equitable distribution of resources. Specifically, it shows which areas received sufficient transport infrastructure provision (HH cluster), and which area required improvement (LL) cluster. The LL cluster indicates the under-provided areas which require more treatment. Furthermore, the outlier shows areas that require more assessment to investigate the impediments of service provision which leads to the dissimilarity pattern.



## 4. CASE STUDY AREA

This chapter provide an overview of the study area, including its current accessibility and equity condition, as well as the current DM process for road development. It also explains the stakeholder identification result.

### 4.1. General overview of Java Island

Java island is the study area of this research. It is an island in Indonesia where Jakarta, the capital city, is located. It covers over 120,000 km<sup>2</sup> area with 6 provinces which are DKI Jakarta, Banten, East Java, West Java, Central Java and DI Yogyakarta. Java is home for more than 50% of Indonesian population that makes this island the most populous island on earth.

Although Java is the most dynamic island in Indonesia and contributes the most to the country's economic development (Simanjuntak et al., 2017), this island is still suffering from disparity problems. Due to the better road infrastructure compared to the southern part of the island, the northern part experiences more development in economy, social activity and mobility (ibid). As the resource allocation for road infrastructure development in this island will impact the whole country, this island will be the most representative location to be a case study in developing SDSS prototype for resource allocation in road infrastructure. Figure 8 illustrates national road infrastructure network in Java island.

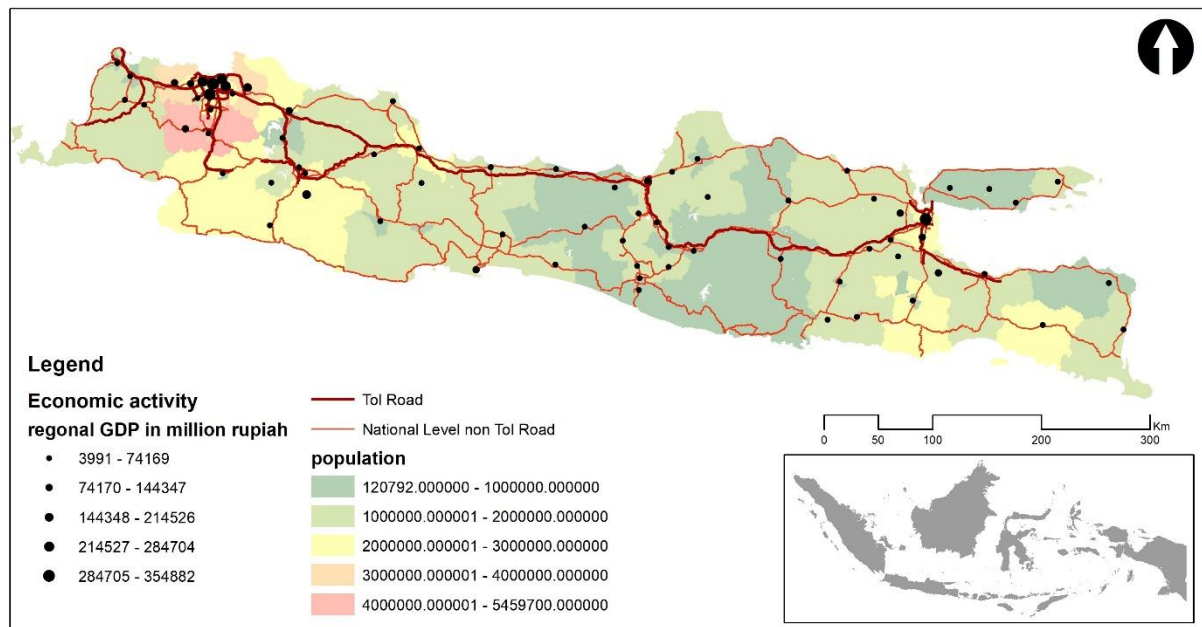


Figure 8. Java national road (highway) networks.

Source : Modified from Ministry of Public Works and Housing. Department of Highway, 2015

\*Economic activity: using urban cities and districts (urban and rural) with population more than 1 million as a proxy

For the preliminary test of the prototype development, West Java, DKI Jakarta and Banten were used as the case study. However, the final analysis was conducted on the entire Java Island. This western part of Java provides more diverse accessibility conditions compare to east and central java, as it covers the most accessible regions (Jakarta) and the least accessible regions (southern part of west java). Hence, it gives an overview of accessibility variation throughout the island.

## 4.2. Accessibility

Accessibility cities and accessibility cumulative GDP were used as indicator to describe the current accessibility condition in the study area. These indicators were calculated using contour measure method. The measure units of the accessibility cities were the number of urban cities that can be reached within 2 hours travel time. Whereas the accessibility cumulative GDP was explained by the cumulative regional GDP of these cities, which indicates the potential of economic opportunity of the observations. Figure 9 shows the road network of provincial to national level road, existing and planned, which is considered in the accessibility calculation.



Figure 9. Road network java island

Source : Ministry of Public Works and Housing. Department of Highway, 2015 and SMEC (2017)

Figure 10 and Figure 11 show the accessibility map of Java island in two indicators, regional GDP and number of urban cities. The map shows the accessibility level and location of urban cities as the destination. Generally, these two indicators express similar accessibility pattern. The highest accessibility is concentrated in the south-western part of the island, where the national capital, Jakarta, and Bandung are located. It followed by the eastern part of the island, where the second biggest city in Java, Surabaya, is located. The centre part of the island, where Semarang, Surakarta and Yogyakarta are located also indicates higher accessibility. It is obvious that the massive road infrastructure provision in these big cities such and their surrounding leads to better accessibility compared to other areas.

On the other hand, some areas in the southern part of the island (especially in West Java and East Java), specifically the bordering area between central and east java and the eastern part of the island are not economically accessible, i.e. people cannot access the economic activity locations within 2 hours travel time. This condition is affected by the different quantities of local road networks between the southern and northern parts of the island. Smaller local road network in the southern part leads to low accessibility. Unlike West and East Java, the southern part of Central Java indicates high accessibility. As one of the more develop cities in Java island, Yogyakarta has a better road infrastructure provision which entails better accessibility to and within this location. However, the location of economic activities that is indicated by the urban cities also have a significant influence on the accessibility. As seen in the map, locations with the lowest accessibility are concentrated in areas with less dense economic activity, while locations with the highest accessibility are located in denser economic activity.



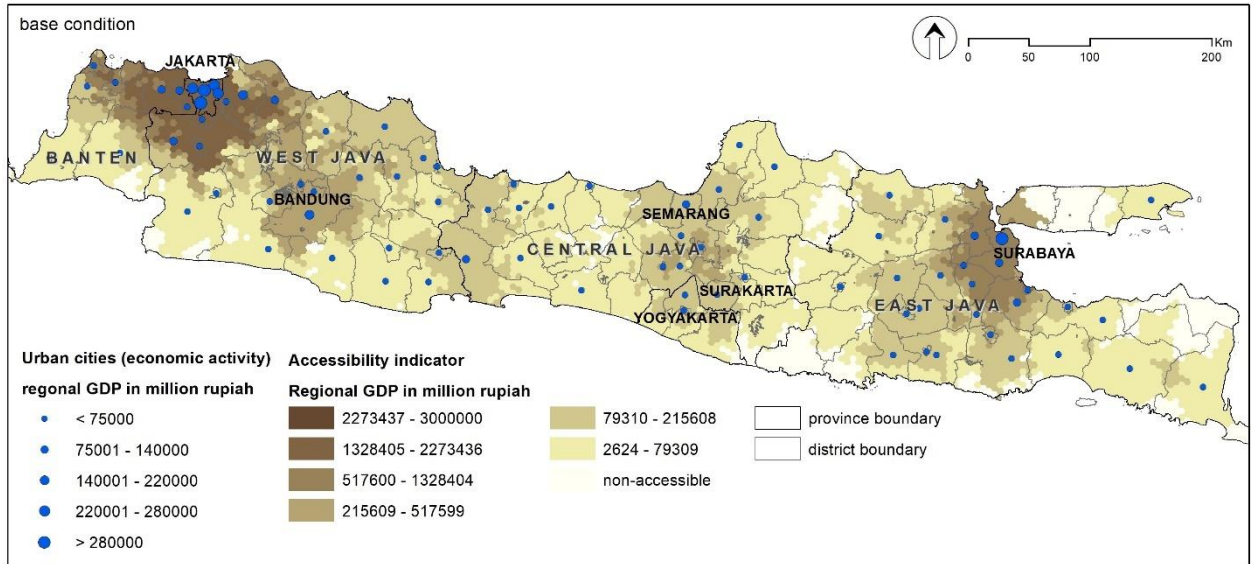


Figure 10. Accessibility (RGDP) map

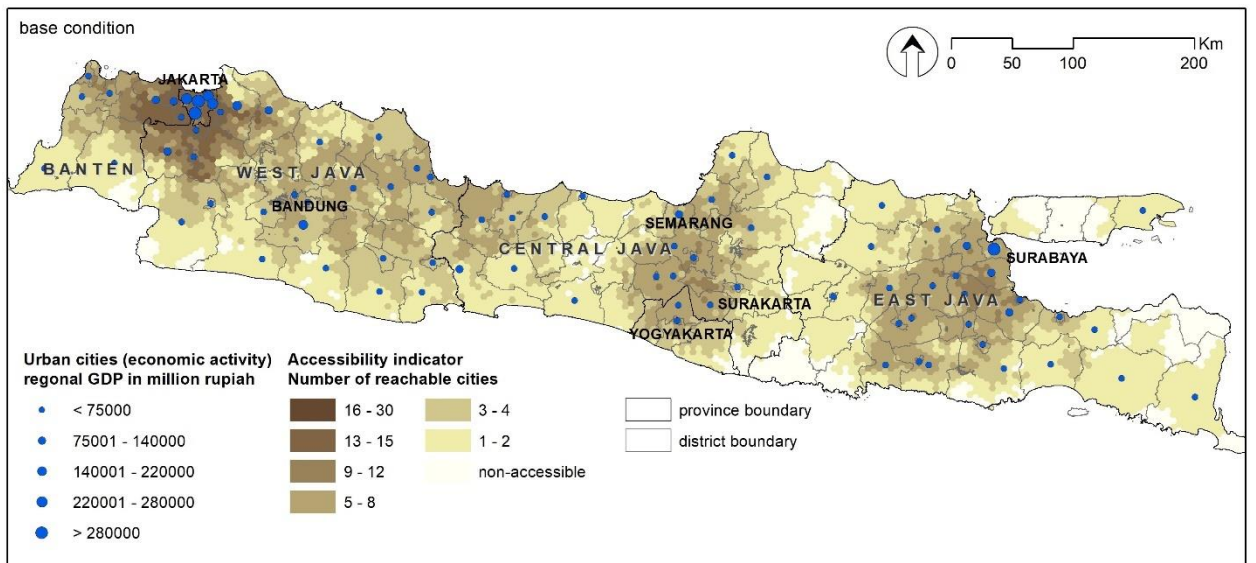


Figure 11. Accessibility (number of urban cities) map

Considering the accessibility map result, we can see that the disparity of accessibility between the south and northern part of the island emerges because big cities in Java are mostly located in the northern part. Hence, the northern part of the island is provided with better road infrastructure provision, and is in closer proximity to the economic activities that have high regional GDP value. Figure 9 explain that mostly existing national road network are concentrated in Jakarta and Surabaya.

Table 2. Ten (10) highest accessibility by city

Accessibility within 2 Hours	
RGDP	Cities
Kota Bekasi	Kota Tangerang
Kota Jakarta Pusat	Kota Bekasi
Kota Jakarta Timur	Kota Jakarta Pusat
Kota Depok	Kota Jakarta Barat
Kota Tangerang	Tangerang Selatan

Kota Jakarta Utara	Kota Jakarta Timur
Tangerang Selatan	Kota Jakarta Utara
Kota Jakarta Barat	Kota Depok
Kota Jakarta Selatan	Kota Bogor
Kota Bogor	Tangerang

From Table 2, which shows the aggregated value of accessibility by district, it can be seen that the greater Jakarta megacity which is called Jabodetabek (taken from the initial syllables of Jakarta, Bogor, Depok, Tangerang, Bekasi) are listed in the top 10 cities with highest accessibility. Jabodetabek is one of the largest megacities in the world based on its population. Bogor, Depok, Tangerang and Bekasi (Bodetabek) are home to 1.382.296 people (Statistical Board (BPS), 2015) who commute daily from their respective origins to Jakarta for both work and leisure. Figure 12 shows that location with high accessibility, mostly serve high population number. However, most districts in Central Java have low accessibility while they have to serve a large population.

As the capital city, Jakarta is the busiest city in the country. Thus, sufficient road infrastructure to support the high mobility is highly required. The high accessibility level of Jabodetabek is due to the fact that this area receives the highest road infrastructure provision. Jakarta has the highest percentage of road length compared other provinces in Java island (Simanjuntak et al., 2017). In Figure 9, It is also shown in the road network map that toll and national level roads massively support Jakarta and its surrounding compared to other locations. However, this city is suffering from unprecedented traffic congestion since the number of motorized vehicles is much larger than the capacity of the road network to accommodate them (ibid). Therefore, the accessibility level might be lower if the traffic indicator was incorporated in the analysis.

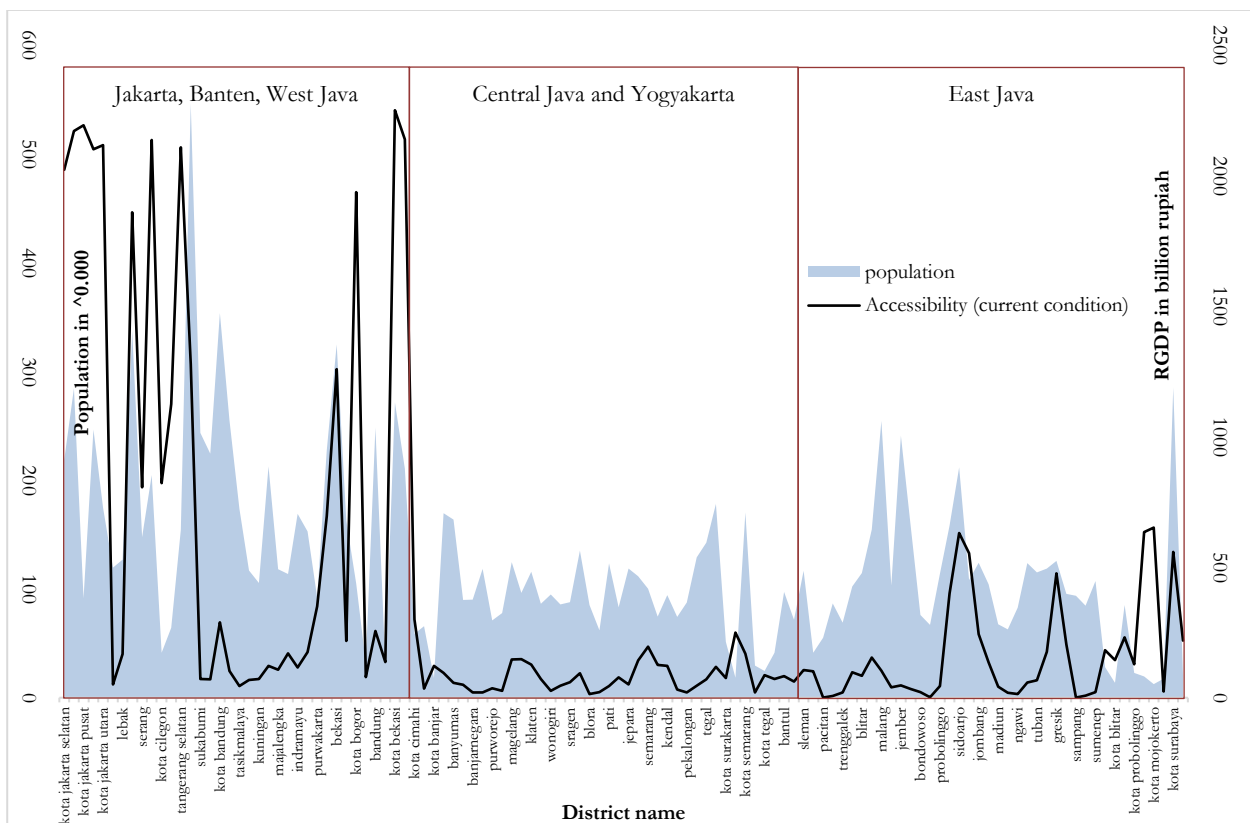


Figure 12. Current condition of accessibility and population

### 4.3. Equity

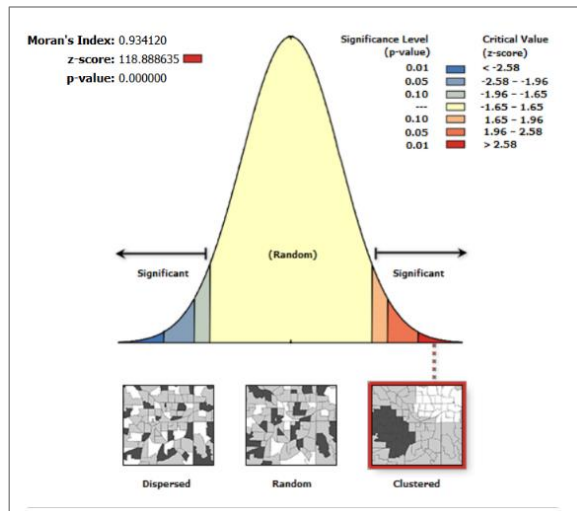


Figure 13. Global Moran's I (RGDP accessibility) within 2H travel time

The value of global Moran's I of the accessibility regional-GDP indicates clustered distribution, which is 0.9341. As describe in Figure 13, the index suggests clustered distribution of accessibility value. However, we cannot claim that there is equitable accessibility in the study area by only using global Moran's I index. To get a broader picture of the spatial distribution of accessibility, the local indicator of spatial association (LISA) was used to identify the spatial autocorrelation pattern in the local level. This indicator was shown in LISA map in Figure 14. These maps illustrate the cluster distribution of similarity and dissimilarity overlay with population number, which helps to identify clusters of over-provide and under-provide area.

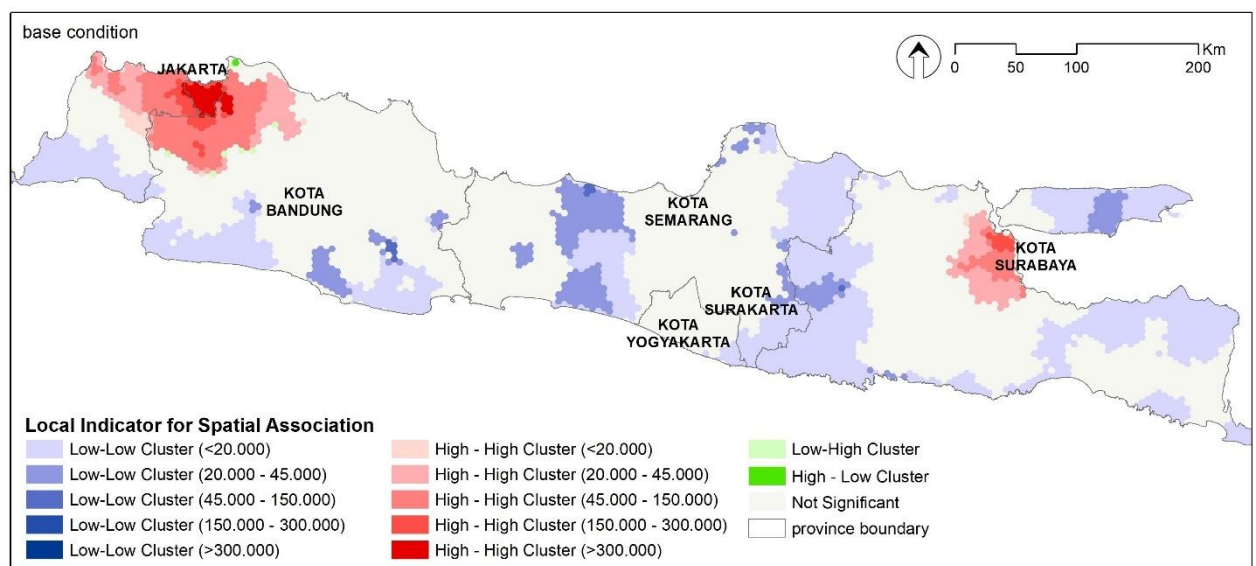


Figure 14. Local indicator of spatial association map

Subsequently, Figure 14 shows the blue colour as the low-low cluster that imply low accessibility surrounded by similarly low accessibility value. The red colour represents high accessibility locations that are surrounded by similarly high accessibility location, whilst the colour gradation signifies the number of population. Alternatively, green colour implies dissimilarity, with dark green indicates high accessibility locations surrounded by low accessibility location, and conversely light green indicates low accessibility surrounded by high accessibility value.

As shows in Figure 14, the clusters of high accessibility are concentrated around greater Jakarta and Surabaya. Jakarta is clustered as high-high accessibility while serving the highest number of people. However, some areas in high accessibility cluster have low population. This location indicates over-provided area. On the other hand, dark blue colour indicates areas that are clustered as low-low accessibility but serve a large number of people. This demonstrates under-provided area.

#### 4.4. The decision-making process and mechanism in Indonesia

The planning process of road development in Indonesia was established based on the national development plan, which is documented in the national long-term development plan. In the period of 2015-2019, the third national medium-term development plan (RPJMN) was established with 9 national development agendas based on the current government policy named “NAWACITA”. The agendas of transportation development policy include (Department of Highway Ministry of PUPR, 2015):

1) Decentralization and regional development

The road development agendas are directed to support the establishment of strategic economic development centre, which emphasises on the accessibility improvement of the under-developed area to the economic opportunity.

2) National connectivity, urban transport and infrastructure investment.

The national development agenda are directed to the following: 1) support the improvement of national connectivity to achieve equity, which is emphasised on national toll-road development to support national industry and logistic, and to support the economic corridor, other economic hub, and non-economic corridor, 2) public transport development, and 3) effectivity and efficiency improvement of the infrastructure investment

Improvement of accessibility in under-developed area to reduce disparity is one of the national agendas, which becomes the objective of road development plan. Hence, the concept of accessibility is proposed in this research.

##### 4.4.1. National road development planning mechanism

To implement the national planning agenda, the government of Indonesia through National Development Planning Agency (BAPENAS) developed spatial planning document for national and regional levels. This document is termed as Rencana Tata Ruang Wilayah (RTRW) which is divided into national level spatial planning or Rencana Tata Ruang Nasional (RTRWN), province level spatial planning *Rencana Tata Ruang Provinsi* (RTRWP), district and city level spatial planning or *Rencana Tata Ruang Kabupaten* (RTRW Kab) and *Rencana Tata Ruang Kota* (RTRW Kota). For the road development particularly, the document is translated into general road network plan document which is termed as Rencana Umum Jaringan Jalan (RUJJ). Figure 15 shows the process to develop RUJJ

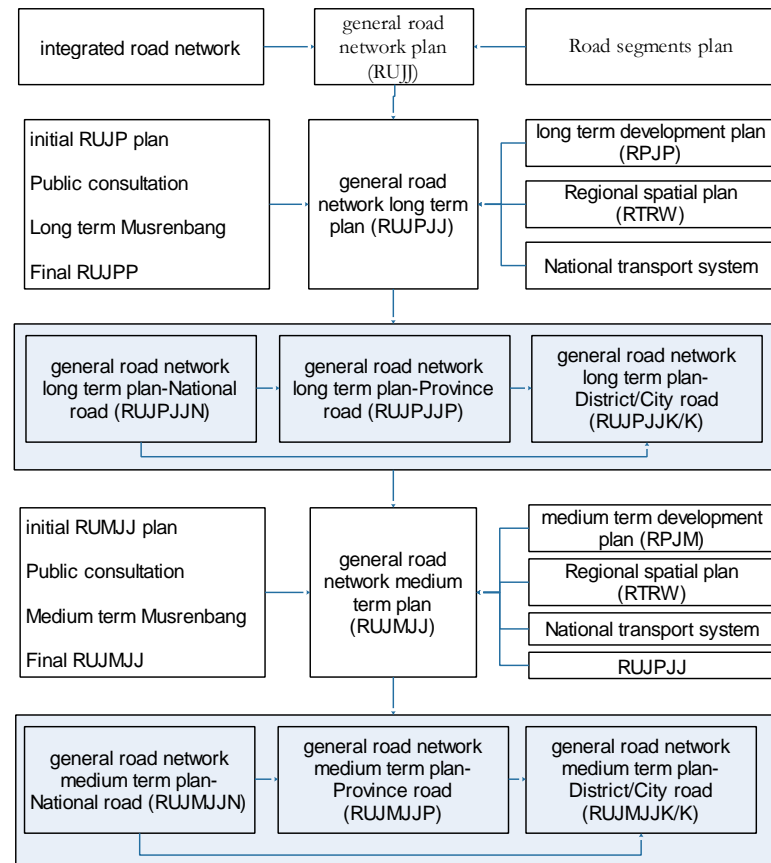


Figure 15. General road network plan document development manual

Source : Ministry of PUPR, (2012)

These documents are used as a guidance for annual road development planning and budgeting, implemented by the Ministry of PUPR. According to the stakeholders from sub directorate of planning and network system integration, department of highway the Ministry of PUPR, the annual planning and budgeting was implemented based on bottom up and top down approaches. As he said “... *the planning and budgeting for road development is a combination process, there are initiatives from local governments and our own plan (national plan). We evaluate the proposals, if it corresponds with our plan then it will be prioritized based on the budget availability.....(the location selection for national plan) is a command from the leaders...based on president program which is translated into 5 years strategic planning document....*”. The local government initiative is a bottom-up planning mechanism, whilst the national program is a top-down planning mechanism. The mechanism of local government proposal is explained in Figure 16.

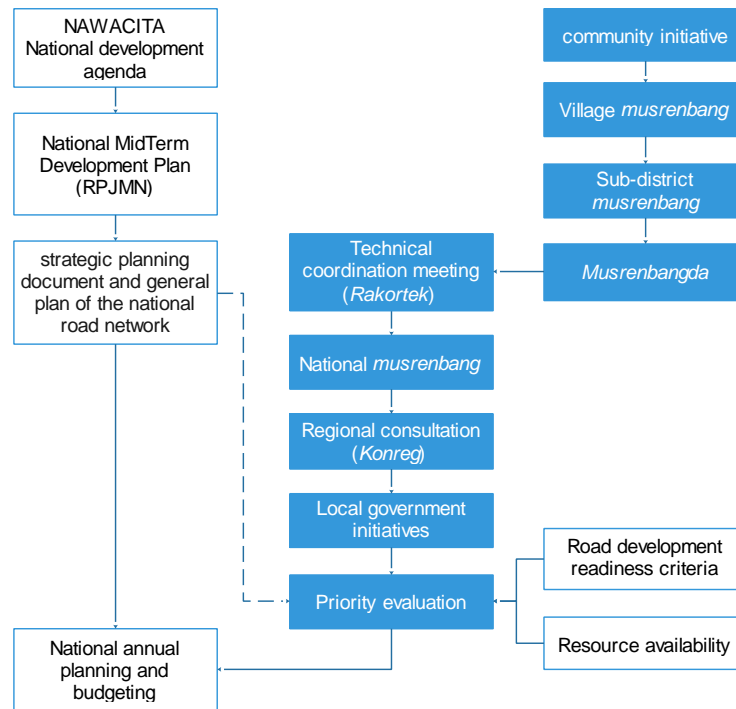


Figure 16. General flowchart of Ministry of PUPR planning process  
Source: own resource, 2017 (interview and Republic of Indonesia, 2004a)

The national road development plan is established based on the national policy, which is implemented in strategic planning document or *rencana strategis (renstra)* and RUJJ. Road is developed to support other sector, as mentioned during the interview by the data and information unit in the ministry of public works “*The road development, actually, supports other sectors. For example, to support new outlet development such as airport, port or development of tourism area which require support from new road development...*” Hence, road development plan is adjusted to the needs of other sectors.

The bottom up process is started from the participatory mechanism in a village level. This process involves local community participation, which is conducted through *musrenbang*. *Musrenbang (Musyamarah Perencanaan Pembangunan)* is a stakeholders and community participatory mechanism in Indonesian national and local planning processes (Republic of Indonesia, 2004a). It is conducted through community and stakeholder discussion forum. This process produces integrated planning document for regional level for all sectors including road development planning. It is followed by a technical coordination meeting or *rapat koordinasi teknis (Rakortek)* and national *musrenbang*, which facilitates the coordination between the national level ministries and the local government, to synchronise the local and national plan.

The national road development initiative particularly, is communicated to the Ministry of PUPR through regional meeting or *Koreg (Konsultasi regional)* forum. *Konreg* is a multi-stakeholder forum which is scheduled every year by the ministry of public works to get inputs from multi stakeholders interested in road development program. This forum involves road development stakeholders from local government and other sectors, including other ministries and private sectors.

Multi criteria evaluation is used to prioritize the local government proposal. It will be evaluated based on the readiness criteria. Four major readiness criteria are identified during the interview, namely: 1) legal document availability, 2) pre-assessment document available, which are environmental impact analysis, detail engineering design (DED), feasibility study (FS), 3) land availability, 4) multiplier effect. The proposed locations in the proposals are compared to the national agenda, priority is given to the proposal that aligns



with the national road development plan. Afterwards, the selected proposal is included in the national road development planning.

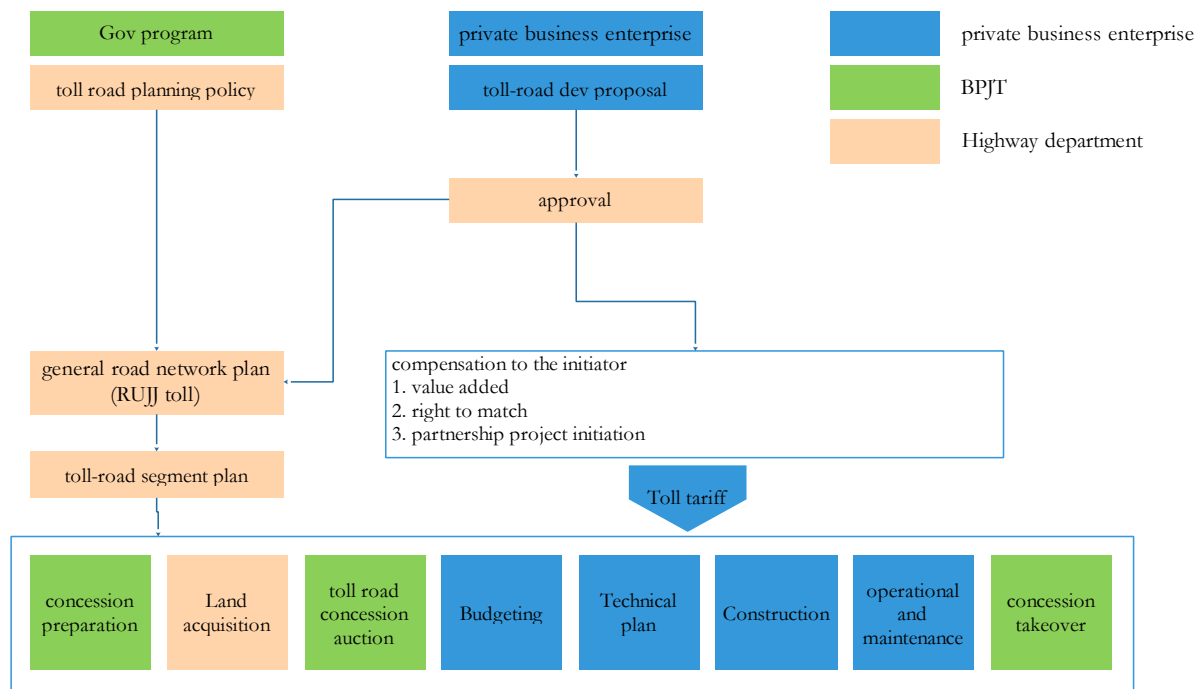


Figure 17. Toll road concession stage  
Source : Badan Pengatur Jalan Tol (BPJT), (2015)

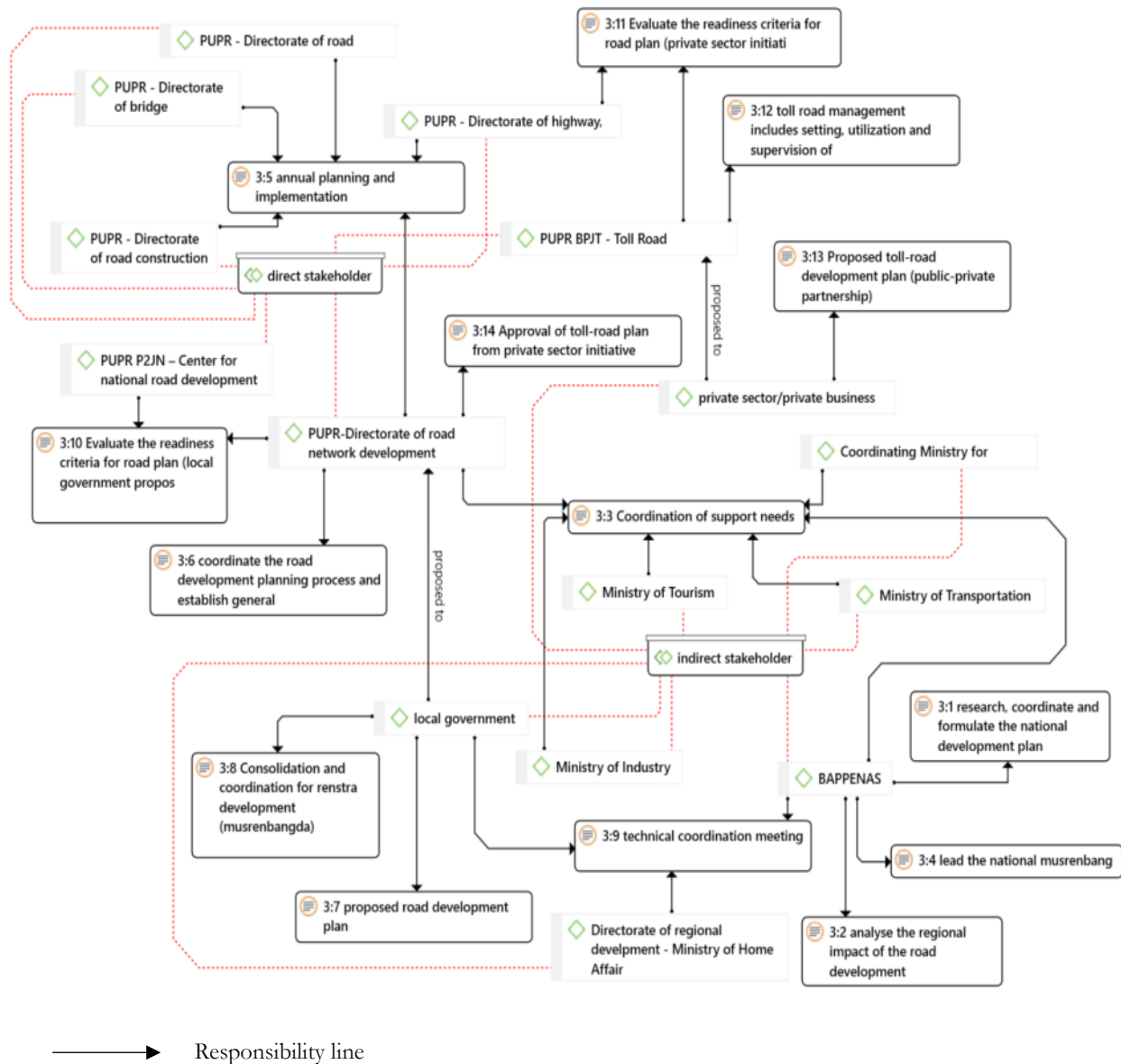
For toll-road development in particular, the mechanism of the development involves private sector as part of public-private partnership mechanism. Figure 17 explains the mechanism of toll road concession, where the initiatives from private business enterprise will be considered in updating the RUJ. Private business enterprise can propose toll-road road development concept to the ministry through Toll Road Management Agency or *Badan Penguasaan jalan Tol* (BPJT), as an agency that were established by the ministry to handle concession of toll-road development. This toll-road proposal is termed as “initiative segments” or “*ruas prakarsa*”. BPJT and highway department Ministry of PUPR evaluate the proposal based on specific indicators, which include 1) the proposed segments should be financially feasible 2) the proposed toll-road segments should be connected to the existing national road 3) pre-FS document available, positive regional economic impact of the proposed toll-road should be indicated in this document and 4) readiness of land acquisition process. As part of the evaluation process, further analysis will be conducted to assess the regional impact of the proposed road segments. The proposal will be approved or disapproved based on the evaluation result. Finally, the approved “*ruas prakarsa*” will be included in the RUJ.

Regional impact assessment of the road development is evaluated in the road development planning process. However, the evaluation is conducted partially, for each road segments is based on the FS document. Even though the multi stakeholder coordination is conducted in the *konreg* forum, the evaluation processes do not involve the stakeholders, local government, private sector and other institution. Since road development is conducted to support other sectors, collaboration is required in the evaluation and prioritization process.

#### 4.5. The stakeholders

During the interview, two types of stakeholders were identified: direct stakeholder and indirect stakeholder. Direct stakeholders are institutions that are directly involved in planning, administration, construction and maintenance of road infrastructure (Keig, 2012), which are internal institutions of the Ministry of PUPR.

While indirect stakeholders are other institution or other parties which are not directly involved in the road development process (ibid), yet still contribute to the planning process. Figure 18 shows the stakeholders map and their involvement in the road development planning process based on the interview.



Source: own resource (stakeholder interview, 2017)

Figure 18. Stakeholders diagram

The key stakeholder of national road development is the Highway department, Ministry of PUPR which has the responsibility for organizing the formulation and implementation of road developments policies in accordance to the legislation. This department is divided into several directorates based on specific role. Each directorate has their own responsibility for road development plan. Directorate of road network development is responsible for managing the integration of road development planning. It responsible for internal and external DM coordination.

External institutions of the Ministry of PUPR are consider as indirect stakeholder, as they don't directly involve in the national road development process. However, they are significantly engaged during the planning process. Institution that responsible in other sector such as, the ministry of tourism, the ministry of industry, the ministry of transportation, responsible to coordinate their needs for road development



support. Whilst, BAPENAS as the national planning agency responsible to coordinate the multi sectoral planning in national level.

The needs of local community are managed by the local government. They have the responsibility to inform the needs and the local conditions of road development. They also act as the focal point of community involvement in the planning process. The communication between local government with the ministry is conducted through regional meeting (*Konreg*) or routine coordination with the Ministry of PUPR units in regional level or P2JN, which is held in the provincial level.



## 5. SYSTEM DESIGN AND PROTOTYPE DEVELOPMENT

### 5.1. Decision problem definition

It is undoubted that road network quality improvement induces better accessibility, including to the economic opportunity. To improve economic development in under-developed areas as a part of the national agenda, the Indonesian government prioritizes the road development plan in the under-provided areas. This plan aims not only to improve economic development in specific locations, but also to reduce disparity. However, it cannot be ascertained that the selection of road development and road maintenance locations will increase the accessibility of the under-access areas. There is no certain evaluation of the impact of the alternatives to the equitable accessibility, hence which priority provides more beneficial (equitable access) result is uncertain. Moreover, there are several alternatives that should be prioritize based on the current situations, should the government prioritize the development of toll-road, the development of national road, or just maintain the existing road and improve the quality or upgrade the capacity of existing road.

Furthermore, the decision making for road development involves different stakeholders with varying interests, thus conflict of interest in the DM process is inevitable. Each of them has their own agenda and targets regarding the road development planning. For example, BPJT prioritizes the development of toll-road, while the road preservation unit prioritizes the road maintenance. Moreover, the local government also have their own road development target to support the their regional development. Whereas, they must agree on which agenda should be prioritized in terms of resource allocation. Therefore, this SDSS prototype is developed to facilitate collaborative planning process for prioritizing resource allocation in road development planning.

### 5.2. The aims of the SDSS prototype

This system was designed to assist stakeholders in analysing the impact of the selected interventions to accessibility and equity. With the involvement of stakeholders in the collaborative DM process, it is expected to answer the question of which interventions of road development location are the most favourable to achieve a more equitable accessibility. It has the following functions:

- 1) Providing an overview of the existing accessibility condition in the study area
- 2) Allowing to input interventions as simulations of new road development and road upgrade
- 3) Showing the impact of the interventions on accessibility
- 4) Allowing calculation of resources required for new road development in the simulations
- 5) Showing the comparison of equitability impact between based situation and after the implementation of the intervention
- 6) Providing an interactive user interface with maps and graphs which show the impact of the intervention.

### 5.3. SDSS framework

The prototype consist of four main SDSS components, adopted from Sugumaran & Degroote (2010). The components were DBMC, MMC, DMC and SC as mentioned in 2.3.2. The prototype was developed using the function of scenario 360 CommunityViz Planning Support System (PSS), Network analysis and spatial statistic tools in ArcGIS. The network analysis and spatial statistic were used in the MMC component, while the CommunityViz was used in the visualization of the geographic information. Figure 19 below demonstrates the framework of the SDSS

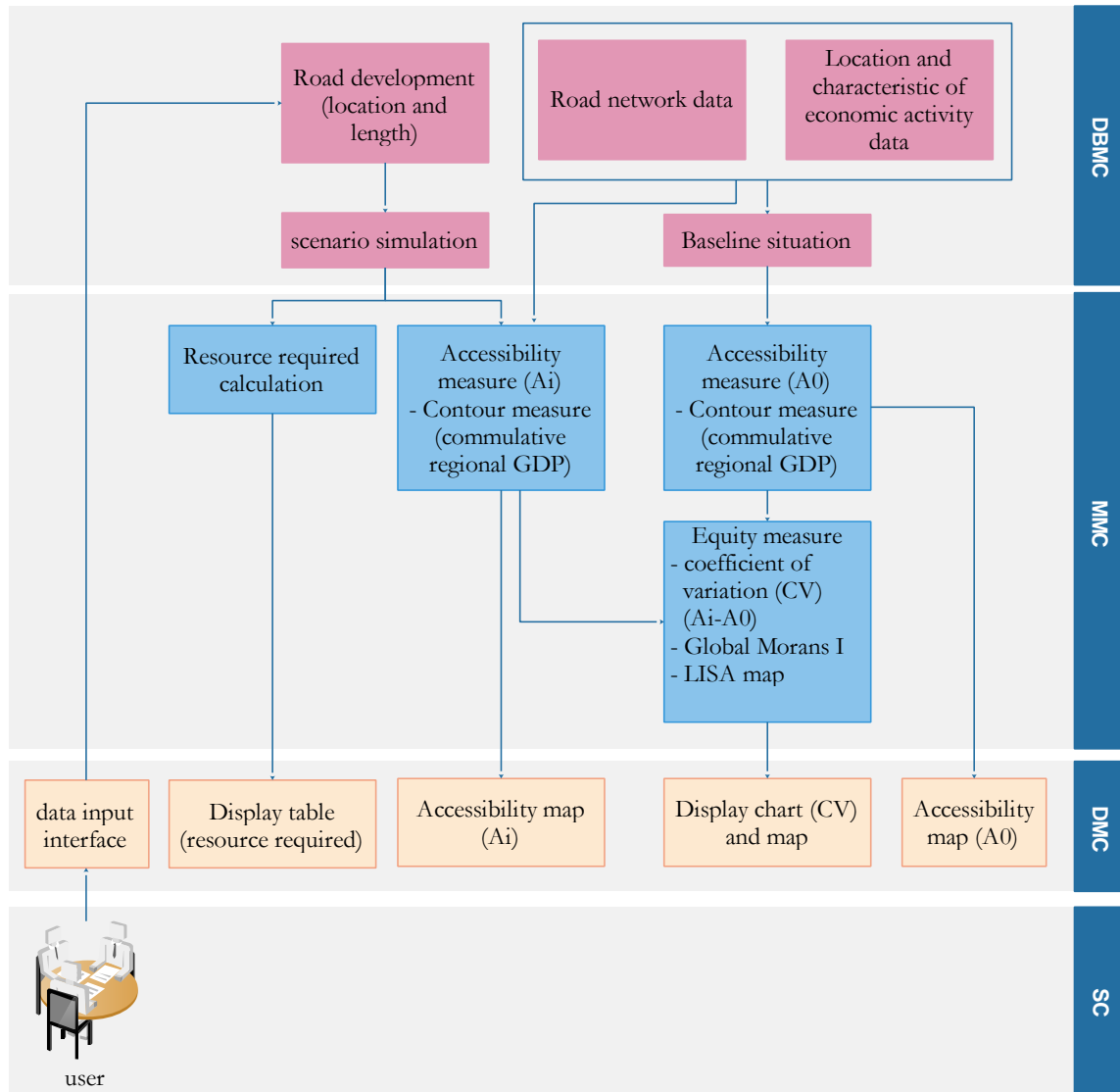


Figure 19. SDSS framework

Source : adopted from Sugumaran &amp; Degroote (2010)

### 5.3.1. Database management component (DBMC)

The DBMC deals with the process of spatial and non-spatial data management and data storage. It functions to manage the relations between spatial and non-spatial data that are required in the prototype. The relations between road networks data, locations and characteristics of economic activities and road development plan location were managed in this component.

Table 3. Data used for prototype development

No	Data	Remark
1	National level road networks (toll and non-toll)	
2	Province-district level road networks	
3	Local level road network	
4	Toll gate location	Generate network dataset (used to calculate travel time)
5	Toll road network plan	
6	National level road network plan	
7	Road upgrade plan	

6	Economic activity location	Gross domestic product (in million rupiah)
7	District map	District boundary
8	Population data	Number of people
9	Land use map	

Spatial and non-spatial data in the prototype development was managed and stored in ArcGIS geodatabase function. It formed a collection of geographic datasets in various types. Geodatabase is an ArcGIS primary data format that function for data editing and management, a physical store of geographic information which has a comprehensive information model (ArcGIS, 2016c). Table 3 shows the data used in the prototype development.

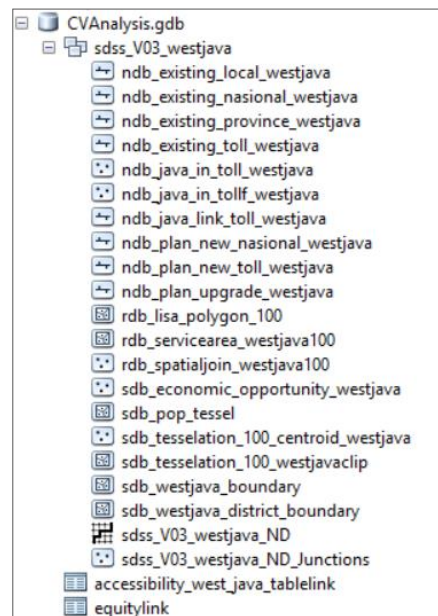


Figure 20. ArcGIS geodatabase

Figure 20 is the overview of ArcGIS geodatabase for the prototype development. The primary spatial data for the accessibility analysis consists of road network data which is managed as a network dataset. It was supported by spatial and non-spatial (attribute) data of the economic opportunity, the unit of observation (hexagon raster tessellation data), land use map, and population table.

### 5.3.2. Model management component (MMC)

The model management component provided functions to manage, execute and integrate different measures through various analytical methods (Irfan, Koj, Sedighi, & Thomas, 2017; Sugumaran & Degroote, 2010). The MMC of the SDSS prototype was designed to have analytical spatial models, i.e. accessibility measure and equity measure that will be integrated into one system. This prototype used ArcGIS software functions as the core of the prototype. Network analysis tool, spatial statistic tool and model builder function were used to measure the accessibility and equity.

#### 5.3.2.1. Resource requirement measure

There were three (3) components of resource for road development which are investment cost, construction cost and land acquisition cost. This prototype calculated the resource requirement simulation based on the average amount of money required to develop one kilometre of road segment. The average resource was estimated based on current road development project; hence it did not reflected the actual resource

requirement. However, the actual resource for road development may vary based on the technical, economic, social and environmental conditions of the location.

### 5.3.2.2. Accessibility measure

Measurement of current accessibility was conducted to show the base accessibility conditions ( $A_0$ ). For preliminary prototype development, contour measure principle was used. This measure calculated the number of economic opportunity, represented by cumulative RGDP which can be reached from origin location within 2 hours travel time threshold.

When users input new intervention data, which represents the new location of road development, the system calculated the new accessibility condition ( $A_i$ ) with the same method. Figure 21 below shows the accessibility contour measure

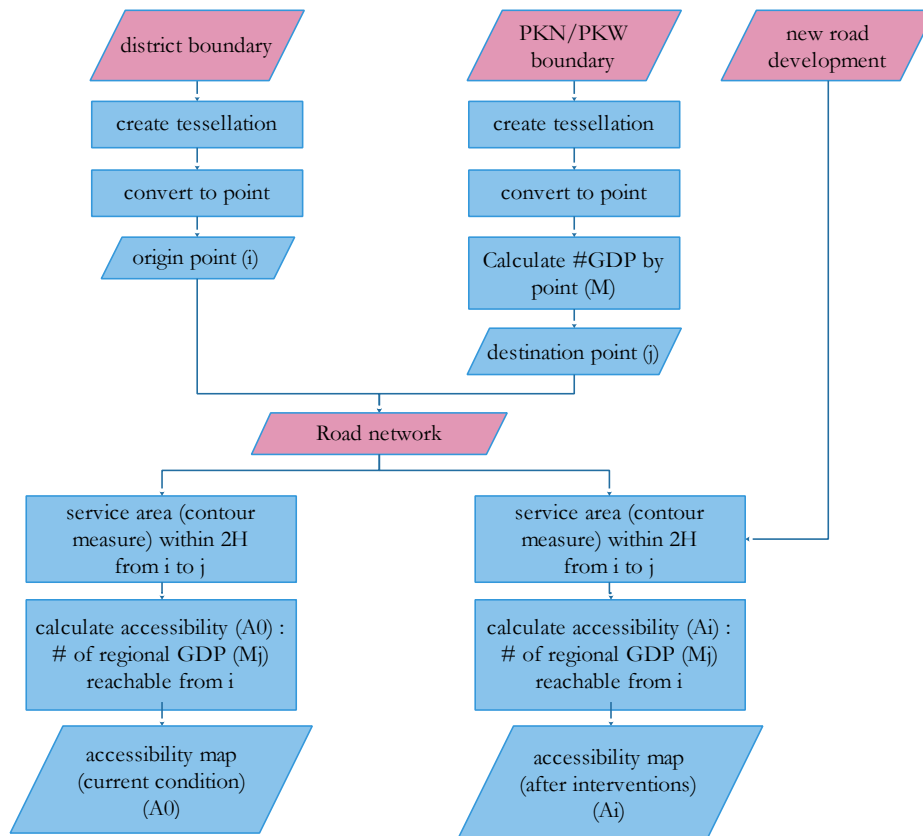


Figure 21. Contour measure accessibility

### 5.3.2.3. Equity measure

As one of the equity indicators, CV was used to calculate the variation of accessibility around its mean. The measure was implemented to both base situation ( $A_0$ ) and after the simulation of the intervention ( $A_i$ ), and the difference between them indicated the increase and the decrease of variability.

Local Indicator of Spatial Association (LISA) is a statistical measure that identifies spatial cluster significance of similar accessibility value around each unit of observation (hexagon tessellation). The ArcGIS spatial statistic tool identifies spatial cluster of feature with high or low accessibility value, and spatial outliers by calculating local Moran's I index (I). The positive I indicates that the feature has similar value with its neighbour, conversely the negative I value indicate dissimilarity (categorise as outlier in the calculation)(ArcGIS, 2016a). The LISA statistic then is represented in LISA map, which illustrates cluster of similar and dissimilarity.

The global Moran's I is proportional to the aggregate of LISAs for all accessibility observation (Anselin, 1995). The mean of I value in LISA statistic formed the Global Moran's I index. Similar with the LISA index, the positive global Moran's I index suggests similarity amongst all accessibility values in the study area. On the other hand, negative value indicates dissimilarity. Figure 22 below shows the calculation flow.

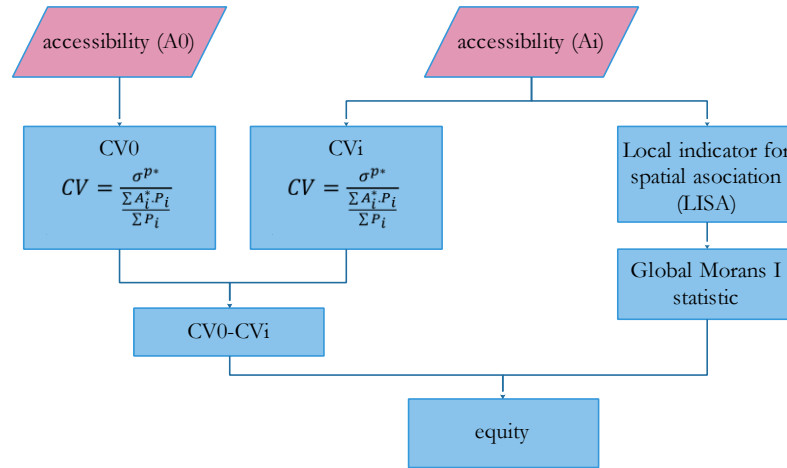


Figure 22. Equity measure

### 5.3.3. Dialog management component (DMC)

Containing the visualisation and data input functions, the dialogue management component allowed the interaction between users and the system through user interface platform. The data input function was used by the users to input the set of interventions of new national level road development data into the system. Users can add new road development data by selecting proposed new road plans that have already been incorporated in the road network database and change it as developed. Based on the typology of road development plan in the study area, this prototype accommodates several types of road development intervention as follows:

- 1) Toll road development plan  
It is represented as toll road development plan network in Java island, which indicates proposed toll road to be built. Some segments have yet to be built in the real world, while some segments are in the middle of construction process and yet to be operated.
- 2) National road development plan  
Similar to the toll road plan, it is represented as the national road development plan in the prototype.
- 3) Road upgrading plan  
The road upgrading is defined by three types of upgrading based on master plan study as follows:
  - a. Function and status upgrading, which include status upgrade to national level road
  - b. Capacity upgrade and geometric improvement, and
  - c. Road expansion by additional lane

The road plan map was taken from two sources: 1) the government plan, which was specified in general plan of national road development document and 2) conceptual (study) plan, which was the result of master plan studies conducted by Indonesia-Australia partnership consultant as a recommendation to the highway department (SMEC, 2017)

CommunityViz in ArcGIS extension was used to design the user interface. The prototype was visualised with accessibility map as the background layer, which is supported by equity map (LISA map), population density map and land use map. Create feature tool in CommunityViz functions as data input and chart tool as visualisation of interactive graph. The formula was established in CommunityViz to visualize the

interactive graph. Figure 23 below shows sample of formula editor to calculate resource requirement for toll road development. The formula was established to calculate the following:

- 1) Average accessibility  
Average accessibility = sum of accessibility divided by number of observation units (number of tessellation)
- 2) Resource allocation (in rupiah and in km length segments)  
Resource allocation = sum of road length\*) times average resource requirement for 1 km road development\*\*)  
\*) the intervention road, which means the length of road that had been selected as an intervention, for example toll road plan that had been selected to be developed by stakeholder  
\*\*) The average resource requirement was estimated based on current road project. This value was generalized and was estimated, the actual value of road development varies depending on the location.
- 3) Equity measure, which consists of CV and Global Moran's I index value  
CV = standard deviation of accessibility value divided by (sum of accessibility times population divided by population)  
Global Moran's I index = average of local Moran's I index

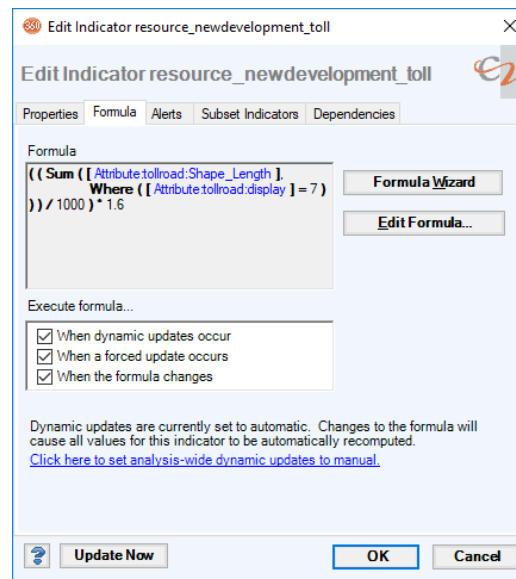


Figure 23. Formula editor in CommunityViz

#### 5.3.4. Stakeholder component (SC)

Stakeholders as the users of the prototype played a role as the decision makers in this system. They were the most important component and are responsible for developing various set of intervention and simulate it through the system. During the collaborative planning simulation (workshop), they were in charge of deciding which intervention should be prioritized based on the simulation and agreement amongst them.

#### 5.4. SDSS prototype operationalization

This section describes the operationalization of the SDSS prototype. Although this prototype was not developed to answer the question of the best location of road development, it provided an overview of the road development impact to the accessibility and equity for collaborative DM purpose.



### 5.4.1. Interface

This prototype is displayed in two types of main interactive display maps, which are accessibility map and LISA equity map. The accessibility map shows the accessibility level of each observation (hexagon tessellation). Figure 24 presents the screenshot of the user interface. These maps are interactive maps that can interactively display the dynamic of accessibility and LISA map based on the intervention.

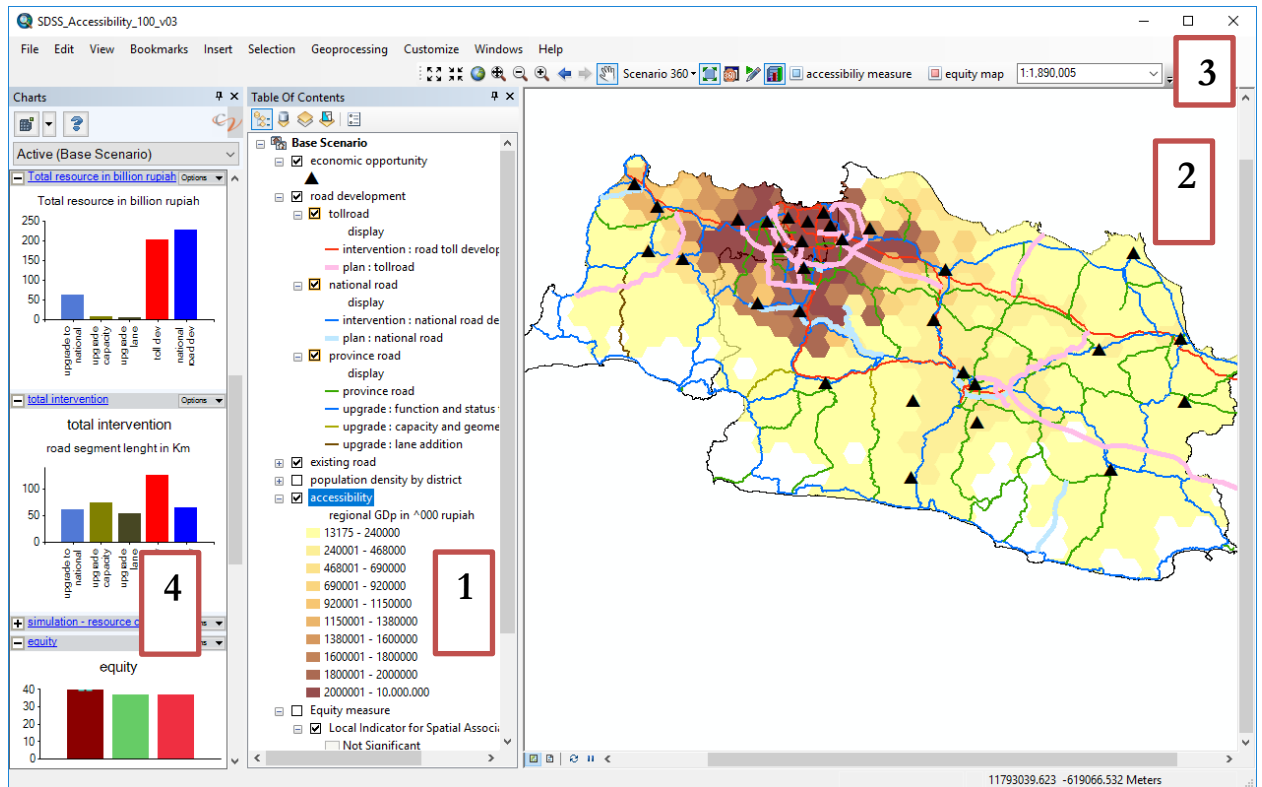


Figure 24. Prototype user interface (accessibility map display)

The prototype layout consists of 4 parts. Part 1 is the table of content (ToC) which accommodates list of available layers. The ToC allows user to activate and inactivate layer whenever they need. It accommodates dynamic and non-dynamic layers. The non-dynamic layers can only be visualized, while the dynamic layers can be updated and functions as data input platform. The ToC contains location of economic activity layers, which include destination, existing road network layer, population layer and land use layer, all of which are non-dynamic layers. On the contrary, road development plan layer, accessibility and equity layer are dynamic layers.

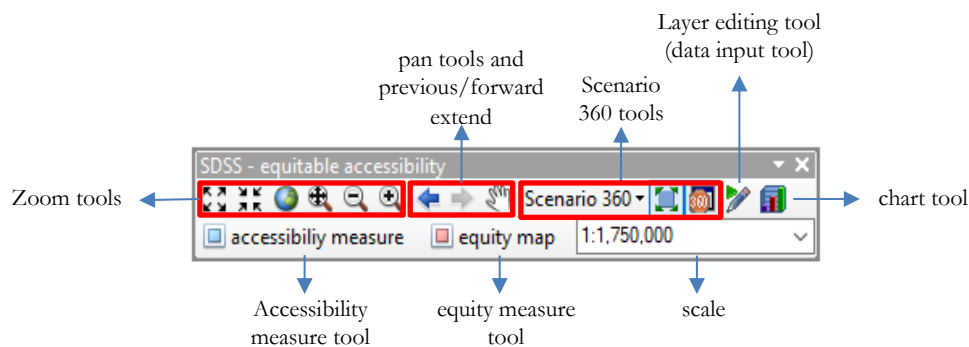


Figure 25. SDSS prototype toolbar

The second part is the map view, it is a platform to visualize each map layer. The third part is the SDSS toolbar (see Figure 25 for detail). The last part is the interactive graph that shows the benefit (accessibility) and cost (resource required) trade-off, level of average accessibility and equity indicator (Global Moran's I and CV) and estimation of resource requirement.

#### 5.4.2. Data input: intervention selection

The “editing tool” functions as data input platform in the prototype. This tool allows user to input the road development intervention data to the prototype. The set of intervention is divided into three categories, namely toll-road new development plan, national road new development plan and road upgrading. Users or stakeholders selected the intervention based on the collaborative discussion, and investigated the impact in the interactive accessibility and equity map. The tools for the data input are presented in Figure 26 below.

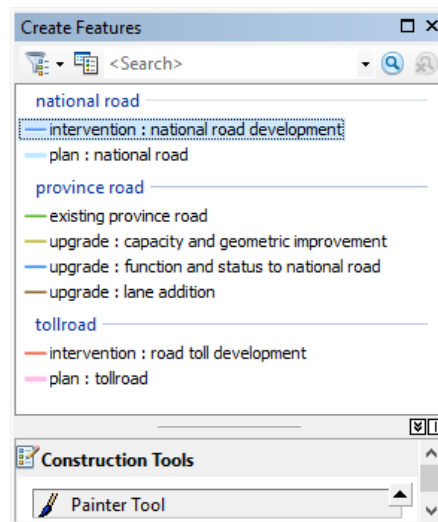
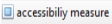



Figure 26. Layer editor/data input tool

#### 5.4.3. Generate accessibility and equity map

The accessibility and equity measures are the core of the prototype. Ideally, the accessibility and equity map changes interactively when the intervention data are input. However, to generate the accessibility and equity result, users have to press accessibility and equity measure button  . This is one of the limitations of the prototype. The accessibility and equity measures are performed in network analysis and spatial statistic tools in ArcGIS that are not integrated to the CommunityViz, hence additional process should be performed. The accessibility and equity results are displayed in both map and graph (see Figure 27). The accessibility value is symbolized by yellow to dark brown colour gradation.

The legend of LISA equity map explains clusters of high accessibility value, low accessibility value and the outlier. The high-high cluster in red colour indicates the high accessibility that is surrounded by similar high accessibility value. And the low-low cluster in blue colour indicates low accessibility value that surrounded by similar low accessibility value. The outliers emerge in high-low cluster format, which is explained by high accessibility value that surrounded by low accessibility value (green colour) or the opposite (yellow colour). While, the colour gradation shows the population number. This LISA map explain the location of under-provided and over-provided area.

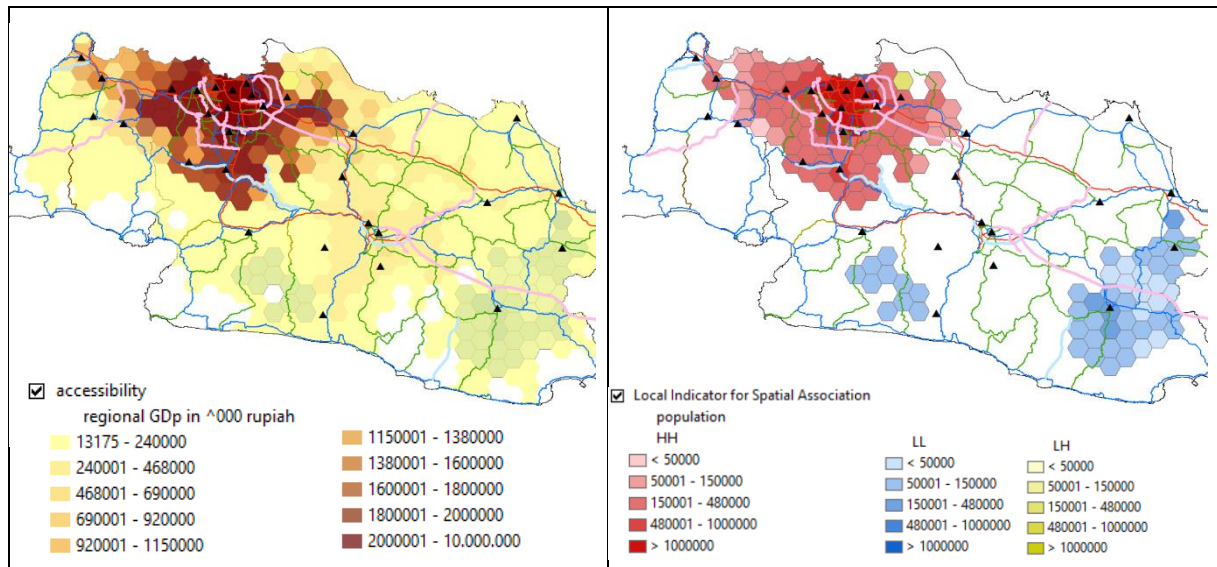


Figure 27. Accessibility and equity map result

Figure 28 and Figure 29 displays the accessibility value in interactive graph. Average accessibility describes the accessibility after the intervention, while current accessibility depicts the accessibility of base condition before the intervention. Benefit and cost trade-off are shown in Figure 29. However, due to the limitation of graph generator tool in community Viz, the trade-off cannot be previewed in XY axis format. This graph explains the investment cost (resource) required to obtain the average accessibility value.

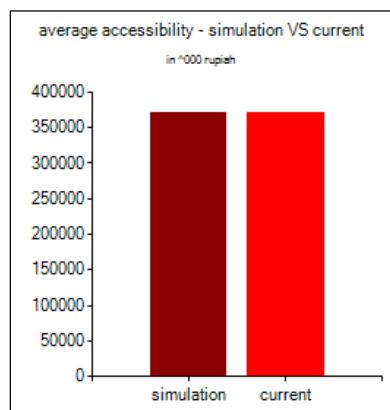


Figure 28. Average accessibility graph

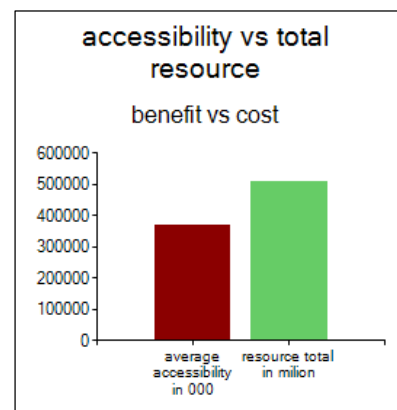


Figure 29. Benefit and cost graph

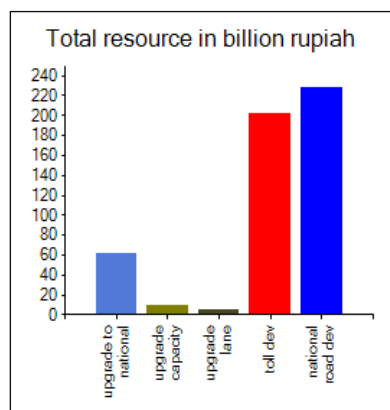


Figure 30. Total resource

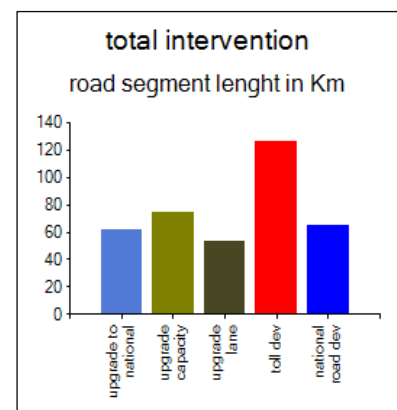


Figure 31. Total length intervention graph

Figure 30 explains the total cost or resource required, which is described by individual type of intervention. While Figure 31 explains the total segments of road development intervention that have been selected by users. This graph helps stakeholders to estimate the total resource required for their selected intervention. It is shown through resource comparison between each intervention type.

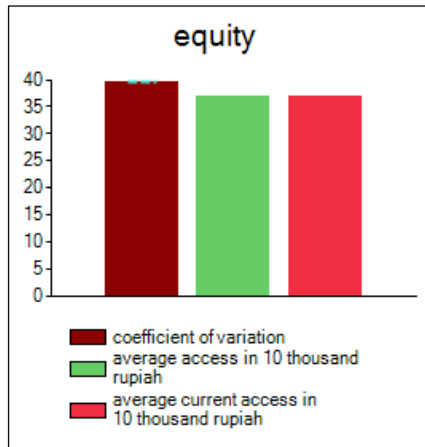


Figure 32. Equity coefficient of variation graph

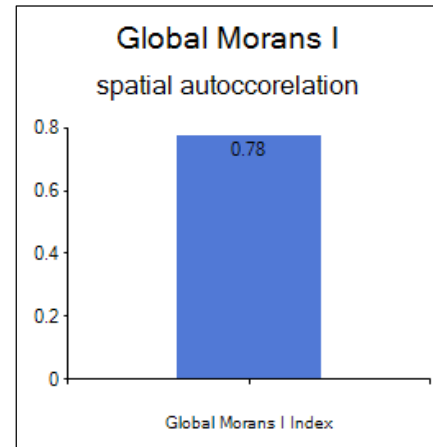


Figure 33. Global Moran's I graph

The equity indicators are shown in Figure 32 and Figure 33. These graphs explain the CV and global Moran's I index. The higher CV value denotes high variability of accessibility values, while Moran's I closer to 1 indicates more cluster distribution. Psychologically, users tend to assume that the higher graph is better, thus the display of CV graph was modified. The higher graph describes lower CV and lower variability, which indicate more balance distribution of accessibility.

## 6. ANALYSIS AND EVALUATION

The first section of this chapter simulates the impact of the road development interventions to the accessibility and equity in the study area. Next, the second section illustrates how the system can support the collaborative DM process. It describes how the stakeholder perceived this system as tools for collaborative planning. It also evaluates their behaviour in using the system in a workshop setting. The simulation result explains the usability of the prototype based on stakeholder's perception.

### 6.1. Impact of the road development intervention

This section simulated the impact of the road development intervention to the accessibility and equity effect. It showed whether the plan could improve the accessibility and equity condition in the study area. It also demonstrated the changes of Global Moran's I index before and after the intervention. As described in 5.3.3, the interventions include new toll road development, national road development and road upgrading. Nevertheless, due to the data limitation, this analysis was generated based on new toll road development and national road development as a national planning agenda. The simulation was performed based on the national road development plan document (completed with the proposed location based on master plan study). It was classified based on road development phase in the planning document.

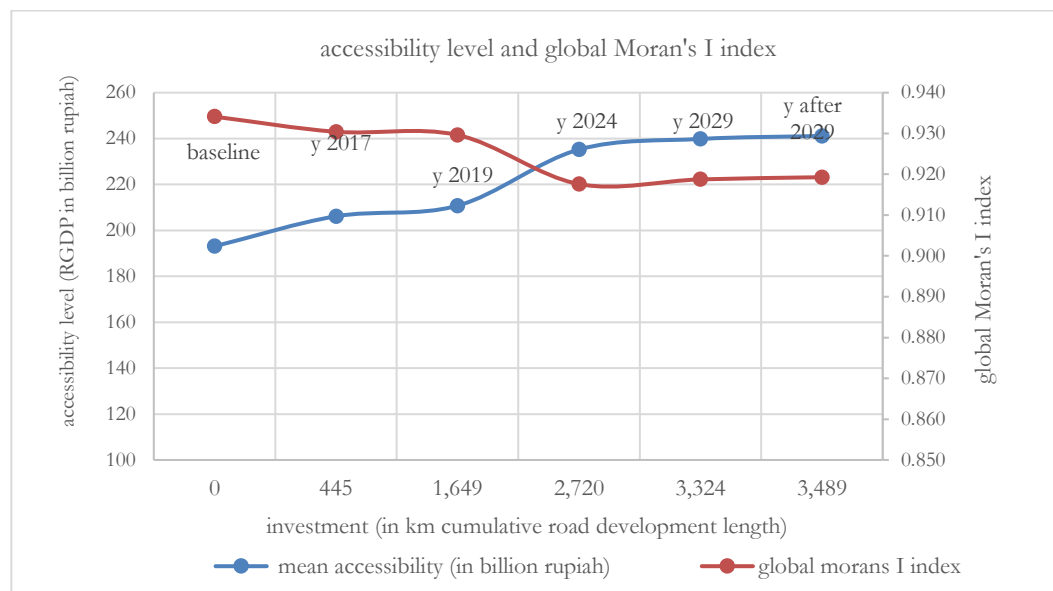


Figure 34. Accessibility level and global Moran's I comparison

Figure 34 shows the trade-off of cumulative road development investment, the average accessibility improvement and the global Moran's I index. The simulation of the intervention was divided into 5 phases. The first intervention is the road plan which is currently being constructed, starting in 2017. The second intervention is the simulation of development in the year 2019, followed by 2024, 2029 and the last intervention is the development in the year after 2029. Figure 35 shows the map of road development simulation by year.

The intervention through the years indicates improvement of accessibility level. The most significant accessibility improvement occurs in the year 2019 to 2024, while in the other years, the improvement is relatively steady. It is influenced by the high investment of road development plan, which is 1071 km of national and toll road plan (see Table 4). However, the highest investment, which is 1203 km national and toll road development plan in 2019, could not improve the accessibility significantly. It is affected by the

location of the development which was concentrated in East Java (see Figure 35), which is able to improve the accessibility in the neighbourhood area of East Java (see Figure 37) but not the overall study area.

The road development in 2019 simulation, induces accessibility improvement in West Java (see A in Figure 37). It is influenced by the development of toll road that connect this area to Surabaya and the development of national road to connect it to the southern part of East Java. In 2024 simulation, the accessibility of Jakarta megacity increases due to the development of outer toll-road around Jakarta (see Figure 37 B). While 2029 simulation shows significant accessibility improvement in location C (in Figure 37). It is the effect of toll-road development plan which connects this area to Central Java and West java. This road is intended to support the new airport that will be located in Yogyakarta province.

The Moran's I value explains cluster distribution behaviour of the accessibility data. Figure 34 shows different changes pattern of the accessibility and the Global Moran's I index. There is a decrease index from simulation of year 2017 to 2024. Significant improvement of accessibility in 2019 to 2024 yet indicates decline of Moran's I index, which explains that the improvement of average accessibility yields more dissimilarity over the study area. Subsequently, the chart shows insignificant increase of the index from year 2029, similar with the average accessibility. However, even though there is decline in the index, the accessibility data distribution is still highly clustered (the values are closed to 1). Hence, it indicates that the intervention simulation does not significantly influence the accessibility data distribution.

Table 4. Simulation total road (toll-road and national road) development intervention

Simulation	Accessibility (in million Rp)	Total road development (segments) in Km			
		Toll road dev.	National road dev.	Total road dev.	Cumulative road dev.
current condition	193,080.27	0.00	0.00	0	0.00
2017	206,153.38	445.41	0.00	445.41	445.41
2019	210,767.98	678.48	525.26	1203.74	1649.14
2024	235,253.55	918.63	152.63	1071.26	2720.40
2029	239,838.16	412.82	190.89	603.71	3324.10
after 2029	241,156.17	35.83	129.27	165.1	3489.21

The improvements of the accessibility of all intervention are mostly located in West Java, around Bandung city and the outskirt of greater Jakarta. It is affected not only by the road development plan in those area but also by their closeness to economic opportunity with high RGDP value. Moreover, massive road development plans were still located in greater Jakarta, thus this megacity is the most advantaged area.

Figure 36 clarifies that concentration of high accessibility are located in areas with relatively high population. However, the significant improvement of accessibility due to the overall intervention do not take place in high populated districts. Figure 36 shows that the greatest improvements are in Kota Cimahi, Purwakarta, Karawang and Kota Bandung (located in West Java) and Kota Malang (located in East Java). The accessibility improvement of cities in West Java were affected with the improvement of their access to Bandung and Jabodetabek due to the massive road development interventions in these locations. While, the improvement of accessibility in Kota Malang was influenced by its access to Surabaya.

The location and value (RGDP) of the economic activities, however, affects the accessibility. Locations with less dense economic activities, such as centre part of central Java, the border of Central Java to East Java and the eastern part of East Java, obviously have less accessibility. Hence, the road development intervention does not significantly improve their condition (see Figure 37).

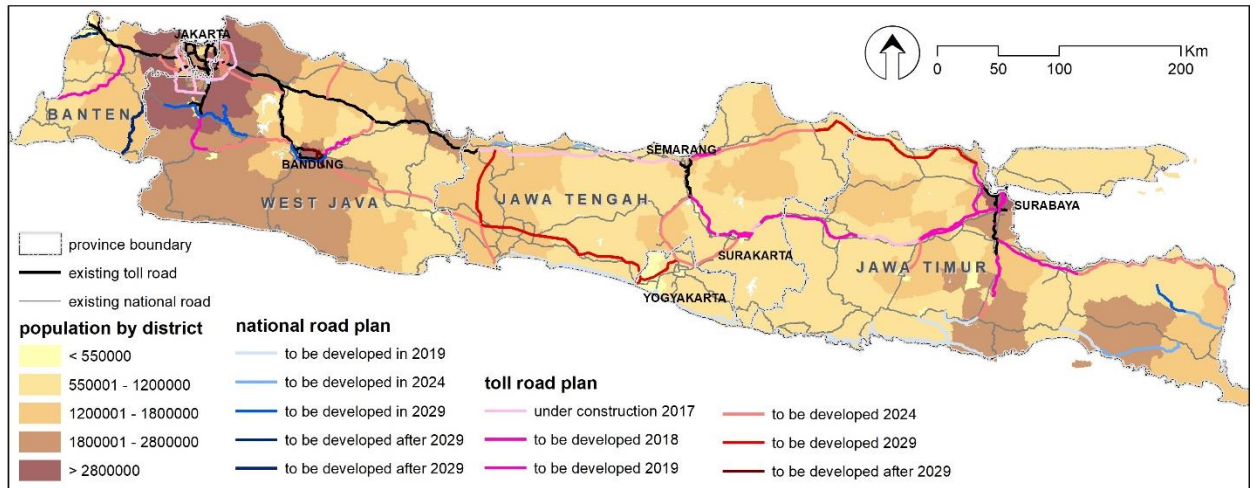


Figure 35. Road development intervention by year

The equity assessment, which was expressed by CV, global Moran's I and LISA map can be seen in Table 5, Figure 34 and Figure 38. The road development simulations were not significantly affected by the cluster distribution. Table 5 shows increased value of CV which indicates less balance accessibility distribution of the simulation. The increase of CV, however, cannot directly indicate the lower equity level, but shows the more variability of the accessibility. Hence, to assist the decision makers in allocating resource in an equitable way, the LISA map was established.

Table 5. Equity indicator: CV and Global Moran's I Index

Simulation	CV
current condition	73.88
2017	77.27
2019	76.57
2024	77.15
2029	77.19
after 2029	76.86

LISA map, in Figure 38, shows less significant changes due to the road development intervention. It shows there are trivial changes of LISA map through the simulations year. The high accessibility location is clustered in the megapolitan and metropolitan cities in Java, specifically greater Jakarta and Surabaya. However, the intervention in year 2024 to 2029 demonstrated decrease high cluster accessibility and increase low cluster in East Java.

The red colour in the map explains the location of high accessibility cluster, whilst blue colour indicates low-low accessibility cluster. The colour gradation describes the size of population. The lighter the colour, the less populated the area is. This map gives an overview of which area is clustered as low accessibility, but should serve high number of population (see blue circles in Figure 38). Figure 38 A, B, D and E are show under-provided area, as it is clustered as low but served high population (indicated by dark blue, population more than 45,000 people). The simulation of road development through the years can improve the equity in area location B. It is indicated by the decrease of low cluster in high populated area. However, the LISA map shows increase number of low cluster area in the Eastern part of East Java (see Figure 38C). It is presumably an indication of unequitable resource allocation, because, even though the accessibility value increases globally, there were an emergence of new low-low clusters. The intervention might increase the average accessibility, but failed to improve the under-provided condition in East Java.



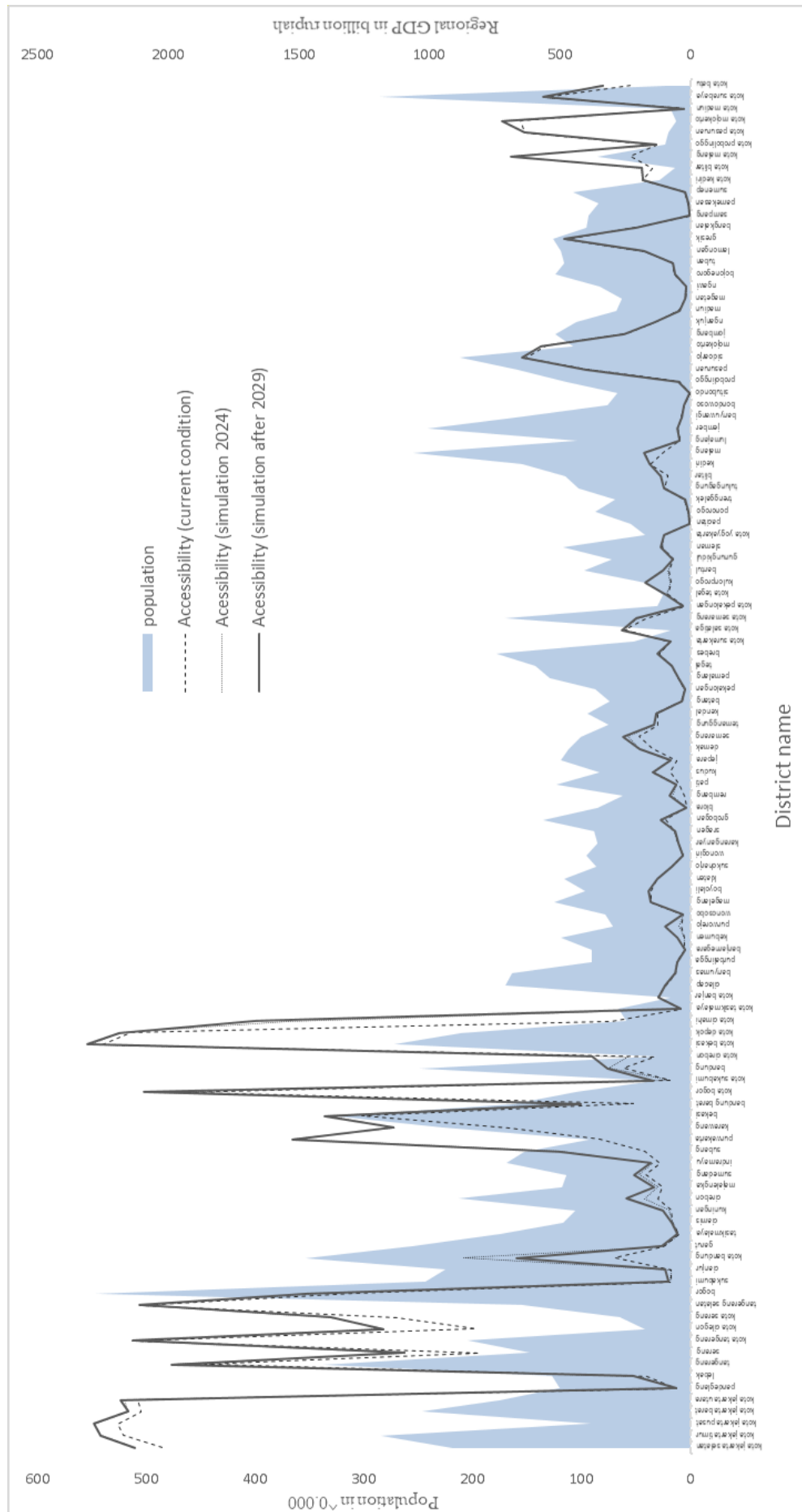


Figure 36. Accessibility and population



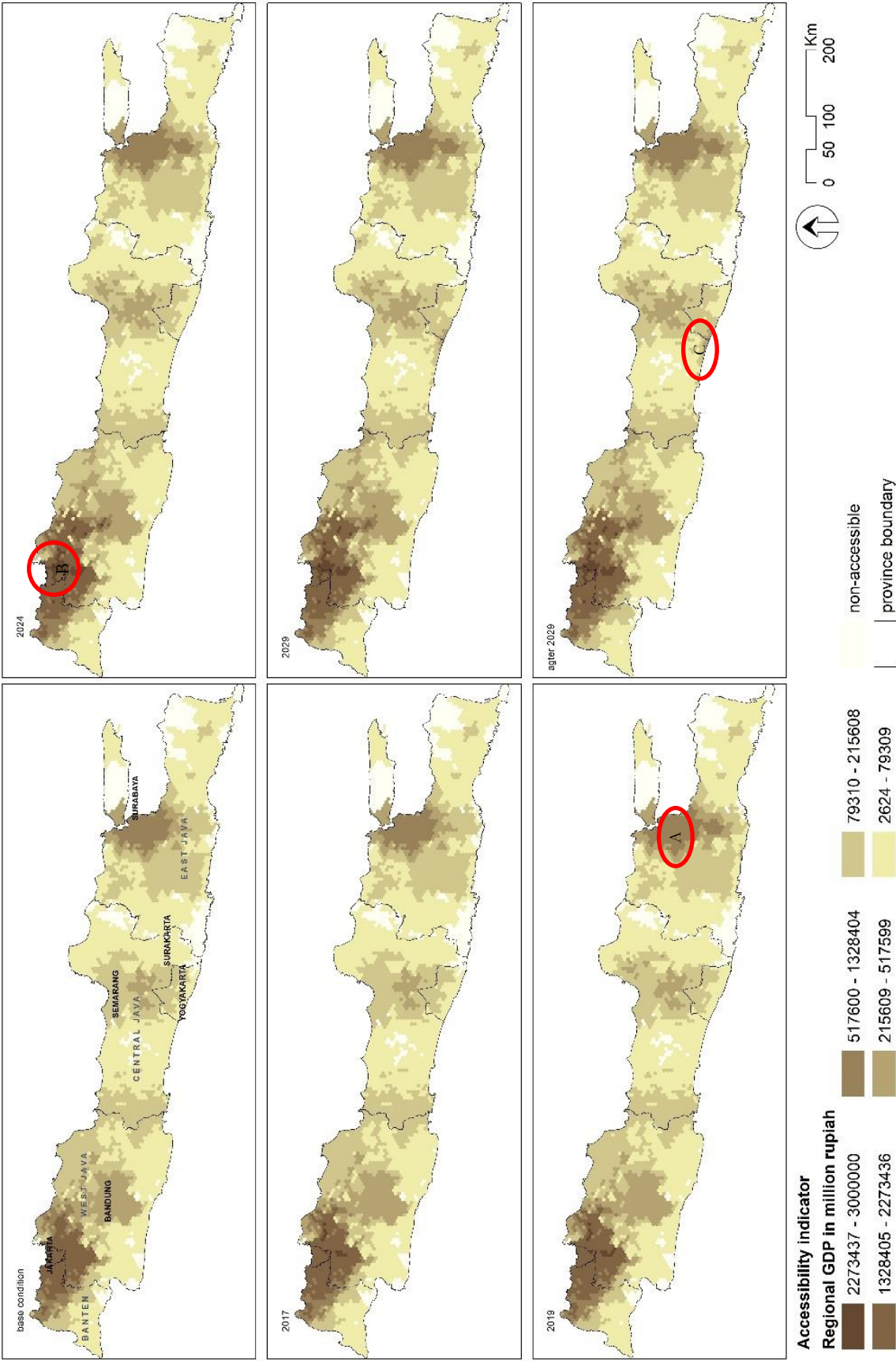


Figure 37. Accessibility level based on intervention

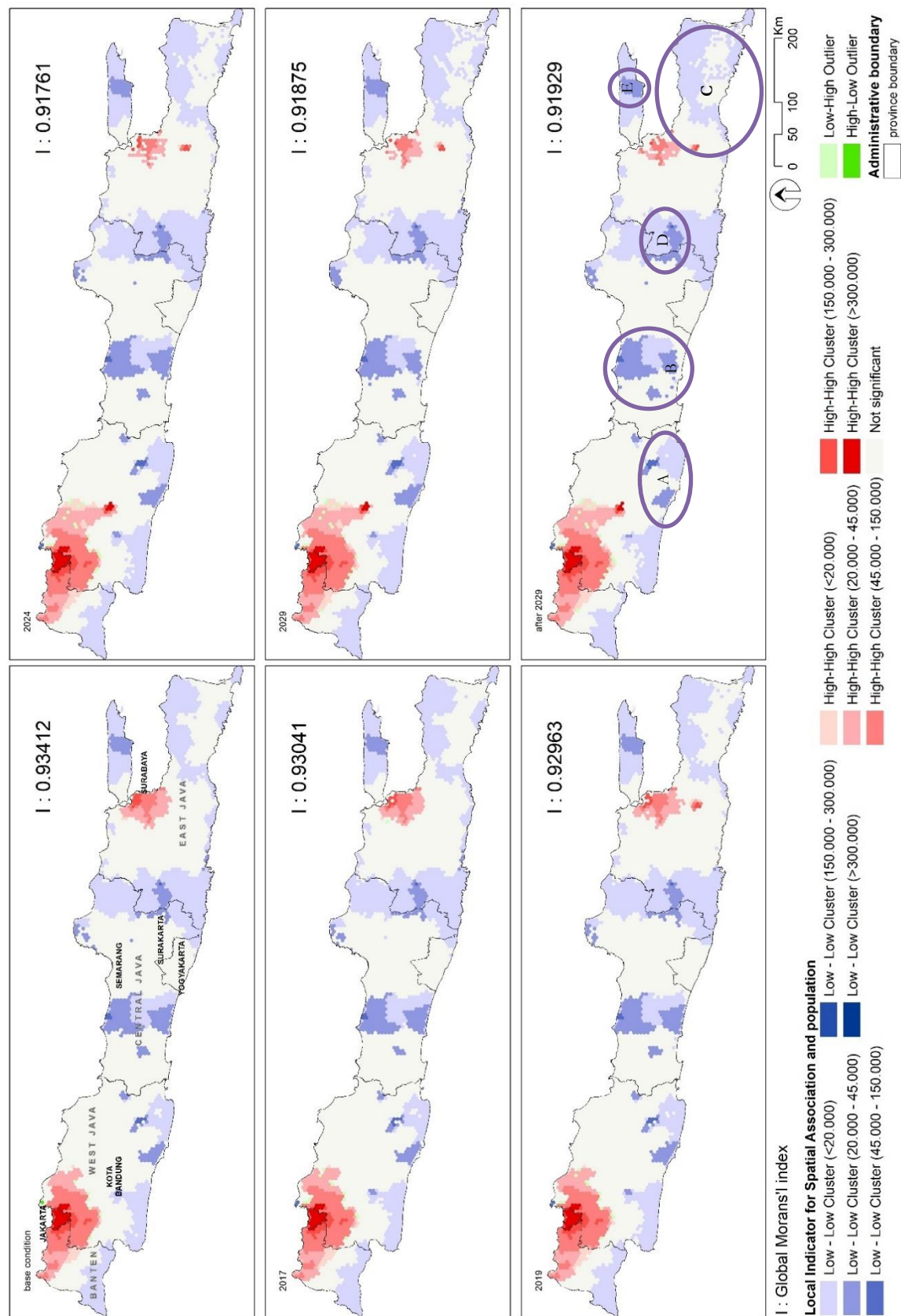


Figure 38. LISA and population map

## 6.2. Usability test and evaluation

The usability evaluation was conducted through two activities, workshop for DM simulation and questionnaire. The workshop was evaluated by qualitative observation, while the questionnaire was evaluated by quantitative Likert scale method.

### 6.2.1. Workshop and Stakeholders input

The aim of the workshop was to evaluate the usability of the prototype to support collaborative planning of road development. Arranged to imitate the DM process of road development, this workshop was designed to simulate the collaborative DM process involving stakeholders from various institutions that take part in the DM process for road development.

#### 6.2.1.1. Workshop results and discussion

In this report, the workshop group will be named based on the workshop locations, which are Jogjakarta, Jakarta and Enschede. The workshops were divided into two sessions. Session one was drawing session, while session two was simulation session. During the workshop, the participants acted as stakeholders who were responsible for road development, and they were asked to select the most prioritised location of the road development intervention to improve accessibility. The final goal was to achieve the most desired equitable accessibility.

In session one, the participants were provided with two sets of hard copy maps, accessibility map and equity map. The equity map was represented by local indicator of spatial association map (LISA). With the aim to facilitate the participant's dialog in deciding the best location of road development to achieve the better accessibility, these maps were also provided as a GIS layer in the prototype. Moreover, these maps were overlaid with the road development intervention plan that will be the option for the participants to select. The participants were asked to use the maps to identify the accessibility problem in the study area. To communicate their idea, the stakeholders were provided with drawing tools to describe their proposed road development location on the hard copy map. The stakeholder worked together in several groups to produce an agreement of the intervention. Figure 39 and Figure 40 illustrates the drawing session of the workshop.



Figure 39. Drawing session (Yogyakarta workshop)



Figure 40. Drawing session (Enschede workshop)

The aims of this process was to evaluate how these two maps can assist stakeholders to understand the decision problem. The accessibility map showed the level of accessibility in each observation, whilst LISA map showed the cluster of low and high accessibility locations. It was observed that the stakeholders preferred to use the accessibility map than LISA map during the session. This is presumably because the accessibility map helped the stakeholder to identify under-access areas that they perceived as locations that needs more road development intervention. In addition, the stakeholders observed that the accessibility map was easier to understand as it shows more distinct information about accessibility value with wider intervals. The stakeholders tend to use the accessibility value intervals provided in the map to prioritize the



intervention location. In contrast, the LISA map shows the cluster of low access and high accesses, hence they could not get the overview of accessibility value for each observation unit.

In session two, the participants used the prototype to evaluate the selected intervention. The analytical function provided real time information of accessibility and equity level. Participants examined the impact of selected intervention to the accessibility and equity level. The simulation was supported with information of estimates resource required, the benefit (accessibility improvement) and cost (road development cost), and the equity level. This information was used by the participants as a consideration whether the selected intervention was beneficial or not, so they could improve the selection.

During session two, it was observed that participants were actively involved in the discussion. They used the prototype to investigate the impact of their selected intervention to the accessibility. However, the participants appeared to focus more on the maps than the graphs. They were inclined to evaluate the improvement of accessibility of under-accessed area, but they did not take into account the equity improvement. Nevertheless, they used the equity measure tool to evaluate whether there are new emergence of low-low clusters in the LISA map or not. They also compared the result with the provided population map (in the 3<sup>rd</sup> workshop) to investigate which area required accessibility improvement (they assumed that the more population, the more access required).



Figure 41. Simulation (Yogyakarta workshop)



Figure 42. Simulation (Enschede workshop)



Figure 43. Simulation (Jakarta workshop)

The inputs from the participants to the prototype improvement can be categorized into three types of inputs, which are inputs in the indicator, inputs in the prototype functions and inputs in the user interface.

#### *Workshop result: additional indicator*

In Yogyakarta and Jakarta workshops, only accessibility and LISA maps were provided. Even though the maps could assist the stakeholders to identify the most needed area, however, more information was required to achieve more reliable selection. In the plenary discussion session, the stakeholders suggested

other indicator to identify the location of the intervention which were land use and population density. With the assumption the denser the population in an area, the more economic opportunities needed, hence this area should be prioritised for the road development. Whereas, land use and spatial pattern map gives more overview of the current function of the land, and thus can be used as a consideration in the intervention selection. For example, agriculture areas need more access to the economic activity locations that provide more agriculture market. This map can also notify the stakeholders which zones are potential for conflict if the road development is implemented, for example when the development is located in customary land, conservation land or other prohibited land.

Furthermore, the Yogyakarta workshops participants also suggested other indicators. Resource requirement comparison between different options of intervention helped the participants to determine which interventions are more beneficial. Additionally, the more detailed information for road upgrading options including its benefit and cost were also suggested to be considered in the prototype. This information will strengthen the consideration of intervention selection.

Based on the feedbacks from Yogyakarta and Jakarta workshops, two additional maps were incorporated to the prototype display and printed for drawing session during the Enschede workshop. Participants were accommodated with sets of accessibility map, LISA map, population and land use map. The participants used the additional two maps as a consideration in determining which locations required more accessibility than the others. Thus, these two maps improved the prototype usability to support the collaborative process in selecting the interventions.

The SDSS prototype should be able to facilitate the spatial communication among stakeholders. The addition of land-use and population maps in the prototype were employed to achieve this requirement. This information was proven to be able to improve the understanding of the participants to the real-world situation. However, the LISA map that was supposed to provide equity information, was deemed difficult to be understood by the participants.

On the other hand, the decision makers of national road development who were participated in Jakarta workshop perceived the prototype differently. As they are mostly experts in road and transport management, they tend to evaluate the technical functions and the quality of the prototype. The experts suggested to consider several aspects which are 1) road side frictions; they argued that these affect the traffic flow, decrease the vehicle speed, and thus reduce time travel to the economic opportunity (Salini, George, & Ashalatha, 2016). 2) trip distribution, which explains the number of trips from the origins to destinations and 3) road geometric, which is also mentioned by (Boroujerdian, Seyedabrishami, & Akbarpour, 2016), to influence the vehicle speed, and subsequently, the accessibility.

On a side note, with the overview of an urban planning students, participants of Enschede workshop suggest to incorporate other transport mode. They argued that all transport modes within a region are interconnected. The interconnection of each transport mode formed the transport network of a region, hence its impact to the accessibility cannot be detached. Additionally, they also argued that the options of toll road development as one of the interventions was not promoted equitability. As toll road requires payment for the user, this type of roads can only provide for people who can afford the tariff. However, since this research did not take into account the affordability, which is usually used in determining social justice (vertical equity), it was not implemented in the system.

#### *Workshop result: additional functions*

Even though the prototype was not designed to calculate the most effective intervention, this function was required to provide a benchmark of the most effective (suitable) location for the intervention (resource allocation). Since the stakeholders have varying point of views to decide the most suitable location for intervention based on their own interest, therefore this information would provide preliminary information

of the most suitable location based on accessibility indicator. The workshops participants from the Highway department argued that, because of the conflict of interest among stakeholders in road development planning, consensus would never be achieved if there was no benchmark as an illustration of the most suitable location for the intervention.

Furthermore, although the accessibility indicator was able to reflect the under-provided and over-provided area, each stakeholder might not only rely on the accessibility indicator for the road development planning. Hence, the integration of this prototype to other system that considers the interest of each stakeholders was required.

#### *Workshop result: user interface*

Students who participated in Enschede workshop emphasised more on the capability of the prototype in providing more informative user interface. The user interface is part of the DMC that facilitates the interaction between the user and the component of the SDSS prototype (Sugumaran & Degroote, 2010). Therefore, this component is important to communicate users' actions to the system, where data are input and result are displayed.

As the participants were international students who had no knowledge about the study area, they needed more detailed information to help their spatial orientation in understanding the map. They needed administrative boundary to explain the border of each region, landmark to help them recognizing places, scale to provide an overview of the extent of the study and local roads to explain all networks used for the accessibility calculation. This information improved the functionality of the maps to help them better understand the study area.

Inputs from Yogyakarta workshop were incorporated in Enschede workshops by providing graphs of resource requirement comparison among interventions, trade-off graph of benefit (accessibility improvement) and cost (length of road needs to be developed/upgrade). These improvements aimed to improve the capability of the system to communicate the output of the system to the user. However, since the participants of the third workshop still needed more time to understand the graphs, further improvements is still required. Furthermore, some graphs which have more than one indicator in one graph (such as benefit and cost trade-off graph) cannot be designed as expected in CommunityViz chart generator. Accordingly, modification should be undertaken.

Spatial DM process requires an iterative, interactive and participative involvement of stakeholders (Sugumaran & Degroote, 2010). The user interface of the prototype fulfilled these requirements by allowing users to interactively communicate with the system by simulating different options of interventions to the system. The system was proven to facilitate the participative collaboration between users in selecting the most desirable location of the interventions. However, the processing time of accessibility measure (about 2 minutes) did not satisfy the users, so improvements are still required to provide more user-friendly interface.

## 6.2.2. Usability Questionnaire

### 6.2.2.1. Perceive usability

The usability questionnaire data was collected during each workshop session and was analysed by each workshop group. Relatively, as described in Figure 45, the participants answered the questions by giving score between 2 and 5. However, since most of the questions were scored in “neutral” answer between 3 to 4, the variability is rather low. The analysis result showed that each workshop group appraised the usability level differently. The participants from local government and academics in Jogjakarta workshop tend to evaluate the usability in high scores. While participants in Jakarta workshop, who were the road development experts, assigned lower scores.

Yet, participants from all workshop groups agreed that the prototype has a high score in accessibility-usability aspect. The prototype is considered to have sufficient function for collaborative environment and easy to be understood by users of various backgrounds. Figure 46 indicates that the learnability (QB1 and QB2) level of the prototype is lower than other aspects. While in Figure 45, participants of each workshop groups agree on the learnability score, which is lower than other aspects. Hence at the beginning of the workshop they asserted that the system was slightly complicated, not easy to be understand and not easy to

be used without assistance and sufficient guidance. These issues should be addressed in the next iteration of the prototype development, otherwise the system can neither be used efficiently and nor be trusted by the users (Boroushaki & Malczewski, 2010)

Jogjakarta and Enschede groups had similar evaluation in most of the usability aspects. User interface, user error protection and operability were scored between 3 to 4 which indicate neutral answer. It can be assumed that the participants were not satisfied with the tools, yet they still anticipated to use the functions.

Generally, users agreed that the prototype can assist the collaborative planning process, it is showed by the distribution of the answers that are mostly between 4 to 5 (see

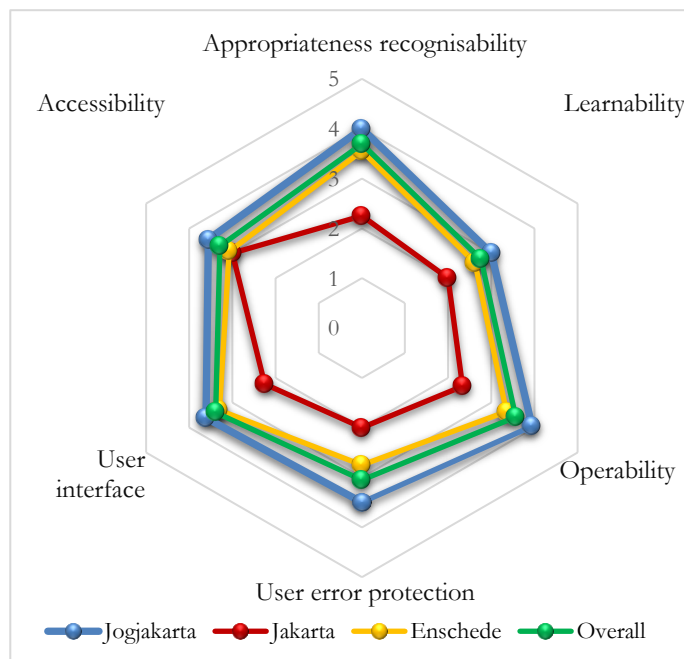


Figure 44. Spider diagram perceive usability

Figure 45). Moreover, the prototype was overall scored good in appropriateness recognisability aspect.

It was found that users who are road development experts in Jakarta workshop gave lower usability score than another workshop group (see Figure 44). During the workshop discussion, it was observed that the stakeholders in Jakarta perceived the prototype as a ready to use system that can be implemented directly to the DM process. Thus, they expected a complete system that satisfied the current DM making needs. This high expectation led them to score the usability lower than the other workshop group participants.

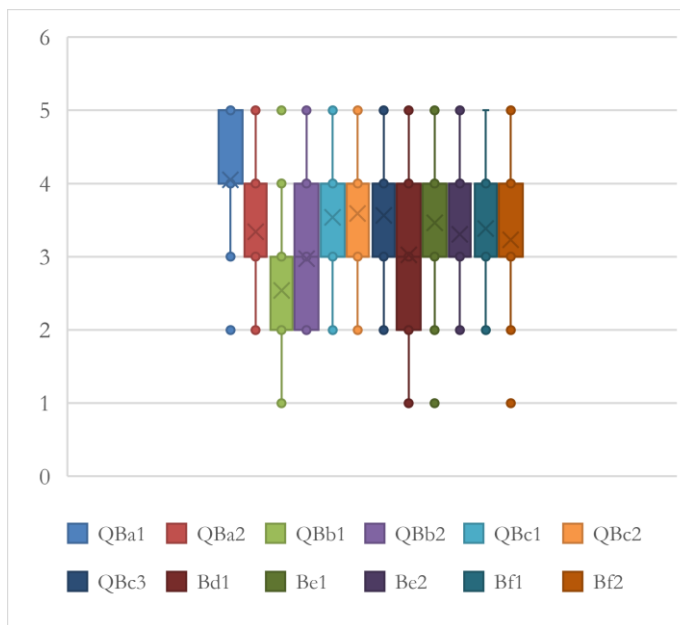


Figure 45. Box plot perceive usability questionnaire data

Appropriateness recognisability

QBa1 : helps the planning process

QBa2 : reliable information

Learnability

QBb1 : easy to use without assistance

QBb2 : sufficient guidance

Operability

QBc1 : easy to use

QBc2 : well integrated

QBc3 : practical to use

User error protection

Bd1 : informative alert of mistakes

User interface

Be1 : sufficient overview (access. map)

Be2 : sufficient overview (equity map)

Accessibility

Bf1 : sufficient functions for collaborative environment

Bf2 : easy to be understood by various background

#### 6.2.2.2. Advantage of the collaborative planning workshop

Beside the usability, the questionnaire was also used to measure the advantage of the collaborative planning workshop based on user perception. The questions captured user's understanding of whether the collaborative planning approach that supported with SDSS would improve the communication amongst stakeholders and assist the DM process. However, these questions were not given to the Enschede workshop groups, because of their limited knowledge about the collaborative planning in the study area.

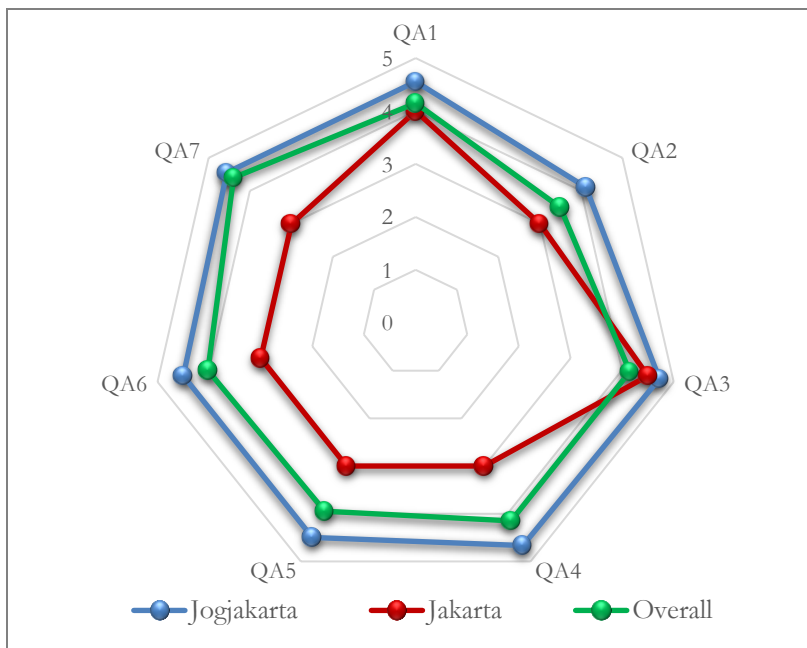


Figure 46. Spider diagram: advantage of collaborative planning workshop

QA1: helps me to learn about the spatial impact of road development location

QA2: helps to understand the disparity of road service

QA3: Collaboration induce better road planning

QA4: allows users to exchange ideas and understand others needs

QA5: helps to communicate the consequence of road development planning

QA6: helps to understand internal (organization) impact

QA7: helps to understand external impact



Generally, the users agreed that the collaborative approach which had been simulated during the workshops would improve the DM process. Therefore, the data distributions indicate similar behaviour with the perceived usability aspect. Users tend to give score ranging from 3 to 5 for the questions.

Similar to previous analysis, Jakarta workshop participants tend to give a lower score for each question. However, as shown in Figure 46, the stakeholders in Jakarta group agreed that the collaborative planning approach can assist the DM for road development with better outcomes. They also agreed that the prototype helped them to understand the spatial impact of the road development location.

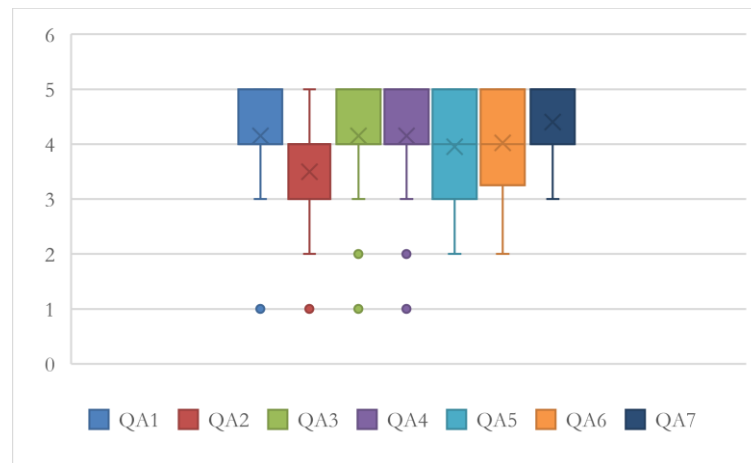


Figure 47. Box plot collaborative workshop advantage questionnaire data

There are shortcomings in Likert scale methodology. First, we cannot presume that the respondent has the same point of view in perceiving the value of the score. Moreover, there is a tendency that users answer the question in the neutral score which cause uncertainty in the analysis result. Furthermore, respondents tend to avoid extreme responds, they prefer to agree with questions that are expected by the experimenter (Nadler, Weston, & Voyles, 2015).

Notwithstanding the shortcomings, the use of questionnaire was able to indicate the usability level. It could describe the different points of view between user groups based on their backgrounds and expectations. It had been proven that the different expectations between user groups generated varying perceptions about the usability level.



## 7. CONCLUSIONS AND RECOMMENDATIONS

This research aimed to answer research questions with respect to the development of SDSS prototype for road infrastructure development. This chapter discusses the conclusions and research findings to address the research objective as well as research limitations and recommendations for future research development. The first section discusses the conclusion and discussion, while the second section presents the research limitation, and recommendations afterwards.

### 7.1. Discussion and conclusion

#### 7.1.1. Existing condition of accessibility to the economic opportunity in study area

To answer the first sub-objective, this research evaluated the existing condition of the accessibility in Java island, by applying contour measure or daily accessibility based on cumulative RGDP and cumulative number of cities. Coefficient of variation (CV) and spatial autocorrelation method, which includes Global Moran's I and LISA explained the equity. The accessibility is described as the cumulative economic opportunity that can be reached in two hours travel time from the origin (point of observation). CV describes the spatial variability distribution of the accessibility, while, the overlay of LISA and population map provide an overview of under-provided and over-provided area. High accessibility cluster with low population explains over-provided condition, while low accessibility cluster with high population explains under-provided condition. These equity indicators were used in this research, to assist the decision makers in deciding an equitable distribution of resources.

The highest accessibility areas in Java island are located in greater Jakarta area, Surabaya and their surroundings. The highly accessible cities are mainly located in districts with high number of population. However Central Jakarta and Bogor have high accessibility even though both cities serve smaller population number. The least accessible areas are located in the centre of Central Java, the boarder between Central Java and East Java, southern part of West Java and the eastern part of East Java.

The spatial autocorrelation analysis demonstrated cluster behaviour of accessibility distribution. Similar to the accessibility map, LISA map shows that the cluster of high accessible areas are concentrated in Jakarta and Surabaya and their surroundings. It signified that these areas are located in the most advantageous locations, which have sufficient road infrastructure and close to economic activity centres. Therefore, people in those areas have easier access to the opportunities which are provided in the economic centres, hence potentially improve their economy.

As RGDP determines the attractiveness of the economic activities, hence, the significant different of RGDP value between economic activities which are located in big cities and small cities influenced the result. Furthermore, this research used the urban cities and districts with population more than one million people as a proxy to define the centre of economic activity, so this location may not be distributed evenly throughout the study area. The uneven distribution of economic activities also influenced the accessibility result.

The low accessible and non-accessible location are not only dependent on the transportation network, but also the spatial distribution and the masses (RGDP) of the economic activities. Thus, the lowest accessible locations are mainly located in area with low density of economic activities. The decision makers should clearly understand the concept that the low and high accessibility value is not solely influenced by the quality of transportation network, to prevent blunder in the DM process.

### 7.1.2. The development of SDSS framework and prototype in resource location allocation for road development

The Indonesian government applies top-down and bottom-up approaches for the road development planning process. The top-down mechanism still dominates the DM process, which is highly dependent on the president's policies. Hence, the national planning agenda emphasises road development based on presidential policy, which are focused in 1) border areas are that currently inaccessible, 2) southern Java road network (*jalan lintas pantai selatan jawa*) and 3) strategic areas (economic, tourism and industrial area). One of the transportation development policy objectives is to improve national accessibility and connectivity to achieve equity. Hence, this research proposed the concept of equitable accessibility as a proxy to achieve this policy objective. All road development agendas should be adapted to this policy, however the mechanism to decide priority road segments is still questionable.

This research identified that, the road development planning process is a comprehensive process which is started by general national planning and particularised to sectoral planning. The national road development sector is the responsibility of the Ministry of PUPR. The resource allocation for national road development is implemented by the ministry, which is directly involved in the road development implementation. While, the general planning involves external stakeholders, who are not directly involved in the resource allocation mechanism. Based on these direct and indirect involvement to the resource allocation planning, this research categorizes the stakeholders into two categories, direct and indirect stakeholder.

To facilitate the communication between stakeholder in DM process, this research designed a SDSS prototype to support the collaborative resource allocation DM process. This prototype is intended to be used by the direct stakeholders, to synchronise the perceptions of each directorate in prioritising the resource allocation. In which, requires the involvement of other organizations such as the local government and other ministry to coordinate their needs. However, due to the top-down planning approach, the prioritisation of the resource allocation still has to adopt the national policy.

The domination of the top-down planning process, however, becomes the impediments of the SDSS prototype implementation. Because the national planning accommodates the priority programme of the current president, hence it is strongly affected by the political agenda. It was also stated by Geertman (2017) and P. Pelzer (2015) that the dependency of DM process to the political dynamic, potentially produces a gap for SDSS implementation. Based on the interview with the road development planner, I found that the road development still has to focus on the national agenda. Regardless the political dynamic, a SDSS could be implemented to support the screening and evaluation process that requires coordination between each directorate in highway department, the local government, private business entities and other organisations.

The prototype was developed to simulate the impact of road development on the accessibility. It was proposed only to model a part of the DM process, which is prioritisation of resource allocation. In the real DM for road development, a more complex process is applied. Nevertheless, as accessibility measure is not commonly used in the organization, all stakeholders who are involved in the DM process should be clear with the mean of “accessibility” and what is the goal (Curl et al., 2011). Hence, this measure could be utilised as a proxy to assess road development, in achieving the planning objective. However, the indicators should be agreed by the stakeholders who intend to use it. On the other hand, the stakeholders stated that validity test is essential. Whether the system could accurately represent the real-world problem should be tested before the implementation of the system.

One of the road development planning objectives is to improve accessibility in under-developed area and improve connectivity to achieve equity. Thus, this research proposed the concept of equitable accessibility as an indicator in the DM process, as it is adopted to develop this SDSS prototype. The prototype is divided into four components, DBMC, DMC, MMC and SC. It adopts the concept of accessibility and equity as the core of the system, which is part of MMC and DBMC. The accessibility measure is operationalized using

contour measure method in network analysis plug in of ArcGIS. Whilst equity measure is implemented using spatial autocorrelation (LISA and global Moran's I) principle in ArcGIS spatial statistic tools and CV principle in CommunityViz formula generator. The user interface (DMC), which functioned on the platform for user-system interaction is developed in CommunityViz.

Technically, there are still shortcomings in the integration of ArcGIS network analyst and spatial analyst with the CommunityViz PSS (planning support system). As they run on different platforms, the users should do intermediate action (user have to click accessibility measure button and wait the calculation which required approximately two minutes for the process) before they can see the impact of the intervention they had simulated in the system. Whereas, they expected immediate accessibility impact which can be shown interactively in the accessibility map display without additional process. Moreover, the functionality of chart generator in CommunityViz does not fulfil the requirement of the prototype development, hence, modification should be undertaken. These issue is hindering the user friendliness of the prototype.

### **7.1.3. Implementation of the SDSS prototype for equitable accessibility improvement in study area**

#### *The overview of accessibility and equity measures for a decision support tools*

One of the characteristics of a support system is its user-friendliness. Hence, the selection of accessibility measure should accommodate it. This research applied contour measure based on its easiness to interpret and generate. It provides accessibility value in an easy to understand unit, which is number of RGDP, in which decision makers who have varies backgrounds can easily understand it. The simple calculation of contour measure leads to a faster computation time. As mentioned by Silva et al. (2017), to enhance the utilization of accessibility measure in a support system, the computation time should be fast enough to facilitate users with an interactive function. However, contour measure is limited with the difficulty to determine the travel distance threshold. In this research, assumption about the willingness of travellers to travel back and forth within one day is used to define the threshold, yet we cannot assure that all districts have the same threshold. This measure does not take into account the discount effect of travel time, hence all distance within the threshold are threatened the same.

For a more realistic model, potential measure is more ideal in capturing the real world as it better reflects the behaviour of travellers. It takes into account the discount effect of the travel time. The distance decay function represents the traveller's perception of transport. However, the implementation of potential measure should be followed with a breakthrough to speed-up the computation time. A clearer guidance to interpret the accessibility is also required. Moreover, this measure is more complex due to the necessity to calculate distance decay function.

As mentioned by Bröcker et al., (2006) and Monzón et al., (2013), that there is no ideal method for equity measurement. Hence, the selection of equity measure is rather complicated. The CV and Global Moran's I index are intended to help stakeholder to view the equity in one simple value and, thus, easier to understand. As, decision makers tend to believe a single value index in explaining the real-world condition. Several researchers applied the CV to measure equity, they rely on its capability to measure the data variability. However, this measure fail to guide decision makers in allocating resource for road development in equitable way. Furthermore, there is no guarantee that the less variability indicates more equity.

Other researchers used spatial autocorrelation to explain the equity, which are Global Moran's I and LISA. Several researchers used the characteristic of similarity and dissimilarity of the whole dataset to explain equity. They claimed that similar data distribution, which means cluster distribution of data, reflects equity and vice versa. However, similar with CV, in this research, Global Moran's I cannot explain the equity in the study area. We cannot relate the cluster behaviour of accessibility data with the equity condition.

The application of local indicator (LISA) is able to show a map of high and low accessibility cluster. We can use population as the proxy to indicate the “needs” of transport infrastructure provision. Hence, by superimposing the LISA map and population, the decision makers can obtain an overview of the infrastructure provision level. The overlay of LISA map and population succeeded in giving an indication of whether the resource allocation is equitable or not. The equitable resource allocation is indicated with the decrease of low-low cluster in populated area. In other words, the decrease of low cluster in more populated area and high cluster in lower populated area indicates equitable resource allocation, and more equitable accessibility. Thus, compare to the previous indicator, LISA map best assists decision makers in equitable resource allocation

Furthermore, as suggested by Taleai, Sliuzas, & Flacke, (2014), the promotion of equity is achieved when we consider service standards in assessing distribution of opportunities. We can assume that the distribution of services is equitable when everybody fulfills the minimum needs standard. However, in this research, defining service standards for macro level accessibility to the economic opportunity is a rather challenging task. As still questioned by Silva et al., (2017), “*how much accessibility is enough? Should we, could we identify critical accessibility threshold....*”. Besides, the available norm about minimum service standard focuses more on the technical aspect of road development, making it difficult to be implemented in the prototype.

Talking about the implementation of the measures in a planning support tool, according to Brömmelstroet (2010), accessibility concept, as an integration between land-use and transport planning method, is still lack of utilization. Silva et al. (2017) mentioned that there is a dilemma of planning support developer in improving the scientific reliability of the accessibility measure or the usability of the system. For example, the system should provide an interactive functions which allows a real time interaction between user and computer, while improve the reliability of the tool. Therefore, there should be an intensive engagement between the developer with the user during the development process, to ensure the usability of the system, yet fulfil the requirement to accommodate the planning goals.

#### *Usability of the prototype*

Based on the simulation of national road development plan, it is found that the interventions of national road development improve the average accessibility over time (year of 2017-2034). There is a decline in of Global Moran’s I index and an increase of CV, which suggested more variability of accessibility distribution and more dissimilarity patterns. The LISA map showed the emergence of low-low accessibility cluster in some part of the study area. Hence, I conclude that even though the average accessibility increase, there is inequitable resource distribution in the simulation of intervention, which is indicated by the increase of low accessibility cluster.

Geertman (2006) stated that a SDSS is a geoinformation-technology based instrument with modelling, visualization and other functionality which has been developed to support collaborative planning and DM process. Based on this statement, the findings of the usability workshop proved that this SDSS prototype was able to fulfil its function as a tool for bridging stakeholders’ interests in road development DM process. The workshop participants mentioned that this prototype helped them get involved in the selection of the most required option of road development intervention. It helps them to model the impact of the selected intervention to achieve equitable accessibility as an indicator for describing the planning objective. Furthermore, it allowed users to interact in deciding the most desired location for resource allocation.

Overall, the workshop showed that this prototype was successful in involving the participants in discussion and exchange of ideas. This proved that this prototype was proven can assists collaboration. It could stimulate their eagerness to interact with each other. Furthermore, the workshop participants mentioned that this prototype was applicable to assist the collaborative DM process. This concurs with Andrienko et

al., 2007; Arciniegas & Janssen (2012), who asserted that SDSS prototype was able to facilitate the communication of spatial information amongst different actors. However, improvements are required.

The workshop participants suggested other indicators for considerations in selecting interventions to improve the usability of the prototype. Yet a more critical input came from the Jakarta workshop group, which consisted of national road development experts. They put more emphasis on the technical function and the quality of the prototype. They suggested other indicators that directly impact the accessibility to be taken into account in the prototype, such as road side friction, trip distribution and road geometric. Furthermore, they tend to use mobility as the indicator for road development planning than accessibility.

This research found that most of the participants did not take much attention to the equity measure in the prototype. Instead, they focused more on the accessibility map which according to them, gave more understandable information. Accessibility maps aim to help communicate the impact of road investment to the accessibility (Boisjoly & El-Geneidy, 2017). The participants' focus on the accessibility map could be influenced either by the map display itself, or the gap of facilitation between the workshop moderator to the participants in communicating the message of LISA map. Notwithstanding, they used the printed LISA map to decide the location of the intervention. The low-low cluster of accessibility in the LISA map gives them an overview of which location required more intervention than others.

This research identified that a suitability tool, which is a tool that can generate the most suitable location for intervention is required. As the suitability factors, the stakeholders mentioned that road development should support strategic areas, such as industrial areas, tourism areas, and economic centres, yet avoid restricted areas such as conservation land. The road development experts stated that they needed to get a preliminary overview of the most beneficial location for road development which leads to the most equitable accessibility improvement. This information is important as a benchmark for the collaborative process, to facilitate consensus. The absence of this function will lead on debate of which locations is the most beneficial, based on their own interest. Additionally this function will improve the usability of this prototype to support exchange of information, identify conflict and compromise between stakeholders (Borouhaki & Malczewski, 2010).

During the Enschede workshop, it was found that this prototype provided too many graphs information in the user interface. Users needed more time to understand the information, and they tend to ignore it. As stated by Arciniegas & Janssen, (2012), too much information presented in the prototype decreased user's interest to take it into consideration, even though the information is relevant for the interventions selection. Moreover, participants also tend to skip complicated information.

The three phases workshops suggested that user inputs, especially from the potential SDSS prototype users, are important to improve the usability of the prototype. They help to deliver the message of the most required and applicable indicator which is most suitable to the real DM. Hence, it will improve the model to get closer to the real-world. The involvement of potential users helps to improve the quality as well as the legitimacy of the prototype (Flacke & de Boer, 2017), to be implemented in the real DM process. However, the input of user interface is no less important. As mentioned by Geertman, (2017) and Silva et al., (2017), user-friendliness is one aspect that potentially hampers the implementation of SDSS.

Through the usability questionnaire, this research discovered that the workshops improved user's understanding of the spatial impact of the road development location, especially to the equitable accessibility. They agreed that the collaborative DM process leads to better road planning. This perception is affected by the fact that the DM process involves stakeholders with varying points of view which might lead to conflicts. Thus, facilitation is required for the communication. They specified that this collaborative planning approach helps them to communicate their interest, idea and needs related to road development planning. Based on the usability indicators (appropriateness recognisability, learnability, operability, user

error protection, user interface and accessibility), The majority of users perceived this prototype as usable. However, this prototype is deemed not easy to use without assistance from the workshop moderator. This can potentially hinder the implementation. Furthermore, the road development experts tend to give lower usability score. As they clearly understand the DM needs, they expect more applicability of the prototype. Another reason is that they are more familiar with mobility principle than accessibility in DM process.

#### *Implementation to a planning process*

Boisjoly & El-Geneidy (2017) found that there is a trend of integrating accessibility in transport planning, but the accessibility-based indicator is rarely used in the DM. Similarly, even though one of the transport planning objectives in Indonesia is accessibility improvement of under developed area, the accessibility-based indicator is not used in the DM process. Mobility principle that focuses on reducing time travel is more familiar to the decision makers. The reduction of time-travel is one of the targets (Department of Highway Ministry of PUPR, 2015), however the notions of accessibility in the planning document is not clearly defined. Hence, the decision makers show a reluctance in applying this prototype.

The concept of “accessibility improvement” in the planning documents should be translated into an applicable performance indicator. Hence, the DM can measure the level of accessibility improvement to obtain the planning targets. Additionally, there should be an institutionalization of accessibility concept among the decision makers, and an internal agreement of stakeholders to use accessibility indicator in the DM process. As stated by Silva et al. (2017), that the lack of institutionalization of accessibility instrument becomes an impediment of the application of accessibility-based DM tool. Moreover, accessibility goal needs to be clearly defined with a distinction between accessibility and mobility principle (Boisjoly & El-Geneidy, 2017).

Notwithstanding, according to the questionnaire, there are two significant added values of this prototype to the DM process based on stakeholder’s perception. first, this system helps them to understand about the spatial impact of resource allocation location, especially to the accessibility. And second, they perceive that a collaborative mechanism proposed by the concept of the prototype will leads to a better planning. During the interview, they also mentioned that this kind of tool can help them in screening the development program (process of selecting the most priority program to be implemented). However, they still do not have idea in which process it could be implemented. Because of the limited scope of the prototype compare to the real DM, they require more indicator to be considered. Additionally, due to the domination of top-down approach of DM, as mentioned in the previous sub-section, the prioritization of resource allocations still need to consider the national policy. Hence, the implementation of this prototype might not significantly improve the DM process. However, it still capable, at least, to bridge the interest of various stakeholder with regards to accessibility improvement as one of the planning objectives.

From the technical point of view, for the implementation purpose, we need to improve the user-friendliness of the prototype to increase users willingness to implement it (Geertman, 2017). The calculation time of accessibility measure, for a collaborative DM support tool is still considered too long. It potentially hinders the interactive function of the prototype, hence needs to be accelerated. Moreover, there is also a need to make the measure simple and easy to understand by the decision makers, while clearly represents the complexity of reality (Silva et al., 2017; Taleai et al., 2014). Thus, a simplification of the information in the user interface is required.

## **7.2. Research limitations**

This research has limitations, which are:

1. Due to the data limitation, the utilized accessibility measure does not capture the effect of time dimension and individual preference. Moreover, the overlap service area polygon (that is generated by



the contour measure) leads to double counting in accessibility value and ignores the competition aspect between traveller.

2. This research did not examine the topography aspect into the accessibility measure. Whereas it potentially affects the accessibility due to the mountainous topography of Java island.
3. Even though the Global Moran's I and CV provide single value index which is easy to be interpreted by the decision makers, however those indicators do not significantly explain the equity level in the study area.
4. The processing time of accessibility calculation in ArcGIS platform is considered too long for an interactive tool, thus, hindering the user friendliness of the prototype.

### **7.3. Recommendations**

Based on the research findings and limitations, recommendations for further research and prototype development are proposed as below:

1. Preliminary research before the development of SDSS is required to get a comprehensive overview of the needs and DM mechanism in the study area. Hence, more intensive engagement with the stakeholders is required before the SDSS development. Focus group discussion can be used to establish the indicators, and thus, fulfil the requirement and make the system closer to the real-world problem, hence the system can be applied to support the planning process.
2. This research is applied in Java island, by considering accessibility at macro level. Consequently, the accessibility measure only considers land-use and transport component, and uses contour measure or daily accessibility measure for the accessibility evaluation. To get a more comprehensive and reliable result which is closer to the reality, temporal and individual component can be taken into account in the accessibility measure. The individual component can reflect the needs of travellers based on their individual characteristic. On the other hand, the temporal component will explain temporal constraints such as the availability of opportunity at different time and traveller's time in accessing the opportunity. Hence, the congestion phenomena can be captured. Other accessibility measure (such as potential measure) can be used to evaluate the effect of distance decay to the accessibility level. However, this comprehensive measure might be more efficient to be implemented in local or micro level than macro level due to the complexity and its impact to the user-friendliness of the SDSS system (such as longer processing time, uneasiness for interpretation and data availability). Furthermore, different transport modes can be considered in the accessibility calculation.
3. Instead of adopting the horizontal equity concept applied in this study, further research can combine it with vertical equity concept which takes into account the different abilities and needs, such as income and social class. Furthermore, application of minimum service standard as a threshold for the road development service provision can be considered.
4. Further research can assess other equity measure to obtain the most appropriate equity indicators to be implemented in developing SDSS.
5. To assist the achievement of consensus in a collaborative decision making, this prototype should be completed with suitability analysis to give an overview of the most suitable road segments for resource allocation.
6. There is a need to accelerate the accessibility processing time to improve the user-friendliness, since the lack of user-friendliness is one of the SDSS implementation gap.

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## APENDIX

### APENDIX : Usability Questionnaire

#### Advantages of the collaborative planning workshop

No	Question	Strongly disagree			Strongly agree		
		1	2	3	4	5	
1.	This workshop helps me to learn about the spatial impact of road development location						
2.	This tool and the workshop helps me to understand the disparity of road service in Java island						
3.	Collaboration between each party that has interest in road development induce to better planning for road development location						
4.	This collaborative decision-making simulation allows users to exchange ideas and understand others needs in term of road development planning						
5.	This prototype helps me to communicate the consequence of road development planning location to the other parties						
6.	This collaborative decision-making simulation helps me to understand the impact of the planning to my organization						
7.	This collaborative decision-making simulation helps me to understand external impact of the planning process.						

#### Perceive usability of the prototype

No	Question	Strongly disagree			Strongly agree		
		1	2	3	4	5	
Appropriateness recognisability							
1.	I think this prototype can help the planning process for road development to achieve equity of accessibility to economic activity						
2.	I think the information provided by the system is reliable						
Learnability							
3.	I think I can use this prototype without any support from technical person						
4.	There is sufficient information and guidance to use this prototype						
Operability							
5.	I think the prototype is easy to use						
6.	I think functions in this prototype are well integrated						
7.	I think this prototype is very practical to use						

User error protection					
8.	There is informative alert when I make a mistake while using this prototype				
User interface					
9.	I think the thematic map (accessibility map) gives sufficient spatial overview to decide the location of road development intervention				
10.	I think the equity measure map (LISA map) gives sufficient spatial overview to decide the location of road development intervention				
Accessibility					
11.	I think the interface of the prototype provides sufficient functions to be use in collaborative environment				
12.	I think this prototype is easy to be understand by people in various background				