Spatial Decision Support System for Infrastructure Resource allocation

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February, 2013

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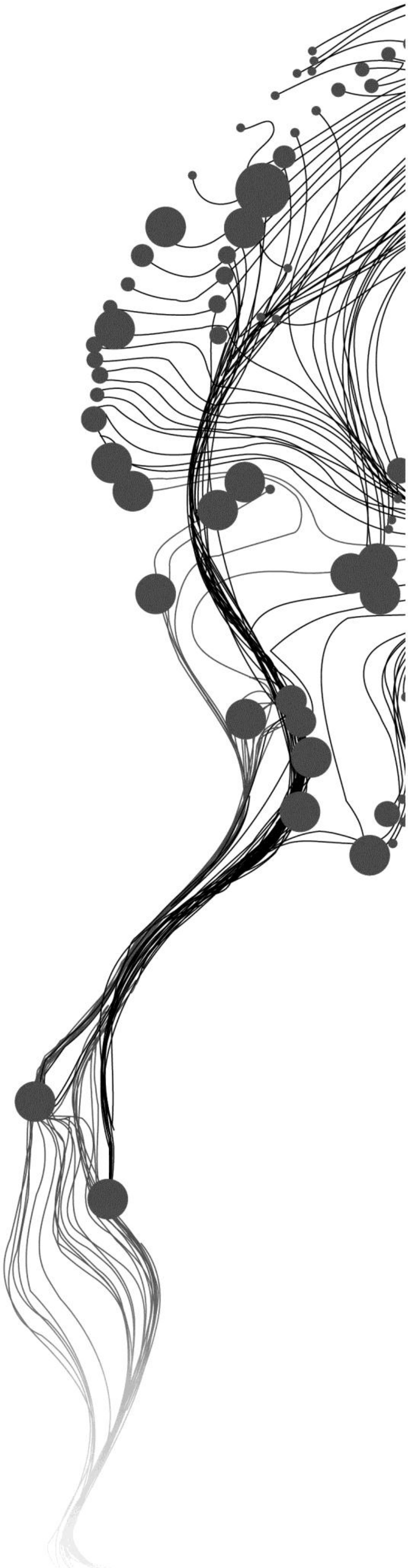

Spatial Decision Support System for Infrastructure Resource allocation

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Thesis submitted to the Faculty of Geo-Information Science and Earth Observation of the University of Twente in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation.
Specialization: Urban Planning and Management

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ABSTRACT

Cities are in an eternal state of change. They grow in size, in density, richer or poorer; they even change their main characteristics. Infrastructure planning is a key concern behind the successful planning of the constantly changing modern cities. Infrastructure planning is a complex task with large investment involved. Expenditure on infrastructure is one of the largest items between countries' budgets. Infrastructure investment is acknowledged as a main economic growth factor and with a significant impact on the quality of life *"Health, Safety, Economic Opportunities"* from both environmental and social aspects. Infrastructure investments usually involve the expenditure of large capital; however, infrastructure investments are declining worldwide.

The aim of the research is to devise a spatial decision support system (SDSS) framework to facilitate the resource allocation process for infrastructure, involving different decision-makers. This paper reports and analyses various strategies (Pro-poor policy, Market Based, Environmental) and methods (Economic Opportunities, Equity Based) that concern infrastructure resource allocation's decisions with different infrastructure goals in assigning expenditures priorities on infrastructure needs. In order to define the adopted criteria for infrastructure resource allocation process based on Current Policymakers concern, recent and on-going studies. Based on the priority concern for policymakers and economic and infrastructure researchers the research adopted the fair distribution of infrastructure resources targeting the pro-poor policy and equity based concept.

Thus identifying the workflow, processes, and methods for the adopted criteria, which will represent the complete decision process in order to design a framework for spatial decision support system (SDSS) and implement initial spatial decision support system SDSS framework that covers the adopted decision criteria of infrastructure resource allocation. The main objective of spatial decision support system SDSS is to support decision makers (e.g. government or municipalities, promoters, etc.) in achieving equitable distribution of infrastructure service the best use of the available infrastructure resources. Thereafter, simulating a real-world situation in order to operate the implemented SDSS to further evaluate the adopted criteria and the selected processes and methods.

ACKNOWLEDGEMENTS

It has been an exciting journey during the process of my thesis time period to be a part of an institution in an extremely diverse environment. Foremost, I would like to sincerely thank my supervisors Ir. M.J.G. Mark Brussel and Dr. J. (Johannes) Flacke for their support and encouragement all throughout which motivated me to perform better and survive through my thesis days. I would also like to pay sincere heartfelt gratitude to Frans Ing. F.H.M. van den Bosch for helping and guiding me through during the selection of my thesis topic. Lastly, I am grateful to my parents and my friends for inspiring me to put my best foot forward.

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1. INTRODUCTION

Cities are a dynamic creature. They are in an eternal state of change. They grow in size, in density, richer or poorer; they even change their main characteristics. Therefore, the need for a successful plan is always there. One key concern behind the successful planning of the constantly changing modern cities is infrastructure planning. Infrastructure planning is a complex task with large investment involved, as the spending on public infrastructure generally ranges from 5% to 23% of gross domestic product (GDP) for both developed and developing countries (Yu et al., 2011).

Infrastructure investment is acknowledged as a major economic growth factor. Infrastructure projects usually involve the expenditure of large capital; it also addresses the needs of several decades in the future. In other words, infrastructure is characterized of being expensive, strategic and long term. Furthermore, infrastructure being a key stone in planning has an important social, economic and environmental impact. For that, different stakeholders, with distinctive concerns, are involved in deciding on infrastructure investments. An important aspect of Infrastructure investment decisions are that they have spatial dimension as infrastructure costs and benefits are distributed spatially (Coutinho-Rodrigues et al., 2011). In brief, planning infrastructure investment is characterized as a complex task with spatial implications and different stakeholders involved.

To provide better solutions to problems related to decision making, and with the need to integrate the spatial dimension to the decision process concerned with issues of spatial nature, research concerned with the decision support system (DSS) has taken a new turn towards the so-called spatial decision support systems (SDSS). Maniezzo et al. (1998) describe the spatial decision support systems (SDSS) as systems concerned with the integration of spatially referenced data within a decision-making environment. They argue that such integration has a positive impact on the decision makers' performance.

Crossland et al. (1995) studied the impact of using Geographic Information Technology (GIS) as a Spatial Decision Support System (SDSS). They discuss that spatially integrated DSS (SDSS) can represent the missing link between policy makers and the complex computerized models. They found that decisions and solutions developed by decision makers using SDSS were faster and with fewer errors.

Following this result, and given the spatial nature of urban infrastructure investment and the different stakeholders involved, SDSS can provide decision makers (e.g., government or municipal agencies, promoters, etc.) with a suitable user-friendly framework for taking decisions about infrastructure, assessing and choosing between different alternatives.

1.1. Background

1.1.1. Urban Infrastructure

In general, infrastructure is understood in terms of technical structures that sustain a society. As defined by Keating (2008) as *"Infrastructure comprises the physical assets that a society needs for orderly operations. They include a variety of assets divided into five general sectors: Transport (i.e., toll roads, airports, seaports, and rail), Energy (i.e., gas and electricity transmission, distribution and generation), Water (i.e., pipelines and treatment plants), Communications (i.e., broadcast, satellite and cable) and Social (i.e., hospitals, schools and prisons)."*

With a variety of existing literature in defining the term itself, Fulmer (2009) regarded infrastructure as *"the physical components of interrelated systems providing commodities and services essential to enable, sustain, or enhance societal* *living conditions*". In both the definitions, infrastructure is considered as a technical structure that sustains a society. However, in this research the term infrastructure indicates the main technical forms, which are transport networks, water and sewerage and electricity and telecommunications networks.

1.1.2. Infrastructure Importance

The improvements in supply, quality and affordability of infrastructure services are essential for poverty reduction and growth stimulation. As put forth by *Dr. Jeffrey Delmon,* a senior infrastructure specialist of World Bank, who is of the opinion that *"Poor infrastructure impedes a nation's economic growth and international competitiveness"* (Dongier & Lovei, 2006). In this context, Willoughby (2004) indicates that *"Insufficient infrastructure also represents a major cause of loss of quality of life, illness and death"*. These indications make the improvements in infrastructure services both morally and economically imperative.

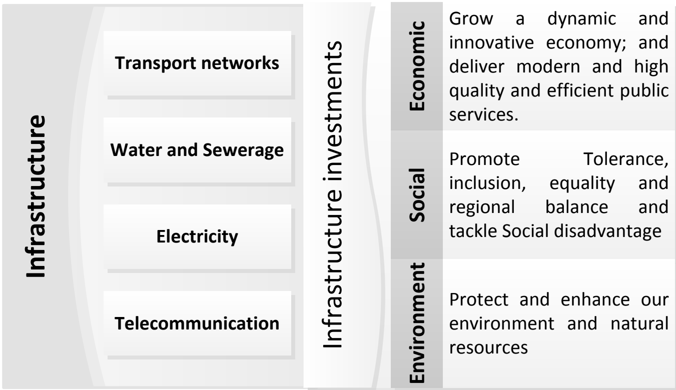


Figure 1: Urban infrastructure - Potential Returns

Infrastructure development has been acknowledged as an important economic growth factor with a high economic, social and environmental return. Thus many recent studies aim at investigating relationships between infrastructure investments and productivity, protection of environment and natural resources and tackling community disadvantage to accomplish equality and regional balance.

1.1.2.1. Economic Performance

According to Aschauer (1989) , Infrastructure investments are proven to be of high return. He argues that infrastructure quality is a significant indicator of a nation-wide economic vitality. However, as infrastructure affects economy, economic growth also affects infrastructure demand and supply. This can cause bias estimation of the overall return of infrastructure investments (Esfahani & Ramírez, 2003) .

Current studies have examined relationships between expenditure on infrastructure and productivity growth, suggesting that the differences in public infrastructure provision throughout a country is directly related to the differences in productivity growth rates of the different regions (Anwar, 2001); He argues that decisions based on public infrastructure expenditure decisions of vital economic importance. He states that the more a country spends on infrastructure the lower the prices, the higher the wages. This gives an overview about the direct effects of the importance of infrastructure, which it has on the economy.

1.1.2.2. Environment and Social Quality Of Life "Health, Safety, Economic Opportunities"

Quality of life is strongly dependent on infrastructure. A society cannot be productive or described as civilized without good transportation services, availability of clean water, and proper waste disposal operations (Aschauer, 1990). Infrastructure serves different aspects of quality of life. For example, constructing a needed freeway may reduce congestion, which means less pollution (better air quality), less travel time and fewer accidents. It may also increase accessibility, whether to leisure activities or more economic opportunities for the disadvantaged. For that, quality of life is always in the centre of interest of infrastructure planning. The concern now is the ability of existing infrastructure and its projection to maintain the current requirements of quality of life and the needed improvements (Aschauer, 1990).

1.1.3. Infrastructure Investments

In many countries, infrastructure investments allocation decision follows the economic and political views of the governments. Governments allocate prudentially infrastructure investments throughout the country (Castells & Solé-Ollé, 2005).

Expenditure on infrastructure is one of the largest items between countries' budgets because infrastructure is considered one of the main drivers of economic development (Chandra & Thompson, 2000). Still, this large amount of resource is never enough to fulfil the increasing needs of infrastructure. The needs are rising because of many reasons. Population is growing constantly and in some cases tremendously; cities are expanding. In addition, the need for more equitable infrastructure requires new infrastructure development. Finally, part of infrastructure investments naturally goes to the maintenance of existing systems.

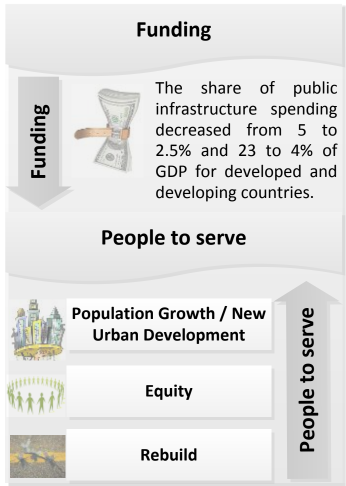


Figure 2: Infrastructure Investment

According to Wismadi et al. (2012), spending on public infrastructure is generally decreasing. For developed countries, it went from 5% of the gross domestic product (GDP) to 2.5. For developing countries, decrease is even more drastic; it went from 23% to 4%. At the same time, the trend of equitable infrastructure provision calls for greater spending on infrastructure from the side of local authorities.

1.1.4. Infrastructure resource allocation

Resource allocation is generally concerned with distributing the available resources among the needs of different groups of people. For the resources designated to infrastructure, allocating these resources have always been a dilemma. On one side, the demand for infrastructure services is rapidly growing due to population growth. On the other side, infrastructure provision costs are rising as well. For that, allocating infrastructure resources is not an easy task.

Government deals with investments designated to infrastructure carefully; they are always the subject of public and political observation. For that, a good planning practice based on adequate high-quality information is required to ensure the highest benefit from the allocated resources by implementing the right infrastructure at the right location at the right time (Martyn, 2011).

Resource allocation is one of the issues of urban planning. Planning methods are considered good when they allocate resources efficiently and effectively. These methods can maintain the required level of service provision to achieve sustainability of infrastructure. Planning methods are fundamental to follow an overall vision and to manage infrastructure needs for a longer term. They are effective for the communities that aim to have sustainable infrastructure or those that experience rapid population growth and/or have ageing infrastructure. Therefore, the central theme of this research is to develop a technique for infrastructure allocation in order to maximise the benefits.

At the local administrative level; such as village or neighbourhood, infrastructure resource allocation requires consideration for the existing infrastructure within the local and surrounding areas. Linear infrastructure networks such as roads or an electrical grid is a kind of the infrastructure system, which is highly interconnected. This kind of infrastructure system requires neighbourhood-inclusive analysis technique for infrastructure resource allocation in the decision making process.

Strategic Resource Allocation is the process of examining the methods concerning funding decisions for infrastructure resource allocation. The first to be defined are the policies and methods through which infrastructure resource allocation will take place.

1.1.4.1. Infrastructure resource allocation Policies and Methods

There are different influences that determine the criteria for infrastructure resource allocation, which could be categorized as policies, theories, concepts/rules, measures and approaches (Figure 3). Policies are defined as the basic principles that direct the government to achieve state objectives relating to the economic and/or environment and/or social and/or well-being of the citizens (Luthra, 2007-2011); policies such as pro-poor, market based and environmental. Theories are the mental models of the perceived reality; consisting of a set of assumptions that provide rational explanation of relationships among a group of observed phenomena(Luthra, 2007-2011) such as e.g. Utilitarian theories or Non-utilitarian theories. Concepts/Rules are detailed descriptions that state what to do and not to do in a specific situation or interpret a law or policy (Luthra, 2007-2011) such as Equity Based. Measures are the ways to quantify a noticeable value or performance using a specific unit. In context to Equity based concept, there are measures concerning Spatial Equity Analysis or Non-Spatial Equity Analysis. Approaches are systematic methods that are used to obtain quantitative data through observations, statistical analysis or modeling to achieve specific objectives (e.g. Total Utility, Curve Dominance Analysis).

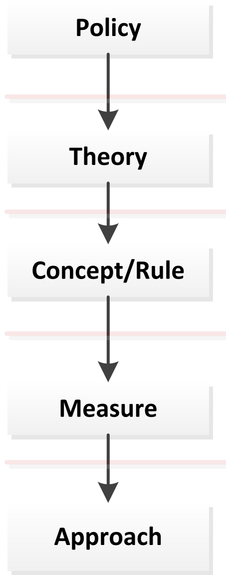


Figure 3: Resource Allocation Criteria

For this study, we will combine the literature review on the policies and methods for the Infrastructure resource allocation with one of the on-going researches to select the spatial decision support system criteria.

1.1.5. Decision Support Systems

The concept of decision support systems dates back to the 1960's, however, by the late 1970's many academicians, researchers developed interactive information systems to assist managers examining semi-structured problems by the use of data and modelling information (Power, 2007). The motive to develop such systems according to Gray (1987) was to provide a "language that would allow executives to build models without intermediaries". In 1980s, researchers introduced an improvement on decision support systems by developing a new type that allows "group" decision support systems (Gray, 1987; Power, 2007). Further, on the year of 1990 marked a new phase in the evolution of decision support systems due to the emergence of relational database. This development was strongly supported by two pioneers of the field *Ralph Kimball* known as *"the doctor of DSS"* and *Bill Inmon* known as *"the father of data warehouse"* (Power, 2007). The following two decades led to a technological shift in the history of DSS by the introduction of 'spatial' decision support systems. The *spatial* element provided the information required for decision making which can be generated through geospatial data processing (Jankowski et al., 2006). For the period of late 1980s and early 1990s, decision support systems were equipped with limited number of spatial functionalities.

SDSS was originally initiated to solve spatial, semi-structured problems by individual (Honey et al., 1991) and group (Armstrong, 1993) decision makers, wherein location and other spatial relationships of direction, distance, adjacency and connectivity led to a fundamental part of problem solution, decision objectives, alternatives and its outcomes (Jankowski et al., 2006).

To attain this purpose, SDSS was required to assimilate: (1) Mathematical and logical models for processing spatial data, (2) Technical and scientific data, (3) Data based on perception (human judgements, probabilities). These necessities prove to be similar to the requirements formulated by Keen (1976) and Ralph et al. (1986) for decision support systems (DSS), in the field of management science. Based on the similar concept, SDSS provides integration of spatial databases, analytical models, and visualization tools with the use of spatial data and decision models.

Following the notion that any computer based system providing information that assists in decision making is considered a decision support system, Geographic Information Systems (GIS) came to be regarded as spatial decision support systems (SDSS), especially with GIS capacities of managing, analysing and visualizing spatial data (Cowan, 1987). Jankowski et al. (2006) even argued that the computational base for spatial decision support systems relies mainly on GIS technology.

1.2. Justification

To conclude the previous section, we can summarize that infrastructure investment has a significantly greater economic, environmental and social effect. However, infrastructure spending is declining worldwide (Yu et al., 2011) which means that infrastructure development has to provide more services with fewer amounts of public funding. In addition, the spatial characteristics of urban infrastructure and the different stakeholders involved.

In order to optimally utilize the existing resources, decision makers should be fully aware of both the current situation and the effects and benefits of their decisions through visualizing different scenarios and alternatives. In real life as well as in theoretical research, many consider spatial decision support systems (SDSS) as a suitable decision environment for similar cases.

1.3. Problem Statement

Infrastructure investment is acknowledged as a main economic growth factor and with a significant impact on the quality of life *"Health, Safety, Economic Opportunities"* from both environmental and social aspects. Infrastructure investments usually involve the expenditure of large capital; however, infrastructure investments are declining worldwide. In developed countries, it is reducing by half; it fell from 5% of the GDP to 2.5%, in developing countries the decrease was more drastic as it went from 23% of GDP to only 4% (Yu et al., 2011). On the other hand, new needs emerged. Local authorities seeking equitable infrastructure provision claimed more expenditure on infrastructure (Yu et al., 2011).

Infrastructure development has to provide better services to the growing population and their activities with the same amount of public funding, or less. This makes the allocation of infrastructure resources extremely disputable with many solutions and alternatives to choose from, and given the spatial characteristics of urban infrastructure investment and the different stakeholders involved, increases the problem of the resource allocation spatial decision process.

1.4. Objectives and Research Questions

The aim of the research is to develop a framework for spatial decision support system (SDSS) to improve the resource allocation process for infrastructure, involving different decision-makers. A suitable user-friendly framework will facilitate the decisions about infrastructure, assessing and choosing between investment alternatives.

To address this main objective, several sub-objectives have been mentioned in (Table 1) below:

	OBJECTIVE	RESEARCH QUESTION
1	Review and analyze policies and methods of infrastructure resource allocation.	• What are the current policies and methods? • Which of the reviewed policies and methods will be adopted for the study?
2	Derive the spatial and non-spatial factors guiding the process of infrastructure resource allocation.	• What are the spatial factors and non-spatial factors guiding infrastructure resource allocation?
3	Identify the process of infrastructure resource allocation using selected policies, methods and factors.	• How the link between selected methods and factors should be to identify the process workflow (the decision tree)?
4	Apply the developed resource allocation process in a decision-making support system.	• Which elements will define the decision support system? • What are the different assumptions that relate to the decision-making process and the integrated models? • What are the alternatives that the process will develop and what is the best way to present them?
5	Implement the decision support system to a real case study.	• Is the framework applicable and producing reliable results?

Table 1: Objectives and Research Questions

1.5. Conceptual Framework

This research will define criteria for infrastructure resource allocation to design a conceptual framework for spatial decision support system (SDSS) and implemented. The conceptual framework consists of four main tasks as following (Figure 4):

- Review current policies and methods for infrastructure resource allocation.
- Define criteria for the process of infrastructure resource allocation (decision tree).
- Design a spatial decision support system (SDSS) conceptual framework.
- Implement the designed system and test it on a real case study.

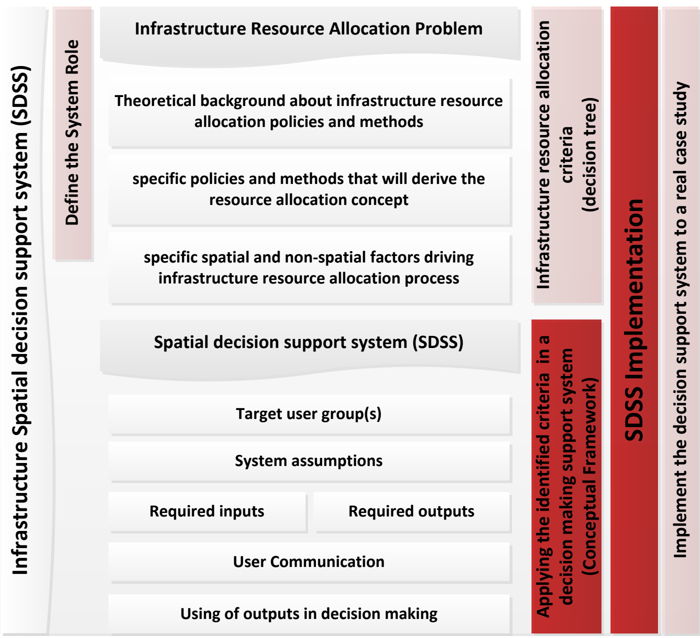


Figure 4: Conceptual Framework

1.6. Research Methodology

The methodology as described in Figure 5 includes the main elements of the research, starting from the Literature review, which presents a background description about the spatial decision support system (SDSS); reviewing the policies and methods for Infrastructure resource allocation and addressing on-going researches to define the policy and methods considered for the research. Further, to analyze both the SDSS characteristics with the defined criteria for resource allocation to be able to design the conceptual framework for the system. Finally, implementing the conceptual framework and selecting a study area in order to check the results of the framework.

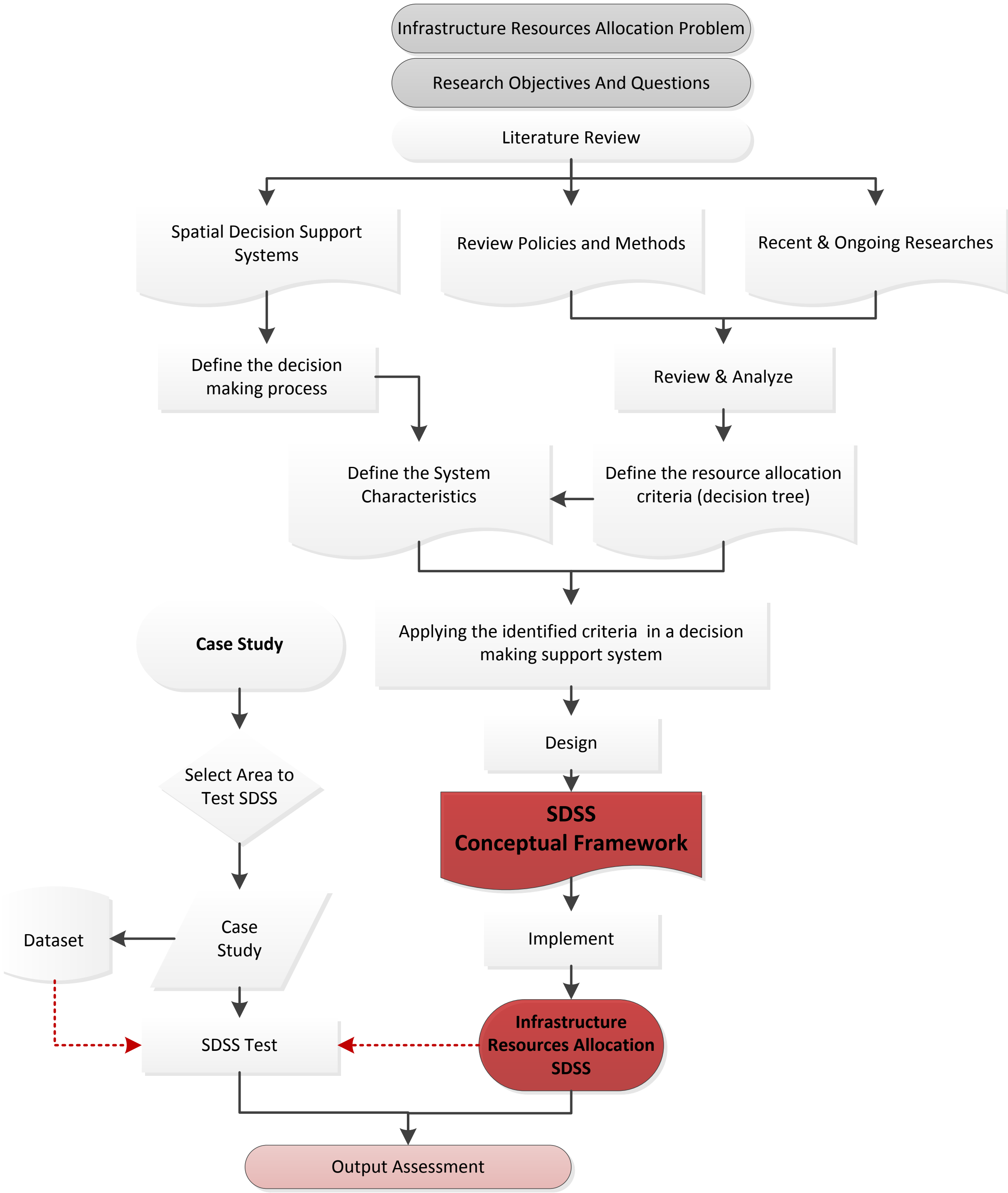


Figure 5: Research Methodology

1.7. Thesis Structure

This research comprises of six comprehensive chapters, as can be seen in the structure represented in (Figure 6) below:

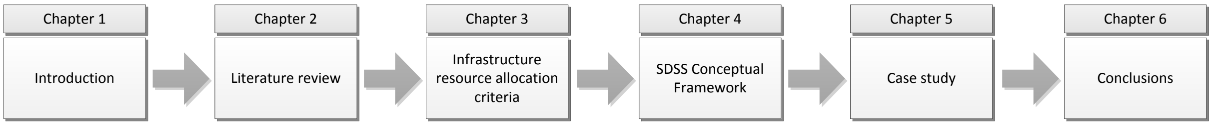


Figure 6: Thesis Structure

Chapter 1: Introduction

This chapter comprises of five main items. Firstly, the background of the research, which consists of different perceptions about urban infrastructure, and the importance of infrastructure. Secondly, justification of the study, by providing evidence for developing SDSS for Infrastructure Resource allocation. Thirdly, the problem statement, which highlights the main problem of the research. Fourthly, the main objectives to be achieved and the research questions used to achieve those objectives. Next is the conceptual framework that shows the framework to implement infrastructure spatial decision support systems. This is followed by thesis structure that explains the content of each chapter of the thesis. Finally, the research design, which explains the research methodology and provides a link to the research questions.

Chapter 2: Literature review

This chapter will explore the infrastructure resource allocation process starting from the concept of the process, and involved decision makers and establish the spatial decision support system and similar SDSS application in urban infrastructure. This will be followed by giving elaborate details on infrastructure resource allocation process, addressing the current policies and methods used for infrastructure resource allocation in order to identify the adapted practice for the system.

Chapter 3: Infrastructure resource allocation criteria

This chapter describes the Infrastructure resource allocation criteria. The strategy for the system is based on the policies and methods addressed in the previous chapter. The suggested practice contributes to improve planning procedures at the local (municipal) level, more so the decision making process related to infrastructure resource location-allocation.

Chapter 4: SDSS conceptual framework

This Chapter presents the initial spatial decision support system SDSS framework that covers the addressed decision criteria of infrastructure resource allocation. The main objective of spatial decision support system SDSS is to support decision makers (e.g. government or municipal agencies, promoters, etc.) in achieving equitable distribution of infrastructure service and achieving the best use of the available infrastructure resources.

Chapter 5: Analysis and results

This chapter demonstrates how local/municipal governments can successfully apply the developed spatial decision support system to make efficient and effective decisions in coordinating and managing resources, to plan for the future.

Chapter 6: Analysis and results

This chapter concludes the aim of study to define criteria for infrastructure resource allocation to design a framework for spatial decision support system (SDSS).

2. LITERATURE REVIEW

This chapter will explore the infrastructure resource allocation process starting from the concept of the process, and involved decision makers and establish the spatial decision support system and similar SDSS application in urban infrastructure. This will be followed by giving elaborate details on infrastructure resource allocation process, addressing the current policies and methods used for infrastructure resource allocation in order to identify the adapted practice for the system.

2.1. Infrastructure resource allocation

Infrastructure plans combined with financial plans, land use plans and corporate business plans is being increasingly seen as a key to successful strategic planning. Some of the municipalities that were surveyed highlighted that departmental decision-making lacked cohesion, in particular efficient and effective spending, which could be seen as a consequence of insufficient links between departmental and planning activities. To quote an example, high-level goals for roads services should be directly interlinked to the relevant departmental prioritisation, along with different municipality departments in the decision-making process for the distribution of available resources. This research thereby intends to represent a selected practice, integrating it with the technical best practices that will facilitate in devising an effective decision-making and investment-planning tool (Boudreau & Brynildsen, 2003).

2.1.1. Concept

There have been various means for formulating an effective infrastructure plan. The identification of infrastructure goals can promote municipalities in assigning expenditures priorities on infrastructure needs. The development of an integrated plan influences the highest benefit of the existing infrastructure and ensures the most proper plan for infrastructure expansion for the future. Integrated plans highlight, the integration between an infrastructure plan and land use plans, business plans etc. Identifying practical methods to plan and define municipal infrastructure needs can propose newer programs concerning user behaviour. For instance, promoting public transport as an alternative transport mode can assist managing the demand on road infrastructures.

There are five practical methods to plan and define municipal infrastructure needs. These methods can assist municipalities to address current needs and to develop long-term planning for infrastructure. There can also be practical ways in achieving sustainable infrastructure. These methods aid in developing an integrated vision and strategy, asset information management systems, build public support and acceptance, explore new and innovative methods for continuous improvement and to prioritize models (Boudreau & Brynildsen, 2003).

2.1.2. Infrastructure investments

The debates about the most appropriate policies to secure sustainable infrastructure development have been intensified since summer 2003 when series of electricity blackouts had taken place in more than a city in Europe (London, Italy, Sweden and Denmark) as well as in the US. These events draw attention to the link between regulation and investment (Von Hirschhausen et al., 2004). Long-term plans for infrastructure investment have been recently an interesting issue for decision-makers. These interests follow the privatization of network industries, which work upon short-term plans and give insufficient attention to long-term plans, especially investment plans.

Since then, various researchers have been arguing about the consequences of privatization. Helm and Thompson (1991) argued that "there has been considerable debate about the static efficiency consequences of privatization, but little attention has yet been paid to the long term effects on investment decisions and the resulting levels of capacity and service quality". On the other hand, Pollitt (2002) noticed that *"privatization and incentive regulation since 1979 has occurred without a noticeable reduction in the quantity and quality of investment or of the associated services"*. In fact, the situation is not that dramatic for instance, electricity is in the case of work almost 99.9% of the time available and the trains are plying all the time all over the world as described by Helm and Thompson (1991). Moreover, Pollitt (2002) concluded that *"message from UK privatization of utilities is that well-regulated companies have no difficulty in financing their investment efficiently"*.

Considering the fact that Governments persist to be one of the most powerful actors in terms of expenditures on social and development programmes, it might be important to address that the infrastructure sectors designed by the government sometimes differ radically and efficiently. The Governments have provided public and private enterprises, in addition to imposing regulation, putting restriction for investors and opening different segments for competition. There are other issues concerning infrastructure investments; level of investments, maintenance and management system.

Optimum level of investment has always been one of the top priorities in the infrastructure investment debate. The main aim of the discussions thus is to address the consequences of overinvestment or underinvestment on the social welfare. Presently, underinvestment in infrastructure is the key concern. It has been argued that overinvestment strategy is the preferable one because social costs of underinvestment strategies are relatively high (Helm & Thompson, 1991). Maintenance is another issue when taking decisions regarding infrastructure investments. When and how to do the periodic maintenance of the assets, has become a difficult technical decision especially with the continuously shrinking budgets. This is the time for the decision makers to make the best fund allocation among deserving needs. The challenges that always face the managers are: making decisions with insufficient data and being asked to reduce all the expenditures and the outsource responsibilities (Siddiqui & Mirza, 1996). These pressures make it difficult for the municipal infrastructure management to take the most efficient long-term decisions.

The management systems of infrastructure have been facing many problems in the decision-making process. They lack complete data or replacement values, using *"non-financial"* value of assets and difficulty in integrating GIS. Accordingly, proper data collection, decision analysis, management reporting and performance modelling have been recommended (Vanier & Danylo, 1998).

2.2. Spatial decision support systems (SDSS)

Nowadays the increase in computers' usage and the technological development in both hardware and software made it easier to build and setup a computer system supporting decision making that came to be known as decision support systems (DSS). Considering the large amount of data involved in decision-making and the complexity of it, these decision support systems have gained popularity in the decision making process.

2.2.1. SDSS definition

The automation of decision-making has always been an objective for researchers. When Simon (1965) wrote, *"If I am right in my optimistic prediction that we are rapidly dissolving the mysteries that surround non-programmed decision making, then the question of how far that decision making shall be automated ceases to be a technological question and becomes an economic question. (p. 90)"*, he was expressing the need back then for automated systems supporting decision-making. He was also questioning the role and capabilities of technology in providing the required support for decision-making.

Laudien et al. (2006) describe decision support system (DSS) as computer based system of analytical models fed by all necessary data in order to assist decision makers solving semi-structural problems. They also point out variety of analysis and methods available for decision-making process with such systems, which emphasise on the importance of choices made during decision-making.

Considering the spatial nature of some decision making processes, spatial decision support systems (SDSS) were introduced in 1990s. The addition that spatial decision support systems (SDSS) propose in the use of spatially referenced data in the decision making process, provides decision makers with a handy interface for the complex models and analysis running in the background of the system. Coutinho-Rodrigues et al. (2011) states that SDSS has a positive impact on decision makers' performance.

Ademiluyi and Otun (2009) are more specific describing spatial decision support systems (SDSS). Not only did they describe what SDSSs are and can do but also what they cannot do, in order to clear confusion about the aim and role of SDSS. The authors declare that SDSS has a positive impact on the effectiveness of the decision-making process rather than its efficiency. From one point of view, a Spatial Decision support system is concerned about the quality of the decision making process and its outputs rather that making the best use of the available resources (time, data, experts,…). However, Crossland et al. (1995) argues that SDSS also improves the efficiency of the decision making process.

2.2.2. SDSS Aim

Spatial Decision Support Systems (SDSS) is a combination of geographic information systems (GIS) functionalities, remote sensing techniques, mathematical models and other decision support functionalities. This combination provides system users (decision makers) with a valuable tool to model and analyze the data and visualize the output based on a question-specific decision tree (Laudien et al., 2006).

Although spatial decision support system acts as a benefit for the decision making process, yet measuring, their exact impact has not been tested. For that matter, the technology of geographic information systems (GIS) was experimented as a spatial decision support system. Decisions and solutions developed by decision makers using SDSS were faster and with fewer errors. Therefore, SDSS improvised the decision making process in terms of efficiency and effectiveness and concluded that although GIS technology is a suitable means to organize, analyze and visualize spatial data, decision makers need a more integrated spatial decision support system (SDSS) as mentioned before (Crossland et al., 1995).

2.2.3. SDSS Components

Conceptually, SDSS is a package of connected software modules that provides an integrated set of capacities. At the primary level, there exists three major components: database, model and user interface, although, in the SDSS literature the number and the precise explanation of components varies. It incorporates a spatial information system (GIS) and a modeling system, integrated together. Moreover, a geo-referenced database, analytical tools and displaying options often exists (Sugumaran & Degroote, 2011). In this research, we identify three core components as can be seen in (Figure 7):

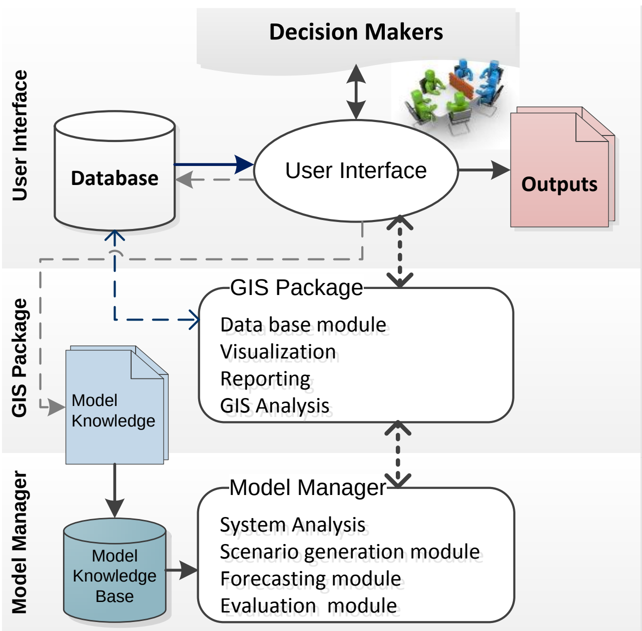


Figure 7: spatial decision support systems Components

2.2.3.1. User interface:

The main link among the decision makers and the spatial decision system, gives the access to system functionalities and the database allowing decision makers to generate required outputs.

2.2.3.2. GIS package:

GIS Desktop packages are software packages, referring to a specific geographic information system application that will be used as a base for our spatial decision support system to assist the functionalities for producing, managing, organizing, analysing and visualizing geospatial data.

2.2.3.3. Model manager:

It is the core of analytical model, which includes new features/functionalities required for generating the necessary outputs by the spatial decision support system.

2.2.4. Decision makers performance

The complexity of urban planning decisions is obvious (Witlox et al., 2009) and many have made use of spatial decision support system to deal with this problem.. Spatial decision support system can help non-technical stakeholders (governments and communities) and even support planners while dealing with spatial information related to planning and resource allocation activities (Tsamboulas & Mikroudis, 2006).

Crossland et al. (1995) discusses that spatially integrated DSS (SDSS) can represent the missing link between policy makers and the complex computerized models. This can be done by comparing the decision-making processes for a real case with and without using a spatial decision support system wherein they found out that decisions and solutions developed by decision makers using SDSS were faster and with fewer errors. For large-scale infrastructure investment, SDSS can assist decision-makers to choose the best decision from the different proposed alternatives (Coutinho-Rodrigues et al., 2011). In addition, for activity allocation, SDSS proved to present satisfactory results in assisting decision makers to allocate different land uses (Eldrandaly, 2010). For tourism planning, an SDSS environment integrates all the factors effecting tourism planning and links the spatial data with the different attributes, thereby giving decision makers the flexibility to manipulate each of these criteria and see how this could affect the system in order to reach a sustainable touristic plan (Beedasy & Whyatt, 1999).

SDSS has also been used for undertaking various resource allocation works. In the work done by Coutinho-Rodrigues et al. (2011), a real-world problem motivated the use of SDSS. Decision makers had to choose the best alternative for developing a water-supply system needed for an expansion plan for the city of Coimbra, Portugal which included the main elements of large scale investment, it's spatial implications and the multiple criteria (social, economic, and environmental) involved. Thus, an SDSS prototype was developed in order to assist the decision-makers to choose amongst the different investment options. This SDSS prototype comprised of four main functionalities: data management (storage, retrieval, and display of spatial and non-spatial data), investment alternatives' evaluation, alternatives' comparison and selection and finally, a sensitivity analysis for the result. However, according to the authors, applying sensitivity analysis to the output indicated a robust result.

Eldrandaly (2010) integrated an artificial intelligence (AI) technique with GIS technology to develop an SDSS, to deal with the multi land use allocation problem. Multi land use allocation is the dilemma of how different types of land uses are able to share the same area. According to the author, the system feasibility was checked by experimenting it on a real case of land use allocation that proved to show satisfactory results.

On the contrary, Ademiluyi and Otun (2009) argued that spatial decision support systems can never replace expert judgment, as it cannot run on its own. The system needs inputs and parameters to run the necessary analysis and modelling which draw the characteristics of the produced scenario. This scenario or potential solution depends on the experience of experts and the norms of decision makers involved. In this research we are not trying to replace the role of experts and decision makers but trying to offer a tool, which can assist them and make their role more effective.

2.3. Infrastructure resource allocation practices

This research discusses the relationship between infrastructure investments, considering equity in public investments distribution. These discussions are required to develop a framework to allocate the resources in the areas where they are most needed. The concept of *fair* distribution has a different perspective, trying to understand this relationship, for which a conceptual framework will be developed clarifying the equitable approach to infrastructure investment and how it can encourage the economic growth. The four main infrastructure types that will be addressed in this research are transport networks, water and sewerage, electricity and telecommunications network.

We can address the different influences that determine the criteria for infrastructure resource allocation, which could be categorized as policies, theories, concepts/rules, measures and approaches in one of the on-going researches which is *"Equity based resource allocation for utilitarian and non-utilitarian planning"* (Wismadi et al., 2013a) where we tried to analyze these different influences determining the criteria for this study (Figure 8). The policy is Pro-Poor which targets poor people and is aimed at reducing poverty, allowing them to be involved in the policy process (Z Curran & Renzio, 2006). The authors addressed the equity based concept which is aimed to achieve fairness and impartiality towards all concerned based on two theories utilitarian and non- utilitarian; Utilitarian theory which is a *"Measure of equality of mental reaction or satisfaction on the received resource or welfare"*, and Non-Utilitarian *"Measure of equality of opportunity as a result of received resource"* (Wismadi et al., 2013a). However, the authors used two different measures of spatial equity analysis for equity based concept. The spatial equity analysis includes location, shape or size and defines to what extent urban public facilities are allocated while non-spatial equity analysis is that information which does not include any geometric considerations (Liao et al., 2009). Therefore, in the next section, we will define our criteria required for this research, based on the similar elements as mentioned above for the resource allocation criteria.

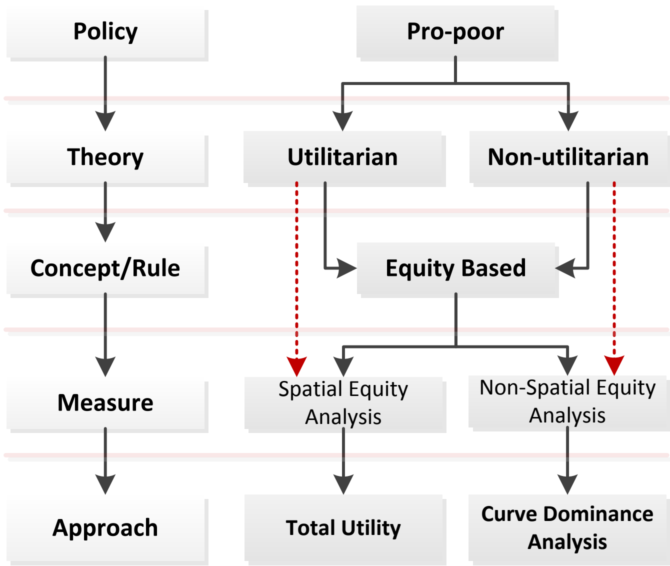


Figure 8: Resource Allocation Criteria (Equity Based Study)
Source: Adapted from (Wismadi et al., 2013a)

2.3.1. Review policies and methods

2.3.1.1. Policy

Policies can be understood as the basic principles that directs the government to achieve state objectives relating to the economic and/or environment and/or social and/or well-being of the citizens (Luthra, 2007-2011). Public policies are mostly one amongst the three types: redistributive, distributive, or regulatory. This research mainly reviews the redistributive policies in the context of pro-poor, market based, environmental and social policies that have been discussed briefly in the next section to follow.

2.3.1.1.1. Pro-poor policy

Pro-poor policy is one of the social policies. As Barbour (2001) addresses *"Social policies include government programs that seek to provide economic security for people who cannot help themselves, as well as other government assistance that improves the quality of life for individuals"*. Social policies whether distributive or redistributive including social welfare and social security aims to support peculiar groups of society. Pro-poor growth has been defined differently in the recent literature. Concerning the generic definition, *"The growth process is said to be "pro-poor" if and only if poor people benefit in absolute terms, as reflected in an appropriate measure of poverty"* (Ravallion & Chen, 2003). Rather than the rate of income growth explained by the previous definition, this one aims to focus on the rate of change in poverty. This definition targets the poor in the context of their living standards that is the main objective of the pro-poor policies. Other definitions are policy-oriented definitions and few others are more generic. One of the policy-oriented definitions states that *"Any distributional shifts accompanying economic growth favour the poor, meaning that poverty falls more than it would have if all incomes had grown at the same rate"* (Baulch & McCulloch, 2000; Kakwani & Pernia, 2000). This definition means that pro-poor growth policy is that one which makes the rate of income growth of poor people exceeding that rate of the non-poor. This definition focuses only on the rate of growth, which not always means a gain to the poor, as there is always a big gap between assets of their income and the minimum living standards. It would be better if the economic expansion shifted radically from *"pro-rich"* to *"pro-poor"* and bring some absolute gains for them.

A major challenge for governments especially with the ever-increasing population is to provide essential infrastructure and services to all its inhabitants, considering the intention for poverty reduction. Poverty is still a major problem and administrators should find new ways to solve their problems regarding urban infrastructure comprehensively. Pro-poor urban infrastructure development is a term that refers to the approach that enhances the access and usage of the poor inhabitants to infrastructure and services. This kind of access could be; either to the city networks or by providing more options to the areas where they live. Pro-poor urban infrastructure development is a major section of city development strategies which aims to reduce poverty (Ravallion, 2004).

In recent times, consideration has started to be given to enhance equality of opportunities, distributions of assets and political participation rather than securing equality only in incomes (World Bank, 2005). What is still required is careful monitoring and evaluation for the differences that occurs in the performance of the responsible institutions (Ravallion, 2004).

2.3.1.1.2. Market based

Market-based policies are those regulations that *"Encourage behavior through market signals rather than through explicit directives or the harnessing market forces"* (Stavins, 2002). They have potential to deviate the agenda of governments, firms and individuals to improve the outcomes according to their own interests. The aim of market-based polices is to achieve outcomes through the self-interest of the governments, firms and individuals and the key target is to change attitudes to improve income levels, education and quality and standard of living (Pannell, 2001). There are two advantages of market-based policies over the traditional ones. The first is allowing governments or firms to make the required adjustments to fit the structures of their businesses. The second is discovering the cheapest ways for future target achievements. The theoretical potential of the market-based polices is delivering outcomes similar to the command and control mechanism, a significant disadvantage of which is that the outcomes delivered are at low industrial financial cost and the overall net social cost with lower value (Whitten et al., 2004).

Market-based policies have three potential levers: Price-based, Rights-based and Market. Price-based polices concern change behavior by changing prices of goods and services in the markets. They provide certainty to the costs of achieving the outcome. Rights-based polices, promote controlling the desired quantity and quality of the goods or services by the community. Market friction polices stimulate the market to generate the required outcome. The aim of these policies are improving the work of existing markets, reducing transaction costs and/or improving information flows. These policies are less common and the responses to them are less certain and on longer terms (Whitten et al., 2004).

2.3.1.1.3. Environmental

Barbour (2001) defined the environmental policy as *"a regulatory policy that often leads to debates on balancing the protection of the environment with the protection of business"*. These are policies where a competition exists between the environmental needs and the society as a whole. This can be better understood in terms of interests involved at different levels. Among many, the dominant interest is of the local communities that are dependent on resources provided by the environment to sustain a living. However, certain parts of the society also incorporate legitimate interests, the most evident being the concern of biodiversity. Furthermore, issues of taxes that are being utilized to subsidize costs for water or support engineering works like major storages also persist. Therefore, to address all these concerns, an appropriate institutional framework can be regarded as one of the utmost challenges for policy development.

In Environmental policy, governments have enacted affectively and responded to the on-going demands of the communities through proper regulatory mechanisms resulting in favourable environmental outcomes. To state an example, approximately eighty Acts have been identified by Australian Petroleum Production and Exploration Association that have had a positive effect on oil and gas industry (APPEA, 2012). The regulatory mechanisms thereby state conditions for improved access and usage of resources such as through conservation acts which limits the use of land if covered with native vegetation, and restricts its use for any other purpose. Likewise, various regulations concerning mining indicate a maximum limit of pollution level, minimum necessities for rehabilitation of mining sites and management processes to be used for preventing environmental damages.

2.3.1.2. Methods

Methods have been segregated into two main categories: Theories and Concepts/Rules. Theories are the mental models of the perceived reality; they consist of a set of assumptions that provide rational explanation of relationships among a group of observed phenomena such as e.g. Utilitarian or Non-utilitarian. Concepts/Rules are detailed descriptions that state what to do and not to do in a specific situation or interpret a law or policy (Luthra, 2007-2011) such as Equity Based and Economic Opportunities.

2.3.1.2.1. Economic opportunities

Infrastructure has been recognized as a key resource for education, health, and economic opportunity. Infrastructural development has however been considered as an important economic growth factor with a high economic, social and environmental return. The importance of infrastructure lies in improving the quality of life and economic opportunity, which acts as the main inspiration for investment strategies that should be *fair*. This encourages recent studies to concentrate more on equitable infrastructure investments policies, and the relationships between investing on infrastructure and productivity, protecting the environment and the natural resources and tackling community disadvantage to accomplish equality and regional balance.

Infrastructure investment is also a factor for economic development. Infrastructure can improve economic opportunities for low-income family members and areas. Considering equity in investment decisions does not actually come at the price of other areas but in some circumstances may actually enhance wider development and financial performance. Equity in infrastructure investment may help build the governmental and public agreement required for larger public projects.

2.3.1.2.2. Equity based

Since 1968, social equity was added to 'economy' and 'efficiency' to form the pillars of public administration (Frederickson, 2005). Achieving social equity can be done by providing equal access to resources and livelihoods. The feasible governmental intervention on this regard is to distribute public services fairly among people considering their health, wealth, geographical location, etc... (Chitwood, 1974). Accordingly, distribution of public services is evaluated based on social and spatial equity. Social equity can be expressed through various socio-economic groups of the inhabitants while spatial equity can be expressed through geographical locations.

Along history, equity has been concerned with equality fairness, and any other topic comes into the debate of the political philosophers about social justice (World Bank, 2005). There have been several concepts and definitions of equity in various literatures. In general, equity as defined by Litman (2011) refers to the fairness in which impacts (benefits and costs) are distributed. The other relevant concepts is can be seen in the World Bank Development Report (Dongier & Lovei, 2006) defining equity in two basic principles: equal opportunity and avoidance of absolute deprivation while Bago d'Uva et al. (2009) expanded this concept to cover the three strong areas of convergence i.e. equal life chances principle; equal concern for people's needs, and meritocracy.

2.3.1.2.3. Social equity

In general, social equity is the equitable distribution of impacts. It is defined by Litman and Brenman (2012) as the equal distribution of benefits, disadvantages and costs among people. On the subject of infrastructure, Litman (2011) adds more specific definition for equity. He refers to it in three main dimensions; distribution of impacts as horizontal dimension, income and social class as first vertical dimension and finally mobility, need and ability as second vertical dimension.

Distribution of impacts as horizontal dimension refers to fairness in distribution of impacts among individuals without any favour. All individuals should benefit the same. Everyone should receive equal benefits of resources and bear equal costs. Income and social class as first vertical dimension refers to justice in distribution of impacts between groups who have different abilities or needs. At times, it is defined as social or environmental justice. These groups are distinguished either by their income level or by social class. It is achieved by any project considering low economic or socially deprived groups (e.g. Fair transport policies). The last is mobility, need and ability as second vertical dimension, which considers individuals with disability or special constraints.

2.3.1.2.4. Spatial equity

Spatial equity is the equal distribution of individuals on geographical location affected by particular projects. By (Stöhr & Tödtling, 1977; Thomopoulos et al., 2009), it is dropping of disparities between different living levels. Maro (1990) defines the practical means for applying spatial equity. It can be by identifying criteria defining fairness in the allocation of basic social services, activities and development resources. Talen and Anselin (1998) define it as the correlation between spatial distribution of services/activities and spatial distribution of different socioeconomic groups; the definition show that spatial equity and social equity are not apart from each other. In this context Tsou et al. (2005) state, that spatial equity is one of social equity forms.

2.3.2. Analyze policies and methods

There have been many recent studies discussing different aspects related to infrastructure resource allocation targeting on the Equity Based concept, reflecting the current investment strategies as the priority concern for policymakers as fair distribution of infrastructure investment resources.

2.3.2.1. Policymakers practices (current investment strategies)

It can be a challenging and complex endeavour to achieve positive long-term community development impacts, supported with the help of community initiatives. To a large extent, various programmes and initiatives are not able to deliver in their full capacity despite a stipulated time period, goodwill and invested resources by governmental firms and communities. In quite a few cases, the result of poor planning can be blamed in giving rise to negative attitudes about governmental firms by generating conflicts and creating dependencies in regard to distribution of profits and benefits (IFC, 2010).

In the beginning of year of 2012, there can be seen unending economic depression and fiscal crisis engulfing large parts of the developed world, also affecting rising economic powerhouses like that of India wherein many people still remain poverty-stricken. In many political debates and discussions, the fundamental basics of a capitalist system are being in question and have been regarded as the most appropriate way to transform the financial system in order to prevent future collapses. Even with the widespread crisis situation, enhanced technologies, changing attitudes and a hope for reconstruction shown by the revolution made by micro financing have given way to newer opportunities to serve global poor through market based innovations. These are being explored by motivated entrepreneurs who believe in taking greater risks for overwhelming social value and little financial reward. Such ideas have led to the evolution of the new field of 'impact investing'. In just a span of few years many funds have been allocated and hundreds of dollars are being invested in the coming year (Harvey et al., 2012).

In the recent history, philanthropy of a newer form has emerged, known as *"Philanthrocapitalism"*. The term suggests, *"Private giving can fill the void left by diminished government spending on social and development programmes"* (McGoey, 2012). Critical acclaims highlight that philanthropy does not act as a substitute for stronger support from the government in terms of social welfare. McGoey (2012) however challenged this assumption in his works and explored newer philanthropic initiatives that compelled to increase financial support from governmental authorities towards private sector enterprises. Nonetheless, according to him governments remain one of the most powerful actors in the *philanthrocapitalist* makeshift.

2.3.2.2. Recent and ongoing studies

There have been many recent studies influenced by the current policymaker practices as mentioned in the previous section, discussing different aspects related to infrastructure resource allocation targeting on the Equity Based concept, reflecting the current investment strategies as the priority concern for policymakers as fair distribution of infrastructure investment resources.

Firstly, addressing the mutual effect of infrastructure and economic development has become a prior concern for both economic and infrastructure researchers. Many researchers developed models that work on national level to study the effect of infrastructure development on economic performance in order to assess the infrastructure resource allocation process (Cohen, 2010; Elhorst et al., 2012; Gutiérrez et al., 2010; Wismadi et al., 2012; Yu et al., 2011). However, for more decentralized management or when it comes to more disaggregated level of analysis, it is a different story. Thornton (2007) argues that in a micro level study local conditions and preferences must be considered. Wismadi et al. (2012) also discusses the differences between economic indicators used to evaluate the effect of infrastructure on economy at national and local level. At local levels, if the modelling of infrastructure - economic interaction is more accurate, it influences the decision makers to get a less biased image.

Wismadi et al. (2013a) suggested preference modelling for decision support systems concerned with resource allocation that addresses both social and spatial equity. The proposed preference modelling takes into account the neighbourhood inequalities mainly when taking spatial equity in consideration. To test the performance of the developed preference model versus other preference models that disregard spatial equity or the A-spatial preference models, Wismadi et al. (2013a) conducted a study to compare both their performances in accordance with two welfare theories: utilitarian and non-utilitarian. This comparative study is conducted by applying the two types of preference models on a case study of resource allocation. The focus of the case is the improvement of four types of public infrastructure (Transport, electricity, telecommunication and water) in the region of Yogyakarta, Indonesia. The redistribution resulting by both preference models are compared against utilitarian and non-utilitarian theories. For utilitarian approach, the results of redistribution are measured by a total utility equation of the additional service to each village. For non-utilitarian, curve dominance analysis is used to evaluate the redistribution effect on equality of opportunities. The developed model by Wismadi et al. (2013a) has proved to be more satisfying than the other: A-spatial preference model for both utilitarian and non-utilitarian welfare theories. The results also reveal the effect of the initial condition of the infrastructure and initial level of inequality on the effectiveness of the used preference modelling technique for equitable resource allocation. This study thus presents an evidence of the importance of considering the spatial factor in resource allocation decision making by adopting a spatial preference modelling technique in the used decision support system.

At micro level (village level), Wismadi et al. (2012) conducted a study to investigate the effect of including the neighbours' infrastructure and economic conditions as well as infrastructure interdependency on the economy-infrastructure interaction modelling. In order to study this effect, he applied three approaches of evaluating economic opportunities of an area. The first one is the base concept that disregards the surrounding. It assumes that the estimation of local economic potentials depends on the combination of existing different types of infrastructure within the study place, not only the quality of each service separately. The second concept starts to incorporate the surroundings characteristics. It adds another factor to the previous concept, which is the economic and infrastructure characteristic of the neighbours. The third concept, and the focus of the study, is the concept that considers in addition to the past two factors, the interdependency of different infrastructures inside a village under study and between it and its neighbouring villages. The estimations of economic opportunities resulting from these three concepts are then validated against the actual data of poverty distribution among Yogyakarta region. The study thus reveals more accurate performance of the third concept in estimating economic opportunities compared to reality. Taking the neighbouring effects of the concerned area into consideration as well as the interdependency between its infrastructure and its neighbours' will increase the accuracy of the result and reflect a better image of the existing reality. This in turn will improve the infrastructure resource allocation decision-making process.

In order to prove the importance of the spatial factor in preference modelling used in the decision support systems, Wismadi et al. (2013b) developed a spatial preference modelling (SPM) technique that includes spatial neighbourhood comparison factors. They believed that this would enhance spatial decision support system's performance in supporting spatial equity. The authors compared the performance of a spatial preference model, which consider the spatial factor as well as the neighbouring objects, against a more commonly used non-spatial preference modelling. The subject of comparison is the achievement of equality in allocating resources for transport infrastructure development in Yogyakarta, Indonesia. According to the authors, standard preference models incorporated in decision support systems (DSS) generally aim in transforming the preference values of the stakeholders involved in decision making into a set of priorities. However, such models usually disregard the spatial and neighbouring equity. Even for spatial decision support systems (SDSS), only the resulted priorities are shown on maps but the work behind these results ignore the spatial factor. Estimating individual sense of inequality in such non-spatial context of comparison could be inaccurate. Wismadi et al. (2013b) argue that individual sense of inequality is relative according to local conditions. A neighbourhood in a well-developed city that suffers of bad infrastructure would have a higher sense of inequality than another neighbourhood with the same infrastructure conditions in another area where this infrastructure condition is the average of the area. Such inequalities like the case of the first neighbourhood could not be captured in overall comparisons. It only appears when considering the comparison with the neighbouring conditions. On the other hand, the higher the distance between inequalities the less is the feeling of this inequality. In the context of infrastructure, the importance of the spatial local factor is even more obvious, as infrastructure depends on the interconnectivity between added and existing networks.

2.4. Conclusion

The chapter provides an overview of the key concepts of Infrastructure resource allocation, importance of spatial decision support systems and its components and most importantly introduces the Infrastructure resource allocation practices. These practices comprise of the current investment strategies, which have become priority concerns for policymakers. It is clear from above literature that policies form the guidelines for a government to achieve both long term and short-term objectives relating to economic/social/environmental concerns, which transforms the role of governments as most powerful actors in attaining positive community development impacts. This helps to gain a deeper understanding of these policies by further emphasizing specifically on redistributive policies in the context of pro-poor, market based, environmental policies leading to effective decision-making processes. Finally, we can address that the priority concern for policymakers and economic and infrastructure researchers is fair distribution of infrastructure investment resources.

3. RESOURCE ALLOCATION CRITERIA AND METHODS

This chapter describes the Infrastructure resource allocation criteria. The strategy for the system is based on the policies and methods addressed in the previous chapter. The suggested practice contributes to improve planning procedures at the local (municipal) level, more so the decision making process related to infrastructure resource location-allocation.

The structure of the resource allocation criteria includes various methods and each method as explained in the following section is a development of integrated vision and strategy including description of the approach, context of use and objectives of the practice. Different policies have been studied (Pro-poor, Market Based and Environmental) and methods (Economic Opportunities, Equity Based) have been reviewed and analysed in the literature review section in order to determine the criteria to be chosen for this research. However, current policymaker concern, recent and on-going studies mostly target the Equity based concept, which reflects the current investment strategies and have been elaborated further in this chapter.

3.1. Equitable infrastructure investment

In order to achieve fair distribution, infrastructure investment resources will be subject to the concept of equity. Equity in infrastructure planning is more to prioritize infrastructure investments through discussions between policymakers, civic leaders and residents in order to promote the preparation of long-term vision. In order to develop our conceptual framework to structure the issues facing the governments and explore the aspects for equally distributed infrastructure, this research will explore the equity aspects of infrastructure. Firstly, defining the equity dimensions and the criteria required to evaluate equity of infrastructure distribution. Secondly, describing methods to measure equity of infrastructure distribution. Finally, assessing the conditions and policies that lead to infrastructure equity, which will be the main base for the developed framework.

3.1.1. Why Invest Equitably?

Infrastructure is acknowledged as a key resource for education, health, and economic opportunity. We all depend on public infrastructure as it provides us with the roads that take us to work, the water we drink, the energy that lights our homes and the schools for our kids. Infrastructure development is considered as an important economic growth factor with a high economic, social and environmental return. The importance of infrastructure lies in improving the quality of life and economic opportunity, which acts as the main inspiration for investment strategies that should be *"fair"*. This encourages recent studies to concentrate more on equitable infrastructure investments policies, and the relation among investing on infrastructure and productivity, protecting the environment and the natural resources and tackling community disadvantage to accomplish equality and regional balance.

Infrastructure investment is a factor for economic development. Infrastructure can improve economic opportunities for low-income family members and areas. Considering equity in investment decisions does not actually come at the price of other areas but in some circumstances may actually enhance wider development and financial performance. Equity in infrastructure investment may help build the governmental and public agreement required for larger public projects.

3.1.2. Performance measurement

Widespread utilization of performance measurements in the organization and execution of public programs gives way to many significant questions. Some of these questions include: the issues that can be considered for measurements and how should they be measured, the ways in which performance measurements can be put to use, in what way can managers make use of these measurements to improve the overall performance of public organizations etc. Many studies have previously stated about the significant impacts with the use of performance measurements. Thus it incorporates the capacity to improvise upon the performance levels of public programs which seems most likely as one of its major goals, which thereby increases the possibility of ignorance of public values (Jennings Jr, 2006). However, as the major goal of the research reflects fair distribution of infrastructure investment resources, our main concern will be the equity measurements.

3.1.3. Equity Measurements

To be able to distribute resources equitably, it is of prime importance to understand and define the concept of equity. Notions of equity, equality and redistribution are however seen as concepts linked to each other and direct government interventions. The notion of equality, seen from economical perspective indicates sharing of incomes in an equitable way (Garcia-Valiñas, 2005). This notion necessitates redistribution among groups and most often face problems in its implementation. The notion of equity on the other hand, is significant to development of infrastructure, aiming at provision of minimum levels of service to facilitate people that have access to specific levels of economic opportunities.

3.1.3.1. Capability Approach (CA)

In accordance to the equity concept, Sen (1980) introduced the Capability Approach (CA) as an approach aiming to assess the social equity. Capability approach base the assessment of social equity on equal access to opportunities (Chiappero-Martinetti & Roche, 2009), and defines opportunities as the capability to accomplish functioning desired by individuals (Wismadi et al., 2012). For that, opportunities are not essentially money related. The level of transportation infrastructure service for instance as an indicator of mobility could reflect the level of capability too. A good transportation network provides individuals with a good and reliable means to move around and therefore access to different activities and opportunities (Wismadi et al., 2012). The capability approach is used in this research as the base for the infrastructure resource allocation.

3.1.3.2. Gini-Coefficient of Inequality and Lorenz Curve

Gini-Coefficient and Lorenz Curve are understood as descriptive measures in the study of economy. In the theory of location, these have been defined to find the most optimal location (Maimon, 1988).

Gini-Coefficient is significantly used as a measure of inequality. It has its basis from the Lorenz curve, which is a cumulative frequency curve that is used for comparing distribution of any variable, distributed uniformly, thus representing equality. For constructing a Gini-coefficient, plot cumulative percentages of households on x-axis (horizontal axis) from poor to rich while cumulative percentages of expenditure on the y-axis (vertical axis). Thus the Gini coefficient has been defined in terms of A/ (A + B), where both A and B are areas depicted in the figure above. If taken A = 0, then the Gini coefficient is also 0, this indicates perfect equality while on the other

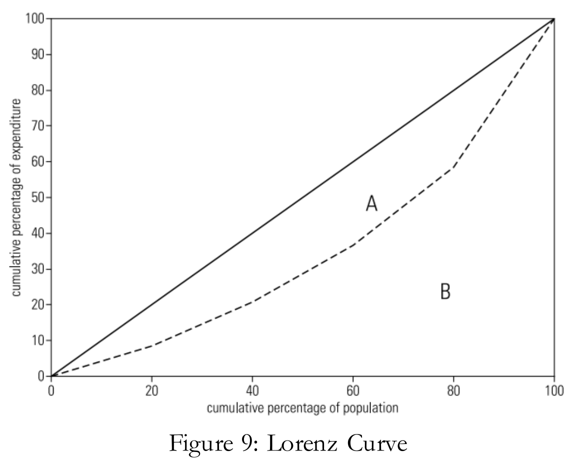


Figure 9: Lorenz Curve

Source (Haughton & Khandker, 2009)

hand, if taken B = 0, then the Gini coefficient is 1, which indicates perfect inequality (Haughton & Khandker, 2009). In this research, the use of Gini-Coefficient of Inequality and Lorenz Curve will be as a social equality measurement.

3.1.3.3. Spatial Autocorrelation

The understanding of the geographic phenomenon takes place by analysing and identifying the geographical patterns. Although maps are a tool to get a sense of the spatial pattern of features, distribution and values of their association, statistical calculations are still more significant in quantifying the patterns. It facilitates comparison between the different patterns of distribution and helps in identifying the clustered patterns, which is required to distribute infrastructural resource equally.

Spatial Autocorrelation is one means of geographical analysis. It is defined by Upton and Fingleton (1985) as *"property that mapped data possess whenever it exhibits an organized pattern"* and as *"it is more useful to define spatial autocorrelation by means of understanding lack of spatial autocorrelation"* In other words, non-existence of connection between spatial features indicates the lack of spatial autocorrelation. This definition is considered to be a subjective definition because 'organized pattern' have many meanings. Upton and Fingleton (1985) state that, spatial autocorrelation cases are undertaken when for instance the values of spatial variation across a map are systematic. This indicates that positive spatial autocorrelation exists when there is an association between high values at one locality with neighbouring localities, while negative spatial autocorrelation exists when high and low values are carried by adjacent localities.

In the same context, Goodchild (1986) state that; *"Spatial autocorrelation deals simultaneously with both location and attribute information"*. Spatial autocorrelation has been also *"concerned with the degree to which objects or activities at some place on the earth's surface are similar to other objects or activities located nearby and reflects"* (Goodchild, 1986). This definition is in accordance to Tobler (1970) first law of geography, which states, *"everything is related to everything else, but near things are more related than distant things"*.

In this research, we will thus use a Spatial Autocorrelation method in order to analyze the geographic patterns i.e. Global Moran's I. *Global Moran's I*, is a widely used statistically measure to test the spatial autocorrelation, based on the value and location of the feature, which is used to evaluate the distribution patterns of the features such as cluster, disperse or random.

In this research, the use of *Global Moran's I* will be as a spatial equality measurement, concerning the distribution for infrastructure resource; the more the pattern is clustered more equitable it is.

3.1.3.3.1. Global Moran's I

Global Moran's I is a spatial autocorrelation measure. It is based on the value and location. It evaluates the distribution pattern (e.g. cluster, disperse, random). *Global Moran's I* helps in identifying the neighbourhood distance which makes spatial autocorrelation become strong (Mitchell, 2005).

The positive value of the *Global Moran's I* indicates that both values for neighbouring locations are either larger or smaller than the mean. If one of the values is smaller than the mean and the other is larger, then the value turns to be negative. Note that; deviation from the mean and the cross-product result are directly proportional. The more the deviation increases, the higher the cross-product result. Moran's Index values lie between -1.0 and +1.0. Then, *Global Moran's I* computes comparison between the Observed and expected values. The computation for z-score and p-value and the differences between data values to indicate the statistical significance of these comparisons. For instance, if a location values are spatially distributed in a random way, the p-value would be statistically non-significant (Mitchell, 2005).

3.1.4. Equity-Based Infrastructure investment

This research will focus on trying to develop a conceptual framework clarifying the equitable approach to infrastructure investment. The conceptual framework that will be developed should have a strategy for assessing needs. Therefore, there is a need for a plan "e.g. five-year infrastructure plan" to clarify how priorities are to be implemented within or across departments and what is the basic required data to assess these needs.

As we addressed earlier the adopted policy in this research is "pro-poor" policy and the chosen method is "Equity", therefore the criteria should reflect in achieving equitable resource allocation.

The criteria will rely on two preference models in determining priorities to address, adapted from on-going study concerns about modelling equitable infrastructure (Wismadi et al., 2013b). The role of a preference model is to translate stakeholders' inputs and preferences into priorities to target. First model is Non-Spatial preference modelling estimating individual sense of inequality in such non-spatial context. Wismadi et al. (2013b) argues that notion of inequality is relative according to local conditions e.g. neighbourhood in a well-developed city that suffers of bad infrastructure would have a higher level of inequality than another neighbourhood with the same infrastructure conditions in another area where this infrastructure condition is the average of the area. Such inequalities like the case of the first neighbourhood could not be captured in overall comparative processes. This led Wismadi et al. (2013b) to introduce the spatial preference modelling approach. Especially in the context of infrastructure, the importance of the spatial local factor is even more obvious, as infrastructure depends on the interconnectivity between added and existing networks.

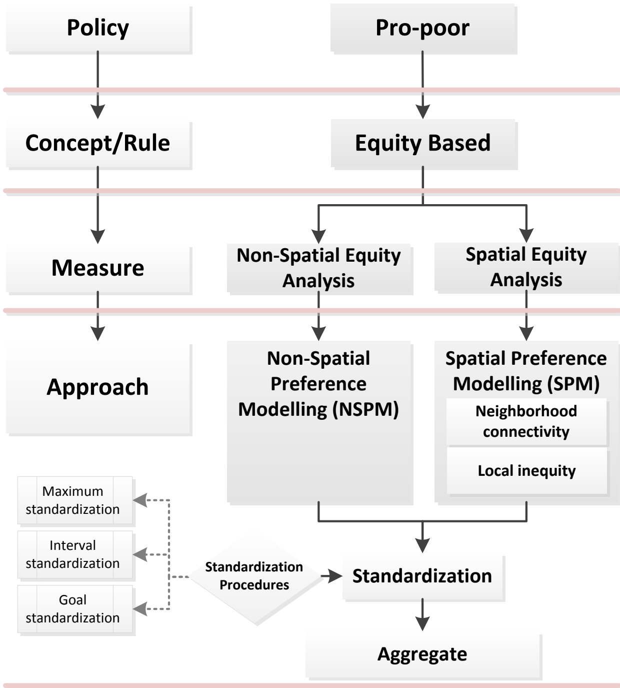


Figure 10: Equity-Based Infrastructure investment

3.2. Infrastructure resource allocation decision criteria (Workflow)

The following section will address the developed infrastructure resource allocation criteria (Figure 11), explaining the workflow that decision makers will follow in order to distribute the available resources, thereby improving the equitable distribution of infrastructure service level.

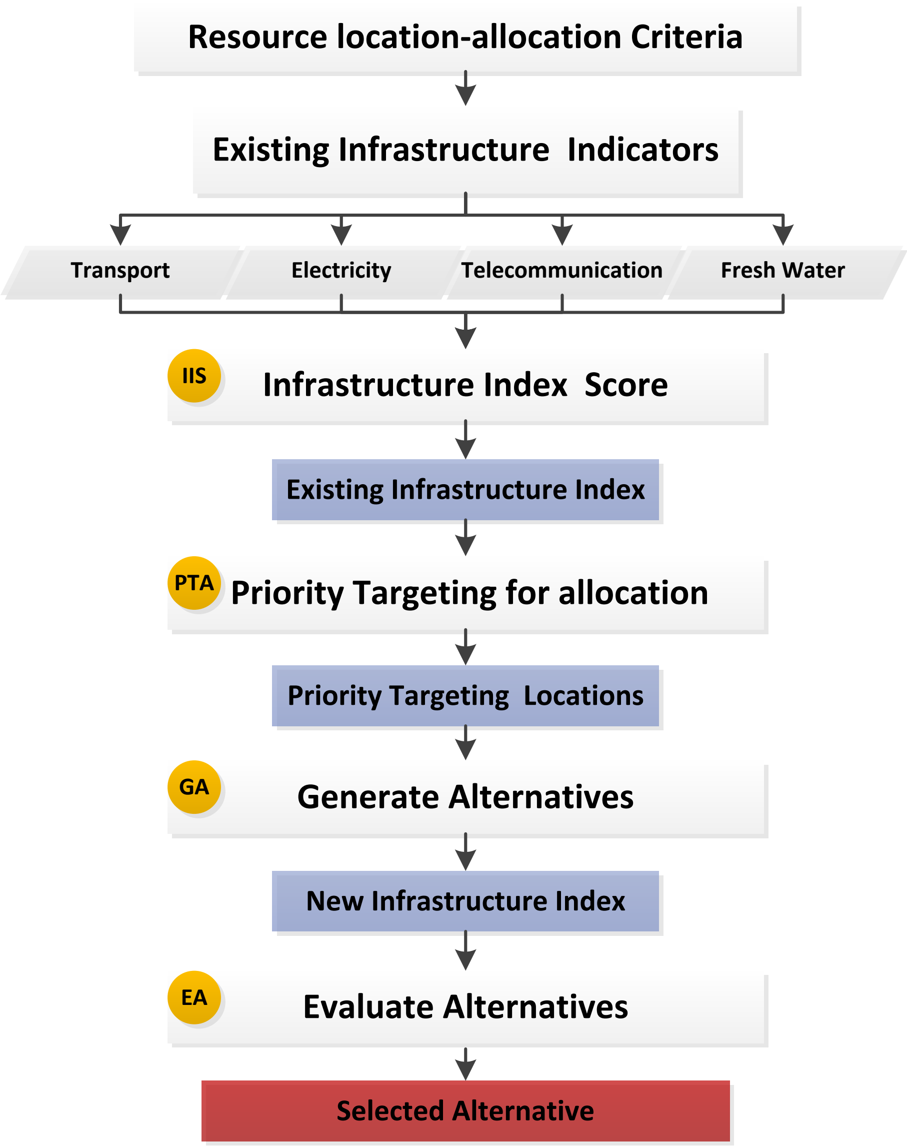


Figure 11: Infrastructure resource allocation Decision Criteria

In the context of this study, the resource allocation process is based on four sectors of infrastructure (transport, electricity, telecommunication and freshwater). The first step in this developed criteria, is to combine those four sectors indicators in order to generate one indicator representing the infrastructure score index using the non-spatial preference modelling or spatial preference modelling approaches. The non-spatial preference modelling reflects the local infrastructural condition for each location, and the spatial preference modelling approaches reflects the neighbourhood infrastructural condition for each location.

The next step is to identify the priority target locations. The decision makers identify deprived locations based on their goal (e.g. poverty line, service level goal …etc.). This step can be addressed by using two approaches, first to assign this goal through the four infrastructure input indicators (e.g. transport poverty line) by generating the infrastructure (goal method - linear scale transformation method) in both implemented models. Second approach is through the calculated existing infrastructure index (e.g. infrastructure index poverty line).

After identifying the priority target locations, decision makers will start to generate alternative(s) to distribute and allocate the additional resources on the identified locations following the same approach used in the previous step, using either the first approach to assign the resources for each infrastructure indicator (e.g. increase travel speed – transport indicator) or the second approach (e.g. increase the infrastructure index). The generated alternative(s) thus represent the different possible alternatives that the decision makers can adopt as a solution.

After generating the possible solution alternative(s) for allocating the available resources, this step involves evaluation of these alternatives. The designed criteria address two evaluators. First, *Global Moran's I* statistic, which is a spatial autocorrelation method based on both unit location (spatial location) and unit value (infrastructure index). It evaluates the infrastructural service pattern expressed (clustered, dispersed, or random) as the criteria target, achieving a fair distribution of available resources. *Global Moran's I* identifies the alternative with the highest score as the most suitable alternatives, representing the alternative with the most clustered areas, which proposes equity in the distribution of available infrastructural resources. The second is *Gini-Coefficient*, which is a measure of inequality, and is based on *Lorenz Curve*, which is a cumulative frequency curve that compares the distribution of an infrastructural service level (index score) with the uniform distribution of the case spatial units (e.g. villages). Based on the results of the two evaluation methods, decision makers can identify the suitable alternatives to choose.

3.3. Infrastructure resource allocation decision criteria (processes and methods)

This section describes the methods and processes in each main process, mentioned in the workflow for the Infrastructure resource allocation criteria as developed in this research (Figure 11).

3.3.1. Existing infrastructure indicators

As mentioned previously, the term infrastructure in this research refers to the four major sectors of transport, electricity, telecommunication and freshwater. Thus the main focus of the study is to understand how to generate an infrastructure score that represents the service level of infrastructure, which is thus representative of all its four sectors.

3.3.2. Generate infrastructure score

In this step we are using two models to generate the infrastructure score adopted from an on-going study (Wismadi et al., 2013b). Wismadi et al. (2013b) introduces two models for equitable infrastructure, which are non-spatial preference modelling and spatial preference modelling approaches.

The Non-spatial preference modelling approach reflects the infrastructural conditions while the spatial preference modelling approach reflects the spatial unit. This means that it reflects the infrastructural conditions within the spatial unit of analysis i.e. the neighbourhood, for this study. Thus for each modelling approach the steps defined in (Figure 12) will be further addressed in the following sections.

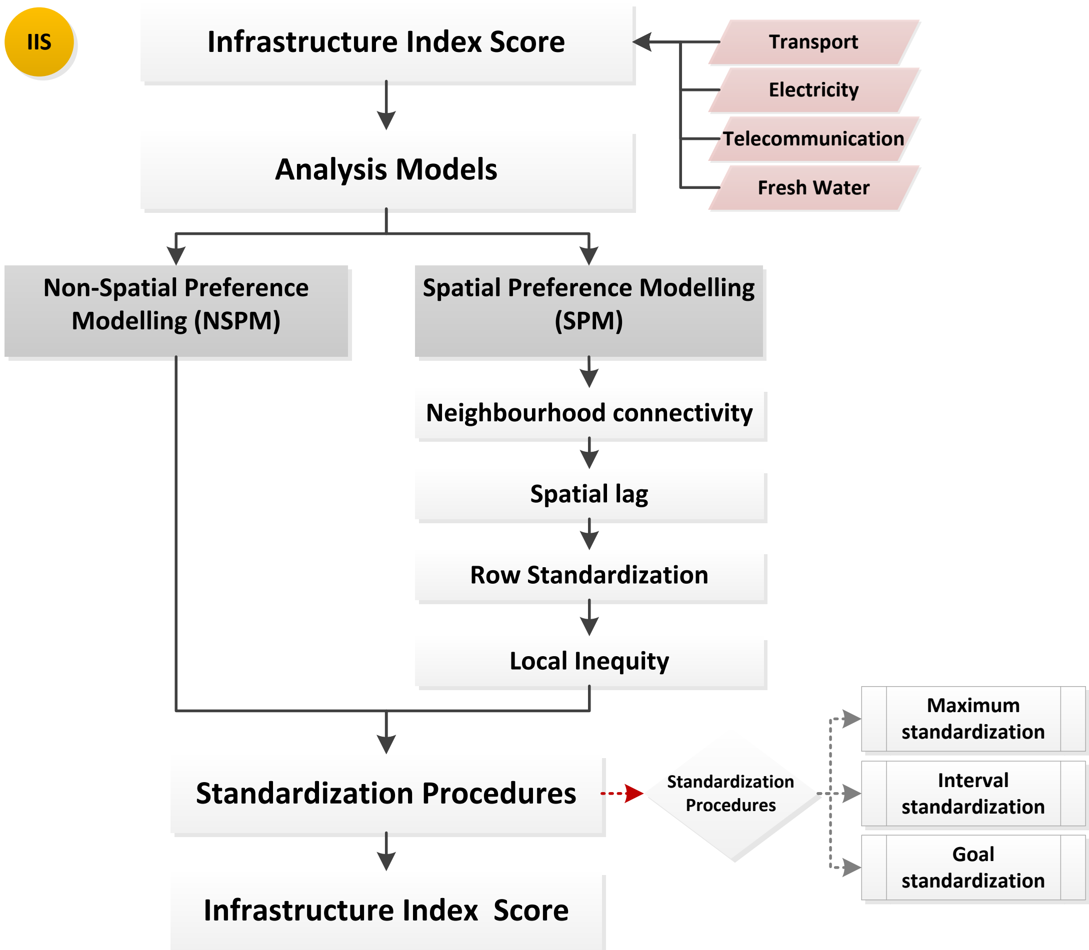


Figure 12: Generate Infrastructure Score

3.3.2.1. Non-Spatial preference modelling

In order to compare the different infrastructure indicators preference models mostly incorporate a decision rule that is based on a variation of ranking amongst objects. For comparison of these objects, a widespread method of linear scale transformation is applied to transform the original scores in the form of standardized scores.

3.3.2.1.1. Standardization methods

Linear scale transformation is a deterministic method used to transform input raw data into corresponding criterion scores and there are three different standardization methods which can be understood as under (Malczewski, 1999).

3.3.2.1.1.1. Maximum standardization

Maximum standardization generates scores based on ratio scale in an aligned manner between *zero* and the highest score. In the case of benefit criteria, the highest score has been standardized to *one*, but in the case of cost criteria the lowest score has been standardized to *one* (Equation 1and Equation 2).The advantage of this standardization method is simply stating that the standardized scores are proportional to the original scores. It is however important to mention that less variation will be observed while comparing the scores.

Equation 1: Non-Spatial Model - Maximum Standardization, Benefit criteria

$$P_{\mathrm{i}} = \frac{X_i}{max\,X}$$

Equation 2: Non-Spatial Model - Maximum Standardization, Cost criteria

$$P_i = \left(\frac{X_i - \min X}{\max x}\right) + 1$$

Where:

P_i	The priority score for the spatial unit of analysis $_i$
X_i	Original (criterion or infra) score of the spatial unit of analysis $_i$
min X	The lowest value of the input set $_i$
max X	The highest value of the input set $_i$

3.3.2.1.1.2. Interval standardization

Interval standardization generates scores based on a relative scale, in an aligned manner between *zero* and the highest score. In the case of benefit criteria, the highest score has been standardized to *one*, but in the case of cost criteria the lowest score has been standardized to *one* (Equation 3 and Equation 4). The advantage of this standardization method is that the variation between scores is exaggerated.

Equation 3: Non-Spatial Model - Interval Standardization, Benefit criteria

$$P_i = \frac{X_i - \min X}{\max X - \min X}$$

Equation 4: Non-Spatial Model - Interval Standardization, Cost criteria

$$P_i = \left(\frac{X_i - \min X}{\max X - \min X}\right) + 1$$

Where:

P_i	The priority score for the spatial unit of analysis $_i$
X_i	Original (criterion or infra) score of the spatial unit of analysis $_i$
min X	The lowest value of the input set $_i$
max X	The highest value of the input set $_i$

3.3.2.1.1.3. Goal standardization

This method of standardization is however similar to the earlier one, but it aims to assign reference points within the range of unit $_i$ values (Equation 5 and Equation 6). These reference points thus represent an ideal score or a goal value that would be accepted by the decision makers.

Equation 5: Non-Spatial Model - Goal Standardization, Benefit criteria

$$P_i = \frac{X_i - \min G}{\max G - \min G}$$

Equation 6: Non-Spatial Model - Goal Standardization, Cost criteria

$$P_i = \left(\frac{X_i - \min G}{\max G - \min G}\right) + 1$$

Where:

P_i	The priority score for the spatial unit of analysis $_i$
X_i	Original (criterion or infra) score of the spatial unit of analysis $_i$
min G	The lowest value of the range goal - range G defined by stakeholders
max G	The highest value of the range goal - range G defined by stakeholders

Finally, by using one of the above methods, the different indicators are identified by the decision makers to represent the four infrastructure sectors, which are represented in different units according to each sector characteristics (e.g. transport sector indicator: travel speed (km/h), telecom sector indicator: average transfer capacity (kbps)). The linear scale transformation method will thus be applied using one of the above methods, based on the advantage for each method and requirements of the decision makers. Thus, the result of the model will generate four new indicators representing the four infrastructure sectors on the scale from zero to one.

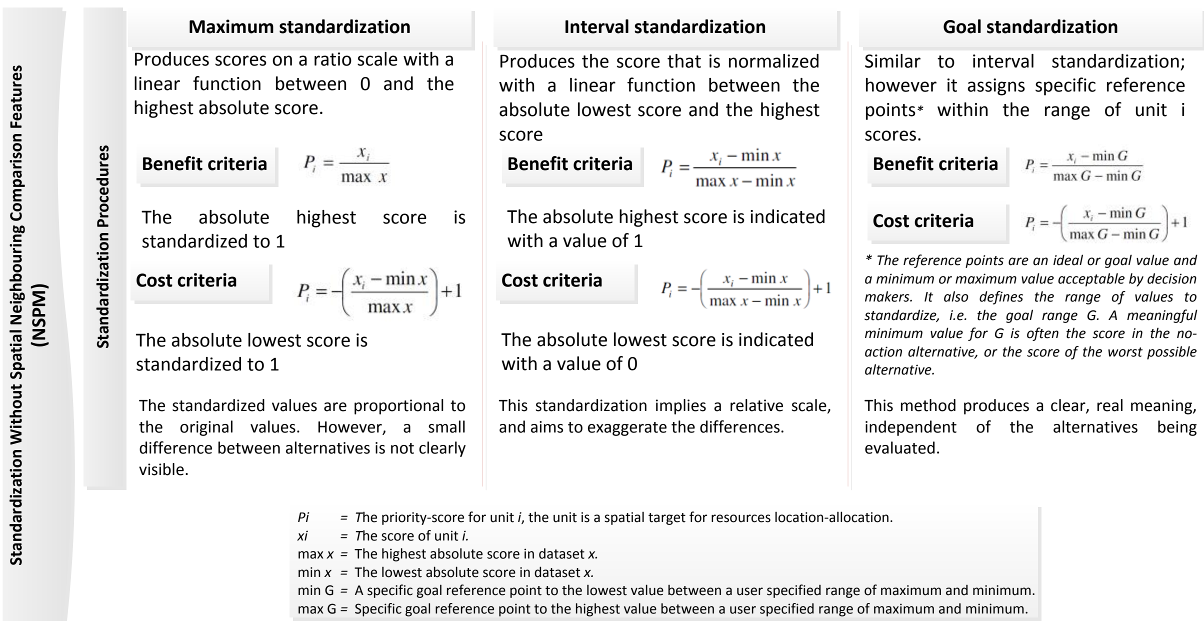


Figure 13: Non-Spatial preference modelling
Source: Adapted from (Wismadi et al., 2013b)

3.3.2.2. Spatial preference modelling

In the spatial preference modelling, the spatial factor of comparing neighbouring conditions is of significant importance. The spatial preference modelling approach in this research has also been developed by Wismadi et al. (2013b) with a spatial autocorrelation feature, that has been done by extending the concept of Moran's I scatter plot formation and combining it to linear scale transformation method.

Moran's I Index is a statistical measure for spatial autocorrelation (Shortridge, 2007) that quantifies the differences between values over an area. It has been widely used in quantifying spatial distribution. However, it has not been utilized in the context of resource allocation (Wismadi et al., 2013b). In the context of this study, *Moran's I* is understood as a correlation between value (X_i) at location ($_i$) and the average values of the neighbours of this location ($X_{lag\ i}$). The neighbouring locations identified through a weight matrix identifying local neighbours, thus generated based on a neighbouring connectivity rule as explained below.

3.3.2.2.1. Neighbourhood connectivity

Neighbourhood connectivity is the way of determining the neighbour polygons. There are two types of neighbourhood connectivity rules. One that considers any polygon that shares an edge or vertex with the concerned polygon as a neighbour polygon, while the other considers polygons to be neighbours if only they share an edge. In this study, the first type was selected for use, as it reflects better representation of the spatial units' neighbourhood connectivity.

The neighbourhood connectivity translated to a binary weight matrix, represented the neighbouring status between the target polygon and neighbour polygons and *zero* for non-neighbours. This way, when taking averages for values, only neighbouring polygons were thus considered in the calculation having a weight of *one* and others neglected with a weight of *zero*.

3.3.2.2.2. Spatial lag

The Spatial lag ($X_{lag\ i}$) represents the weighted average of the neighbouring polygons values. Thus before we implement a linear scale transformation method, standardizing x_i into X_i and $x_{lag\ i}$ into $X_{lag\ i}$ are of prior significance. For both of x_i and $x_{lag\ i}$, the standardizations thus made have been based on a raw dataset of x, thereby the mean and standard deviation $SD\ (x)$ have been applied to the following formula(Equation 7 and Equation 8),

Equation 7: Standardization x_i To X_i

$$X_i = (x_i - \overline{x})/SD\ (x)$$

Equation 8: Standardization $x_{lag\ i}$ To $X_{lag\ i}$

$$X_{lag\ i} = \left(x_{lag\ i} - \overline{x}\right)/SD\ (x)$$

Where:

x_i	The value at location $_i$
X_i	Standardized X_i
$\overline{x}$	Mean value of the input set values
$x_{lag\ i}$	Average value of the location $_i$ neighbouring values
$X_{lag\ i}$	Standardized $X_{lag\ i}$
$SD\ (x)$	Standard deviation of the input set values

3.3.2.2.3. Local inequity

As X_i and $X_{lag\,i}$ are now calculated we could determine the local inequity g_i which represents the difference between the value X_i at the location i and its neighbouring units $X_{lag\,i}$ (Equation 9). Here, a positive g_i represents a higher local inequality whereas a negative g_i represents that location i is a place of location that has a good condition while 0 represents equity.

Equation 9: Local Inequity

$$g_i = X_{lag\,i} - X_i$$

3.3.2.2.4. Standardization methods

Applying the same linear scale transformation methods, which we used in the Non-Spatial preference modelling (Section 3.3.2.1.1) but here we also include the spatial factor through considering the spatial weight matrix and use the local Inequity values instead of the infrastructure indicators.

3.3.2.2.4.1. Maximum standardization for spatial preference model

Maximum standardization generates scores in neighbouring units based on ratio scale in an aligned manner between *zero* and the highest score. In the case of benefit criteria, the highest score has been standardized to *one*, but in the case of cost criteria the lowest score has been standardized to *one*(Equation 10 and Equation 11).

Equation 10: Spatial Model - Maximum Standardization, Benefit criteria

$$P_i = W_{ij}\left[\frac{g_i}{\max \breve{g}}\right]$$

Equation 11: Spatial Model - Maximum Standardization, Cost criteria

$$P_i = W_{ij}\left[\frac{(\min \breve{g}) - g_i}{(\max \hat{g})} + 1\right]$$

Where:

P_i	Priority score for spatial unit of analysis i
W_{ij}	Connectivity weight of the neighbouring location j
g_i	Local equity score of location i
$\max \hat{g}$	the maximum value of g of neighbouring units j
$\min \breve{g}$	the minimum value of g of neighbouring units j

3.3.2.2.4.2. Interval standardization for spatial preference model

Interval standardization generates scores in neighboring units based on a relative scale, in an aligned manner between *zero* and the highest score (Equation 13 and Equation 14). In the case of benefit criteria, the highest score has been standardized to *one*, but in the case of cost criteria the lowest score has been standardized to *one*.

Equation 12: Spatial Model - Interval Standardization, Benefit criteria

$$P_i = W_{ij}\left[\frac{g_i - (\min \breve{g})}{(\max \hat{g}) - (\min \breve{g})}\right]$$

Equation 13: Spatial Model - Interval Standardization, Cost criteria

$$P_i = W_{ij}\left[-\left(\frac{g_i - (\min \breve{g})}{(\max \hat{g}) - (\min \breve{g})}\right) + 1\right]$$

Where:

P_i	Priority score for spatial unit of analysis i
W_{ij}	Connectivity weight of the neighbouring location j
g_i	Local equity score of location i
$\max \hat{g}$	the maximum value of g of neighbouring units j
$\min \breve{g}$	the minimum value of g of neighbouring units j

3.3.2.2.4.3. Goal standardization for spatial preference model

This method of standardization is however similar to the earlier one while generating scores in neighbouring units, but it aims to assign reference points within the range of unit i values (Equation 14 and Equation 15). These reference points thus represent an ideal score or a goal value that would be accepted by the decision makers.

Equation 14: Spatial Model - Goal Standardization, Benefit criteria

$$P_i = \frac{W_{ij}\,(g_i) - \min G}{\max G - \min G}$$

Equation 15: Spatial Model - Goal Standardization, Cost criteria

$$P_i = \left[-\left(\frac{W_{ij}\,(g_i) - \min G}{\max G - \min G} \right) + 1 \right]$$

Where:

P_i	Priority score for spatial unit of analysis i
W_{ij}	Connectivity weight of the neighbouring location j
g_i	Local equity score of location i
$\min G$	The lowest value of the range goal - range G defined by stakeholders
$\max G$	The highest value of the range goal - range G defined by stakeholders

Finally using one of the above methods as previously mentioned, in Non- Spatial preference modelling, will generate four new indicators representing the four infrastructure sectors on the scale from *zero* to *one*.

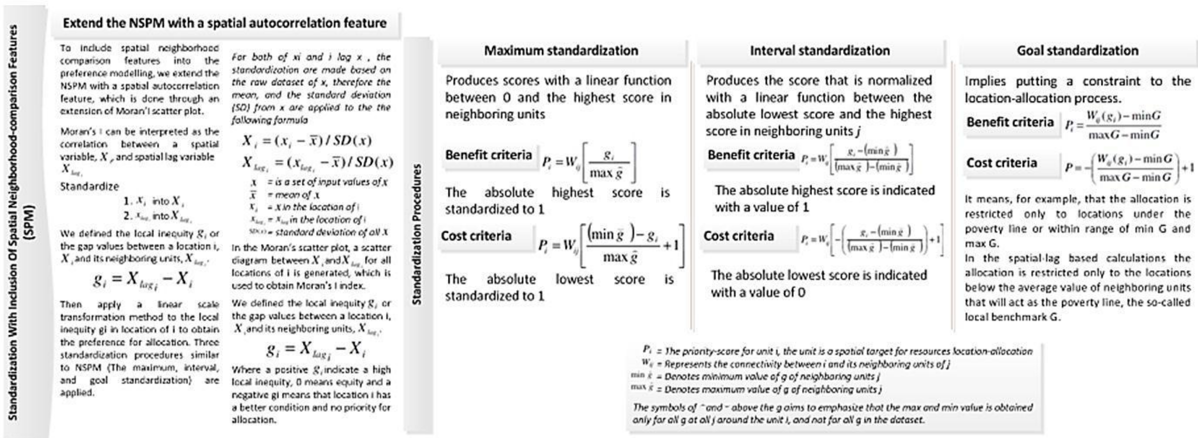


Figure 14: Spatial preference modelling

Source: Adapted from (Wismadi et al., 2013b)

3.3.2.3. Infrastructure score Index

In order to combine the generated four infrastructure sectors, different indicators have been identified by the decision makers, generated from non-spatial or spatial preference modelling approaches. Thus the following method is used for combining the outputs (four indicators representing the four infrastructure sectors) of the used model to generate the infrastructure score index on the scale from *zero* to *one* (Equation 16).

Equation 16: Combine infrastructure score Index

$$P_{i\,Infrastructure} = \left(\frac{P_{i\,Transport} + P_{i\,Electricity} + P_{i\,Telecom} + P_{i\,Water}}{Number\ of\ indicators\ (4)}\right)$$

The output of the previous step will generate the infrastructure index score (from *zero* to *one*) representing the local infrastructural condition for each spatial unit of the study (e.g. village). With this generated index, the infrastructural service level can be identified amongst all the spatial units (e.g. villages) in the study area (e.g. region) over one scale.

3.3.3. Priority Targeting for allocation

Priority targeting locations (Figure 15) are identified using the generated infrastructure index score and the decision makers' goals (e.g. poverty line, service level goal …etc.). Both, the index score and the study goal will detect the priority targeting locations and the needs for the different infrastructure sectors through two possible approaches. Firstly by defining the goal for the four infrastructure input indictors (e.g. transport poverty line) by generating the infrastructure (goal method - linear scale transformation method). Secondly, by using the calculated existing infrastructure index (e.g. infrastructure index poverty line).

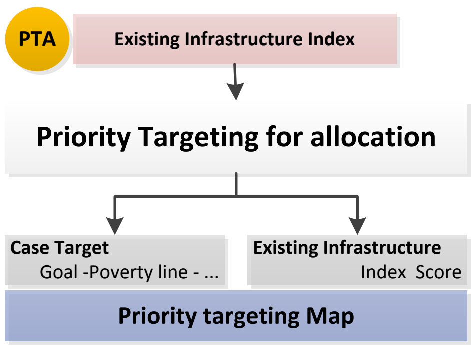


Figure 15: Priority targeting for allocation

3.3.4. Generate Alternatives

Decision makers will produce the different alternatives after identifying the priority targeting locations, to distribute the resources in a way that improves the equitable distribution for the infrastructure service level.

There are many ways to distribute the available resources, taking into account the different backgrounds of the involved decision makers and the different possible targets for each case, which influences generating different alternatives in order to reach the most viable alternatives.

The process of generating alternatives (Figure 16), reflect two possible approaches depending on the available

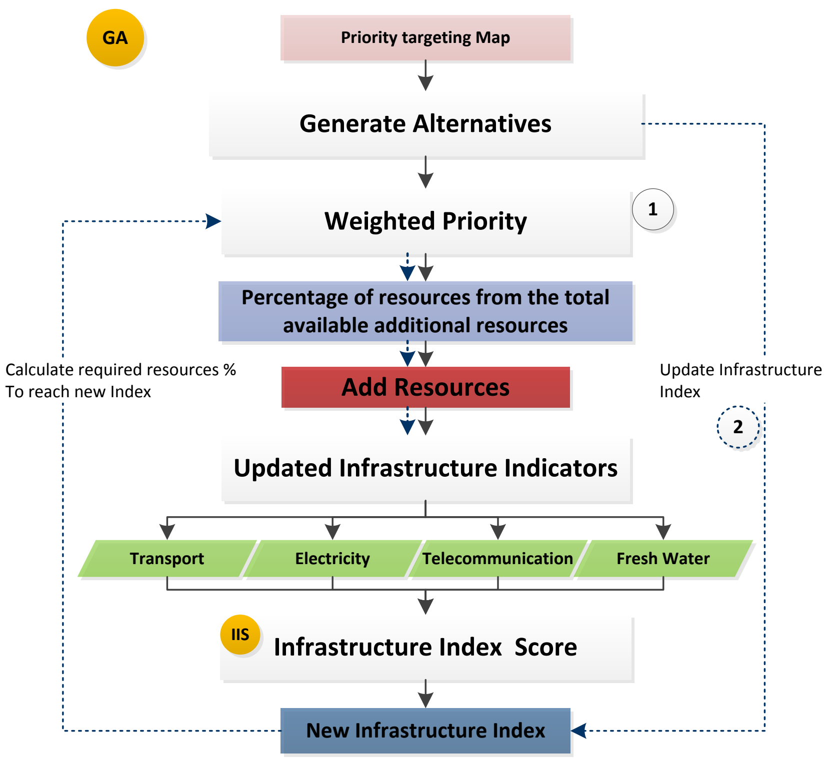


Figure 16: Generate Alternatives

information and the case target.

The first approach moves in the direction of the workflow, which defines a case for improvement for the four used indicators (infrastructure sectors), and use the new values to generate a new infrastructure index, thus representing the new alternative. For similar cases, the workflow will begin from the priority targeting locations, filtering it to the target locations for the alternatives. Then, the infrastructure index is generated in order to address the future consequences after allocating the new resources, which will be used in the last step of the criteria in order to evaluate the different alternatives.

In the second approach, the goal improvements of the case will be applied based on the existing infrastructure index, the improved score index will thus represent the new alternative infrastructure index. Thereafter, with the new index, will follow the weighted criteria process and update infrastructure indicators in order to translate the improvement in the index to a percentage required to improve each sector to reach the target index.

3.3.4.1. Weighted Priority

The first step after filtering targeting locations for each alternative represents a way to identify the percentage of available additional resources that each location requires, based on demographics or socio-economic situation in the study area (Equation 17). Wismadi et al. (2013b) used to normalize the score and got the percentage of resources that each location deserved based on the number of households in each location; a way to normalize the score using a demographic or socio-economic variable.

Equation 17: Normalize the score - weighted priority

$$\alpha_i = \frac{P_i \, . H_i}{\sum_i P_i \, . H_i}$$

Where:

α_i Percentage of resources to be allocated in location $_i$

P_i Priority score of generate infrastructure score analysis $_i$

H_i Normalize variable e.g. number of households in location $_i$

3.3.4.2. Generate New Infrastructure Score

In this step, the percentage of resources should be assigned to each location based on the developed alternative preference by using the existing situation analysis for each location and infrastructural sector conditions; they can allocate this percentage in the sector, which will improve the infrastructure service level. Thereafter, decision makers will generate a new infrastructure score for the study area, based on the new added resources in order to address the future consequences after allocating the new resources. This step will be done for each alternative, so finally the decision makers will have all the generated alternatives with the new infrastructure score.

3.3.5. Evaluate Alternatives

The final step is to evaluate the alternatives generated by the decision makers. The designed criterion addresses the two evaluators in order to identify which alternatives achieve equitable distribution of resources. In order to answer those questions, first evaluator is The Spatial Autocorrelation *Global Moran's I* method while the second method is the *Gini-Coefficient*.

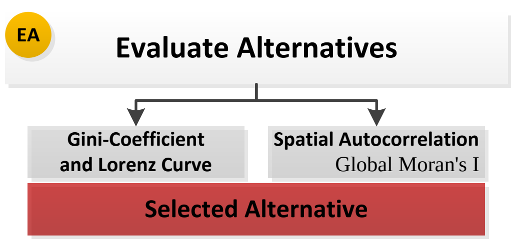


Figure 17: Evaluate Alternatives

3.3.5.1. Global Moran's I

Global Moran's I is a spatial autocorrelation measure based on both unit location (spatial location) and unit value (infrastructure index). It evaluates the infrastructure service pattern expressed (clustered, dispersed, or random) as developed for criteria targeting to achieve fair distribution of available resources. *Global Moran's I* identifies the alternative with the highest score as the most suitable alternatives, as it will represent the alternative with the most clustered areas, which proposes equity in the distribution of available infrastructural resource. Moran's Index values lie between -1.0 and +1.0. If a location values are spatially distributed in a random way, the p-value would be statistically non-significant (Mitchell, 2005).

The Local Moran's I statistic of spatial association is given as:

$$I_i = \frac{x_i - \bar{X}}{S_i^2} \sum_{j=1, j\neq i}^{n} w_{i,j}(x_j - \bar{X}) \qquad (1)$$

where x_i is an attribute for feature i, $\bar{X}$ is the mean of the corresponding attribute, $w_{i,j}$ is the spatial weight between feature i and j, and:

$$S_i^2 = \frac{\sum_{j=1, j\neq i}^{n} (x_j - \bar{X})^2}{n-1} - \bar{X}^2 \qquad (2)$$

with n equating to the total number of features.

The z_{I_i}-score for the statistics are computed as:

$$z_{I_i} = \frac{I_i - \mathrm{E}[I_i]}{\sqrt{\mathrm{V}[I_i]}} \qquad (3)$$

where:

$$\mathrm{E}[I_i] = -\frac{\sum_{j=1, j\neq i}^{n} w_{ij}}{n-1} \qquad (4)$$

$$\mathrm{V}[I_i] = \mathrm{E}[I_i^2] - \mathrm{E}[I_i]^2 \qquad (5)$$

Figure 18: Spatial autocorrelation - *Global Moran's I*
Source: (Mitchell, 2005)

3.3.5.2. Gini-Coefficient

Gini-Coefficient is a measure of inequality, and it is based on *Lorenz Curve*, which is a cumulative frequency curve that compares the distribution of an infrastructure service level (index score) with the uniform distribution of the case spatial units (e.g. villages). In this research, the use of *Gini-Coefficient of Inequality and Lorenz Curve* will be as an equality measurement representing the distribution of the infrastructure service level amongst all the spatial units (e.g. villages) in the study area (e.g. region).

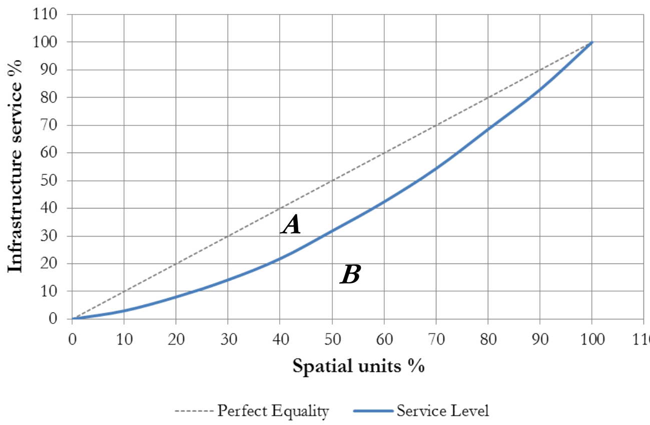


Figure 19: Lorenz Curve calculation

In order to construct *Lorenz Curve*, precise results can be achieved by calculating the mean value between the difference existing in infrastructure service and the generated alternatives then apply an even estimation to the distribution function to match the number of spatial units. As can be seen in (Figure 19), cumulative percentages of the number of the spatial units (e.g. villages) have been plotted on X-axis (horizontal axis) while cumulative percentages of infrastructure service level (score index) on the Y-axis (vertical axis). Then the calculation of *Gini-coefficient* has been defined in terms of A/ (A + B).

Finally, based on the results of the two evaluation methods decision makers can identify the suitable alternative that improves the equitable distribution of infrastructure service level.

3.4. Conclusion

This chapter described the resource infrastructure allocation decision criteria, introducing the developed workflow for the decision makers, incorporating various steps and methods giving the complete detailed explanation of how the process of infrastructure resource allocation can be carried in order to support the decision makers in achieving equitable infrastructure service distribution among their study area.

4. SDSS FRAMEWORK

This Chapter presents the initial spatial decision support system SDSS framework that covers the addressed decision criteria of infrastructure resource allocation. The main objective of spatial decision support system SDSS is to support decision makers (e.g. government or municipal agencies, promoters, etc.) in achieving equitable distribution of infrastructure service and achieving the best use of the available infrastructure resources. Decision makers, should be fully aware of both the current situation and the effects/benefits of their decisions through visualizing different scenarios and alternatives. This chapter will try to address the framework for developed spatial decision support system in order to facilitate, visualize and analyze different scenarios and alternatives.

4.1. SDSS development Framework

Steps required to conceptualize the framework for spatial decision support system (SDSS) include four main steps as can be seen in (Figure 20). Firstly, defining strategies for infrastructure resource allocation by reviewing current policies and methods, besides concepts/rules and measures used by decision makers, to define the required approaches, in order to achieve the goal of the identified decision makers vision, to achieve fair distribution of infrastructure resources. Secondly, designing the system through, defining the infrastructure requirement analysis for resource allocation criteria. In order to design the framework for the spatial decision support system, we first need to clarify the system requirements, which include defining the target user group(s), system assumptions, required inputs and outputs, user communication and using of system outputs in decision-making process. This design step is a transition step to identify the system operations. Thirdly, implementing SDSS by defining flowcharts of system operations, which consist of different modules each of them focusing on a specific part as data management module, visualization module and analysis module; then designing the prototype based on the flowchart and in the end building and testing the SDSS. Finally, operate the SDSS on a case study that fulfils the required data.

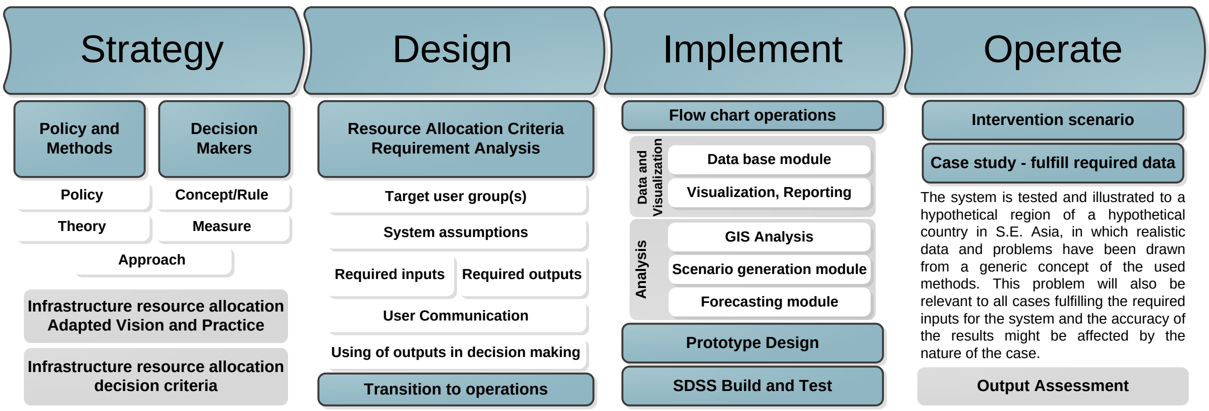


Figure 20: SDSS Framework

For the first step, 0, defined the system strategy as targeting the pro-poor policy, applying the equity base concept as the identified system vision and the adopted practice, which the developed framework should follow and represent. Then 3 identified the workflow (decision tree) of the resource allocation criteria and the detailed processes and methods that will be used to make the allocation decision achieve the adopted vision, which is equitable distribution of infrastructure service level.

This chapter begins from the design step (Figure 20) which will start to collect the system requirements, starting from getting to know who the system potential users (decision makers) are. Then breaking down the developed decision criteria for infrastructure resource allocation into process, identifying each process inputs and outputs, and identifying how the system potential users will communicate with the system and the required outputs supporting their decision making process.

Thereafter, introducing the implementation of the system workflow with identified processes, in order to generate the required outputs for the decision making process, to operate the system using available dataset which fulfils the required inputs for the developed criteria.

4.2. Decision Makers 'Potential users'

The expenditure on infrastructure is one of the largest items between countries' budgets. The current expanse levels are still insufficient to meet populations' needs although existing infrastructure is ageing, demand for more and better roads and improved water and sewer systems is growing. Complex and technical materials are required for decision-making and investment planning should be transformed into non-technical principles and guidelines for decision making to facilitate realizing adequate funding on the long term basis for infrastructure.

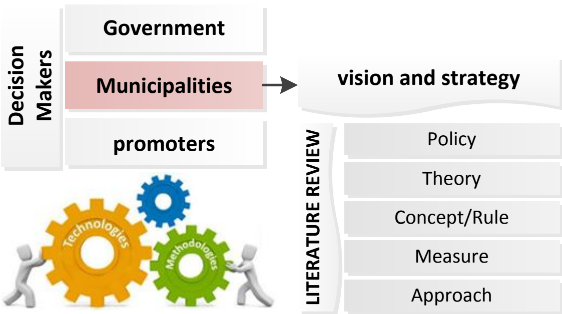


Figure 21: Decision makers' vision

Most of such large investments are public investments and so decision makers are always government, municipal agencies or promoter. They are focusing on planning and defining municipal infrastructure needs from roads, water, wastewater and sewers. Planning methods can promote effective and efficient spending by focusing on resources, which are most needed for the municipality. Accordingly, municipal infrastructure decision makers will be target user groups for this research.

Successful strategic planning is the plan integrating capital infrastructure, land use, financial and business plans all together. Targeting infrastructure goals can help in co-ordinating needs of infrastructure and resources priorities for municipalities. The existence of comprehensive plans can influence the type and place of growth that occurs, and can optimize or maximize the use of existing infrastructure, can assist planning for optimal rehabilitation of new infrastructure to promote effective and efficient spending. Moreover, they facilitate achieving sustainability in infrastructure services within the municipality by maintaining a certain level of service provision (Municipalities, 2003). Spatial decision support system (SDSS) is essential for decision makers in managing infrastructure for long terms especially if the challenges are meeting the needs of rapid population growth, experience ageing infrastructure or achieving sustainable infrastructure systems.

4.3. SDSS framework

This section reflects the framework for developing infrastructure resource allocation SDSS. The previous chapters discussed the nature of infrastructure resource allocation decision making process, laying stress on equitable resource allocation. This section describes a framework for development of SDSS. Thus the section below tries to translate the developed infrastructure resource allocation process decision criteria to a framework for a planning tool supporting the decision making process.

4.3.1. Basic elements of Infrastructure resource allocation decision criteria

Previous chapters introduced the adopted strategy and decision criteria for this research, which will draw the developed SDSS structure. In order to translate the addressed decision criteria to a spatial decision support system, a framework could assist the involved decision makers to achieve equitable distribution of the available infrastructure resources. First step is to translate the main decision criteria process into system components (Figure 22).

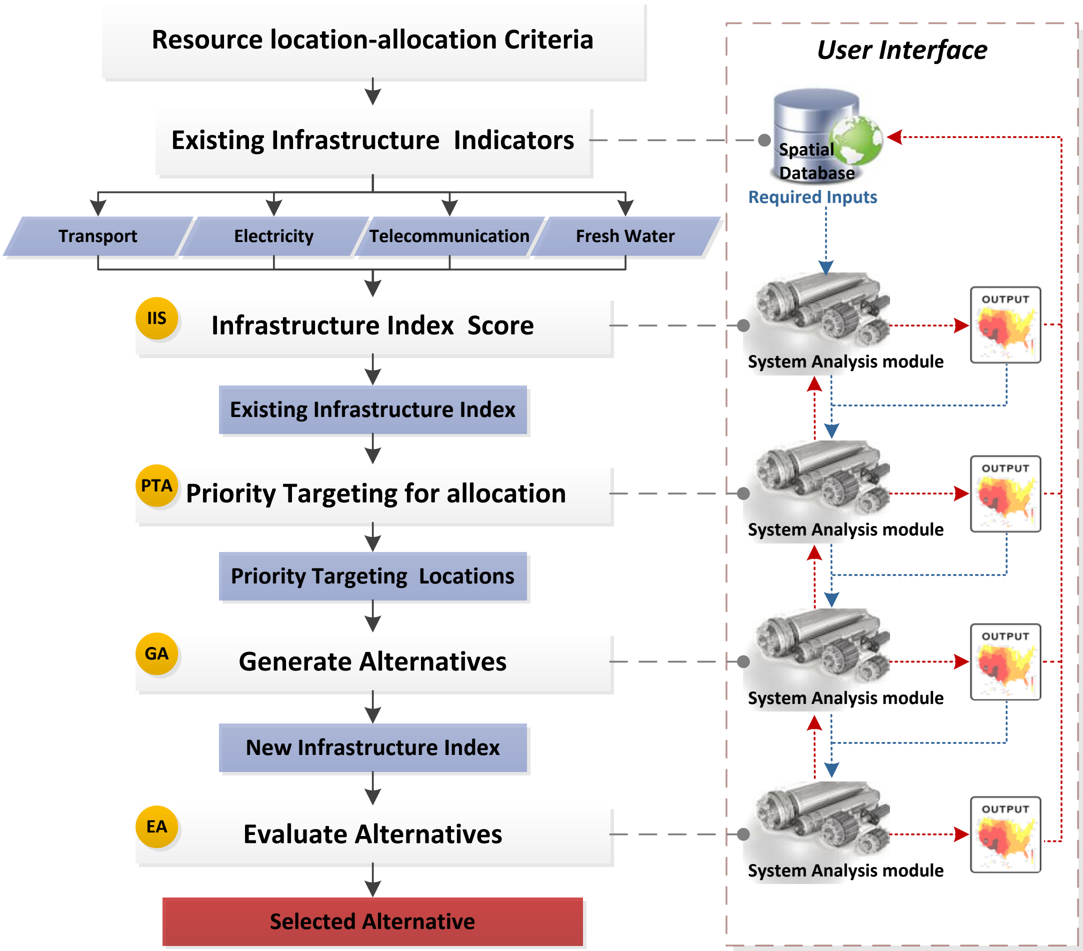


Figure 22: Elements of the decision criteria to system components

4.3.2. Introduce SDSS Basic system components

The basic elements of the developed SDSS structure as can be seen in (Figure 23). The first element incorporates a user interface, which is the main link between the decision makers and the SDSS giving them the access to the system functionalities, allowing decision makers to feed the system with the input information and methods in order to generate the required outputs. Outputs in the (Figure 23) represent all the system output including (1) required output for the decision process, which will be represented to the decision makers and (2) intermediate output, which is required within the process to generate the required

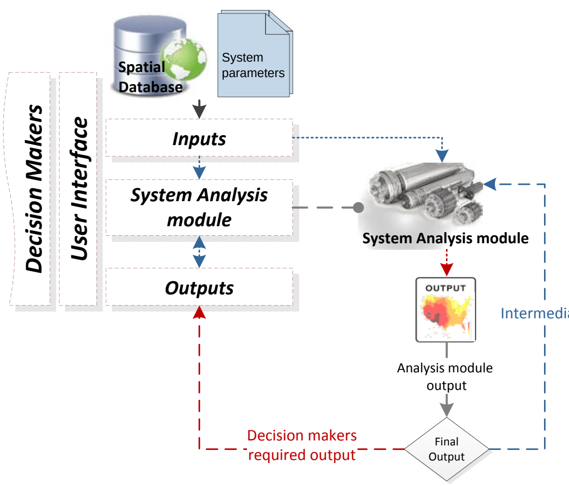


Figure 23: Introduce SDSS Basic system components

outputs. System modules represent the different functions/methods, which is the combined process to generate the required output from provided input.

4.4. Building SDSS

Within the SDSS environment, in order to avoid the technical complications we will depend on one of the existing GIS packages, which will be used as a base for our system. These existing GIS packages consist of several categories.

Traditionally, one of the most powerful packages that incorporated the capacity of dealing with huge amounts of data is that of *ESRI ArcInfo* software. This software is mostly used for building large datasets and is flexible and therefore is easy to integrate with various other applications, that are often related to decision-making applications(Keenan, 2006).

SDSS builders that incorporate third parties or the users, need the flexibility to reflect personalized configurations directed at supporting particular decisions. This necessitates the vendors of GIS to expose information of the functionalities of the system by creating and recording a set of Application Programming Interfaces (APIs). Thus the API's help in allowing the system builder to interact with many different parts of the system (Keenan, 2006).

In order to implement the developed SDSS in this research, *ESRI ArcInfo* package will be further extended, building a new toolbar that will represent a base to implement the developed SDSS. Implementing the developed system within the *ArcInfo* package will save some efforts regarding parts related to the data base management system (DBMS) and the reporting and visualization core function, as the implemented system will make use of the available set of Application Programming Interface (APIs) functionalities within the ArcInfo environment, which will be considered as our system environment. In other words, the input data will be in ESRI data format, making use of *ArcInfo* visualization and reporting for the system output.

4.4.1. SDSS implemented modules

The different modules in the developed SDSS represents the main elements in the infrastructure resource allocations, categorized into visualization module, analysis module, evaluate alternative module. As an initial development for the SDSS, the visualization module is limited to visualise the new added system result and to represent the infrastructure indicators, considering that the system was implemented within the *ArcInfo* environment. In this research, we completely implement the analysis (Generate infrastructure index) module both at the local and neighbourhood condition index.

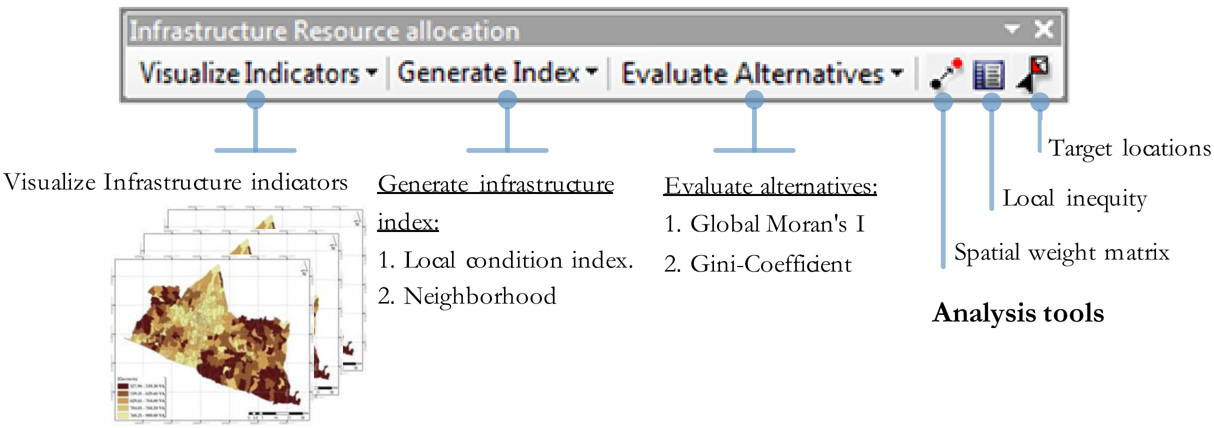


Figure 24: SDSS Toolbar

As (Figure 24) displays the implemented SDSS, the following section will address the design of the infrastructure index module

4.4.1.1. Infrastructure Index score module

Infrastructure Index score is the main indictor for the resource allocation process in this research, beginning from the four infrastructure sectors (transport, electricity, telecommunication and freshwater). The first step in the resource allocation process is to combine the indicators of these four sectors in order to generate the infrastructure score index using the non-spatial preference modelling or spatial preference modelling approaches. The non-spatial preference modelling reflects the local infrastructure condition for each location, while spatial preference modelling approaches reflects the neighbourhood infrastructure condition.

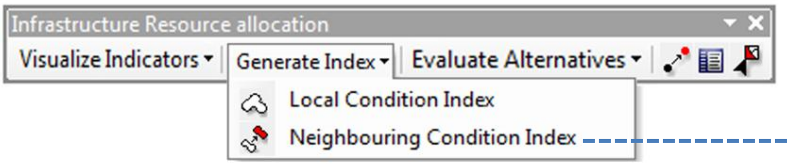


Figure 25: Generate infrastructure score index tools

The following section will undergo the process of generating the neighbouring condition index to address in greater detail how the system links between the different methods and process. Beginning with the required inputs from the decision makers (user) as can be seen in (Figure 26) the user is required to feed the system with the following inputs:

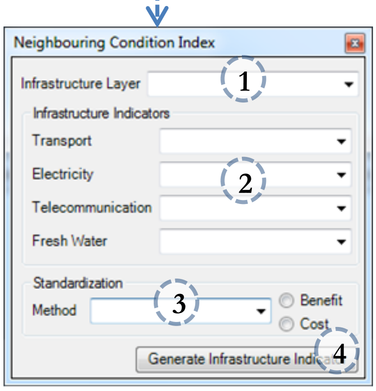


Figure 26: Neighboring index

1) Infrastructure layer, the polygon layer representing the spatial units. The user selects the target layer through the displayed drop-down list, which shows the layers in the ArcInfo table of content TOC.

2) Infrastructure indicators, as it can be seen there is four drop-down lists for the four infrastructure sectors. Each drop-down list displays the selected infrastructure layer allowing the user to select each infrastructure sector indictor (field attribute).

3) Standardization method, drop-down list displays the three defined methods (Maximum – Interval - Goal) and the standardization criteria that the user can select through the radio button showing the two criteria (Benefit - Cost).

4) The last item in the neighbouring condition index window is the generate index button.

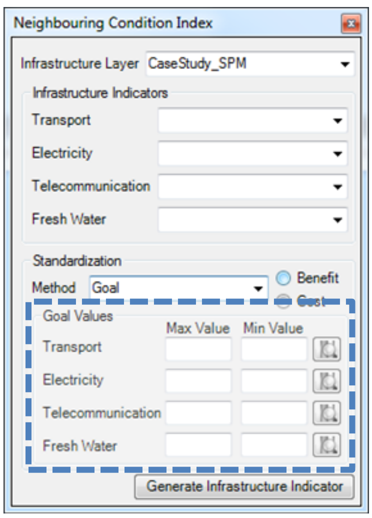


Figure 27: Neighboring index - Goal

After feeding the system with the required inputs and generating the infrastructure neighbouring condition index, the following processes will take place in order, (1) Neighbourhood connectivity process in order to determine the neighbour polygons for each spatial unit. (2) Calculating the spatial lag value, which represents the weighted average of the neighbouring polygons values. (3) Standardizing both the spatial unit value and weighted average of the neighbouring polygon values for each spatial unit. (4) Calculating the local inequality, which represents the difference between the spatial unit value and its neighbouring units. Then the linear scale transformation method is applied by the user, thus standardizing each infrastructure indicator (four-infrastructure type) according to the selected method and criteria. In case of using the goal method the window will automatically increase in height (Figure 27) allowing the user to determine the target goal value(s). Then combining the four generated infrastructure sector indexes to produce the infrastructure index score. Finally, a new classified layer is added to ArcGIS and the infrastructure index score and four generated index for each infrastructure sector is also being added to the infrastructure layer (feature class) as new fields.

4.5. Developed SDSS in practice

Local government/municipal functions in a complex set-up are constantly undergoing changes, which require them to think ahead of traditional approaches. The developed spatial decision support system suggests practical approaches for including GIS technology to assist the decision makers in local governments/municipals to deliver Infrastructure services in a way that achieves fair distribution of infrastructure resources.

4.5.1. SDSS Recommended Workflow

Decision makers can adjust the recommended workflow to their own practice according to the nature of their case scenario as long they are aware of the system goal and output generation methods and processes.

Focus has been laid on the workflow of the decision criteria processes in order to draw systematic steps about the infrastructure resource allocation problem-solving process. Based on combining the adopted criteria process (Chapter 3) and the GIS problem-solving workflow, this research recommends the below mentioned workflow:

4.5.1.1. Defined infrastructure problem

SDSS supports the previous mentioned analysis (criteria: methods/functions) which is concerned about supporting decisions to achieve fair distribution of infrastructure resources, which should be considered when identifying the following first two steps in recommended workflow:

1) Define the infrastructure problem(s)/scenario(s)
2) Identify, collect the required data

After reviewing the applicability of analysing the problem, using the addressed system and the availability of the required input data we move to the next step to operate the system.

4.5.1.2. Generate infrastructure score

In this step, the system generates the infrastructure score based on the four different indicators, the decision makers' selects to represent the overall infrastructure service in order to support the decision makers to identify the existing situation.

1) Existing Infrastructure score
   This is the main system output. The system provides two models to generate the infrastructure score, based on the identity of the problem, using the applicable model to the problem decision level.

4.5.1.3. Resource allocation alternatives

This step requires decision makers to go through the following steps for each alternative; however, it also depends on the infrastructure situation problem/scenario and their vision for the decision. With the provided system output analysis like the infrastructure score and/or the analysis for the existing conditions for the infrastructure indicators decision makers can identify the following:

1) Identify the priority target for resource allocation.
2) Determine the amount of resources to allocate in each location.
3) Distribute the amount of additional resources over the different sectors of infrastructure.

As the decision is based on infrastructure service level including the four different infrastructure sectors, the system is able to understand the added resources in two possible ways.

The first way is to translate the added resources to existing score by increasing the calculated infrastructure score. The second way is through increasing the used indicators to generate the index with the same unit. For example, in calculating the infrastructure score; transport indicator was the travel speed (km/h); in this case, the resources can be translated by increasing the travel speed for location $_i$ from *X (km/h)* to *Y (km/h)*. Then calculate a new infrastructure index representing the index after adding the resources in the identified priority targeting locations for this alternative(s).

The second way provides more accurate results, however it's more applicable when all the different parties are represented in the decision making process, which this research considers as the normal case regarding defining the system potential users (local government/municipal).

4.5.1.4. Evaluate alternatives

This is the last step, after generating the possible alternatives the decision makers agreed about. It represents the final step in order to choose the most viable alternative according to the system strategy. As the addressed goal for the designed criteria is to achieve fair distribution of infrastructure investment resources, the adopted evaluating measure used is *The Spatial Autocorrelation - Global Moran's I* method.

1) Generating the Spatial Autocorrelation - *Global Moran's I index* for the different alternatives.
2) Selecting the alternative with the highest clustered score *Global Moran's I index*

Thus this method was adopted in order to reflect the pattern of infrastructure service level among all the locations. The pattern of infrastructure service level is considered as an indicator to determine the level of equitable distribution of infrastructure service. The more the expressed pattern is clustered it represents more equitable distribution for the infrastructural resource.

4.6. Conclusion

This chapter identified the infrastructure resource allocation SDSS framework, beginning from defining the SDSS development framework and then introducing the decision makers (potential users). Thereafter, introducing the implemented SDSS, and then explaining the spatial preference modelling approach (neighbourhood infrastructure condition) and the required inputs and the generated output. Thus, explaining the role of the developed SDSS in practice and the recommended workflow for applying the developed criteria using the development system.

5. ANALYSIS AND RESULTS

This chapter demonstrates how local/municipal governments can successfully apply the developed spatial decision support system to make efficient and effective decisions in coordinating and managing resources, to plan for the future. This chapter will thus try to simulate a real-world situation in order to operate the government/municipality using actual spatial data in order to evaluate the system and investigate how the developed system can support the decision makers targeting the deprived areas to achieve equitable infrastructure service distribution.

5.1. Infrastructure resource allocation decisions

The need for a successful plan is always there as cities are expanding in size, in density, richer or poorer; they even change their main characteristics, so infrastructure planning is a key concern behind the successful planning. Infrastructure development is acknowledged as an important economic growth factor with a high economic, social and environmental return. However, infrastructure investments are declining worldwide. Currently, the infrastructure development has to provide more individuals, activities with the less amount of public funding.

The infrastructure resource allocation decision needs a well coordinated response among different parties. There are many possible solutions and alternatives to allocate the additional resources, considering the social aspect of fair distribution. The developed SDSS aims to support the decision makers to improve the allocation process.

5.1.1. Scenario

The local authority (municipality) of a hypothetical region in Southeast Asia; requested to identify the infrastructure investment plan considering the government goals of targeting the poor and increasing the equitable infrastructure service level among the region. According to the government infrastructure service index, the poverty line is identified as 0.4. Representatives of different departments of the local authority jointly coordinate to reach a viable plan to determine the additional resources needed for each location in the region in order to reach the target and improve the region infrastructure services level.

Representatives of various departments defined their goal to allocate the resources in the deprived areas considering the government assigned infrastructure index for each location, based on the neighbouring condition, considering the location access to the infrastructure service level as the neighbouring locations.

5.1.2. Problem

The local authority (municipality) involved representatives of these departments, trying to maximize the return of their resource for infrastructure investment. They need to locate the priority targeting locations (The deprived areas) to distribute the new resources among those locations, which improves the infrastructure service level in the region, thereafter determining the amount of additional resources that should be added in each location and deciding how it will be distributed over the region.

In order to identify the problem in greater detail, representatives of these departments have access to the available spatial and non-spatial data about the existing situation in different infrastructure sectors. In addition, these representatives started to identify the needed information to support their decisions as can be seen in the next section.

5.1.3. Current situation and required data

All involved decision makers must encompass a very clear and distinct understanding of the situation. So they briefly introduce the current situation and the available information to all involved parties through maps showing the whole region area in a village level, with descriptive information about existing situation of infrastructure and demographic data e.g. number of households as following. The involved decision makers will discuss the current situation and determine the information required in their decision process.

The available database is for a hypothetical region in Southeast Asia. It is a village-level database, composed of *438 urban and rural villages*. The total number of people within the region is approximately *3.5 million*. The spatial unit of analysis for this study is the village, considering village as the level representing the system. It consists of a variety of attributes connected to data showing the information at the village level regarding different infrastructure sectors, demographics e.g. the number of population and households, and socio-economic activities for each village.

Figure 28: The Study area

This dataset is accessible by the decision makers and will try to identify, the relevant variables needed for building the resource allocation decision.

5.1.4. Selected infrastructure indicators

After decision makers reviewed the available information about the region, and filtered the available information to select the relevant infrastructure variables, they defined the following:

1) The geographic area and the decision spatial level, which is the village level
2) Information required would help to make the infrastructure resource allocation decision.

Relevant infrastructure variables were selected and addressed with description as can be seen in Table 2 below.

Variables	Unit of measurement for the model	Data Description
Transport	Average travel speed (km/h).	Average travel speed to facilities
Electricity	Average electricity supply per household (VA)	Weighted average of electricity supply for poor and non-poor
Telecom	Average data transfer capacity (kbps)	Weighted average of data transfer capacity of fixed line and mobile networks
Water	Average discharge (litre/day)	Water discharge capacity based on each type of source
Population	Number of Population/village	Total village population
Household	Number of Households/village	Total village households

Table 2: Infrastructure performance attributes

The following maps represent the selected indicators based on each village condition (not the neighbouring condition) that the decision makers agreed to use during the process to generate the infrastructure score.

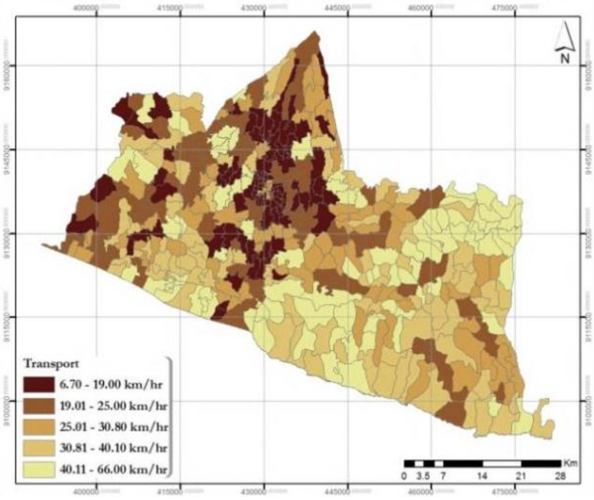


Figure 29: Transport - average travel speed (km/h)

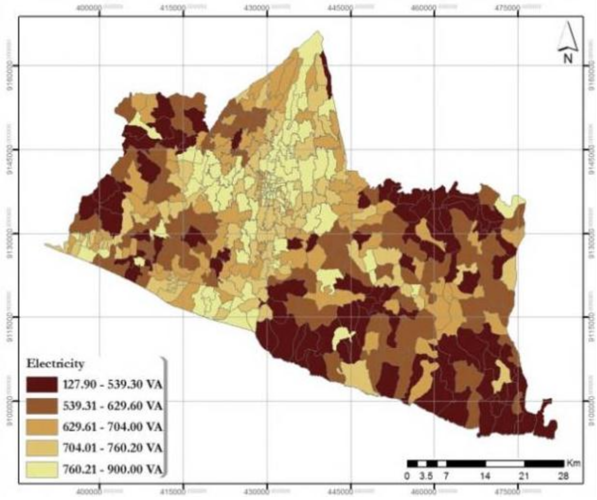


Figure 30: Electricity - average supply/HH (VA)

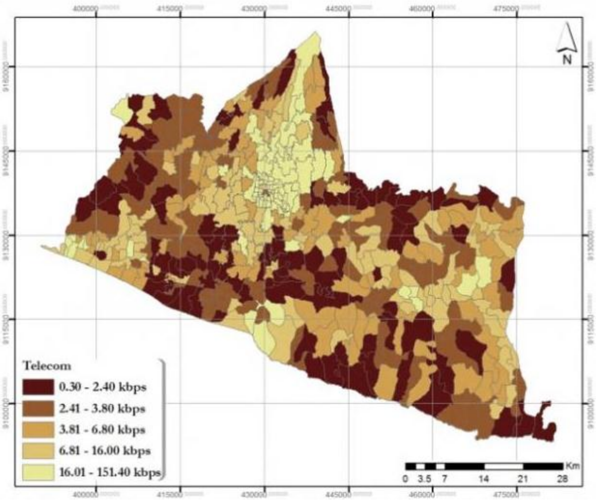


Figure 31: Telecom - average transfer capacity (kbps)

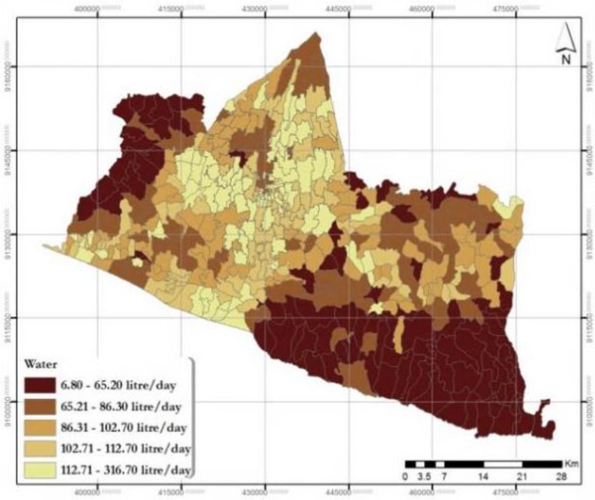


Figure 32: Water - average discharge (litre/day)

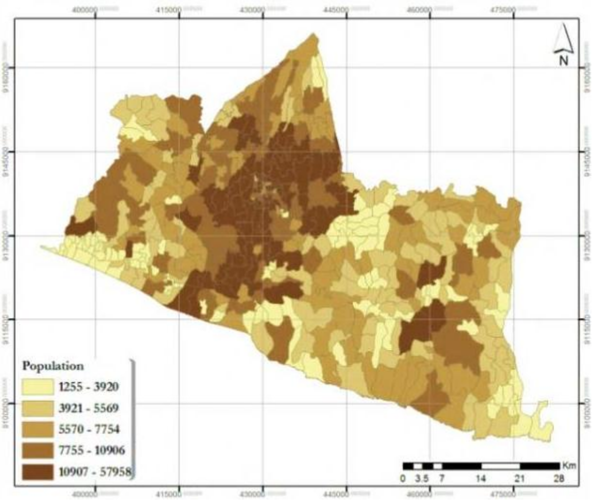


Figure 33: Number of Population

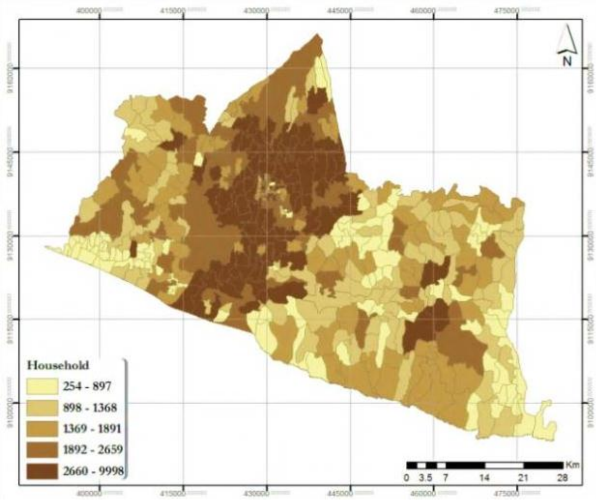


Figure 34: Number of Households

The above given figures give the involved decision makers, a clear vision of the study area, assisting their process to identify the infrastructure situation, and the involved parameters to build their decision.

5.2. SDSS Operationalization

This section will simulate the described real-world situation using the developed SDSS in allocating infrastructure resource to support their decision making process to allocate infrastructure resource.

For this case situation, the decision makers want to generate a target situation based on an assigned index poverty line that means they will not exactly follow the recommended workflow 4.5.1) for the developed system in chapter four which addressed the following steps:

1) Generate existing infrastructure indicator.
2) Identify the priority target locations.
3) Generate alternative
4) Evaluate generated alternative.

The addressed case in will follow the second approach (Section 3.3.4) for generating the alternative for this case, which will be based on the existing infrastructure index. First decision makers need to reach a target situation based on the infrastructure index representing one alternative for the target situation, and in the evaluation step, the target situation will be compared with the existing situation. The case will still clarify the use of the developed criteria as whatever number of alternatives would be a repetition of the applied steps.

The addressed case will generate only one alternative based on the assigned infrastructure index poverty line and the evaluation process will be a comparison between the target and the existing situation of the infrastructure index.

The involved decision makers started to put the needed assumptions and methods for the process, according to the criteria there are different approaches they can go through in order to build their decision. We can address the main points of their discussion in the context of devised criteria and conceptual framework in the following questions:

Q1 Which appropriate Model to represent the infrastructure score?
Based on the case scenario, the infrastructure service accessibility considered as the location access to the level of infrastructure service in neighbourhood locations, which identify using the spatial preference modelling approach (neighbouring condition index).

Q2 What appropriate method to represent the infrastructure score?
In order to indicate the differences among the locations they choose using the Interval standardization method with the benefit criteria as one is the highest score.

Q3 What base would define the priority targeting locations?
In order to identify the priority target locations considering the service index poverty line, decision makers will determine the villages with the calculated infrastructure score less than 0.4 (the poverty line) as the priority target locations.

5.2.1. Generate infrastructure index score

Decision makers now beginning to generate infrastructure index based on the selected four indicators, and the index will represent the existing infrastructure service neighbouring condition.

Using the implemented spatial preference modelling approach they identified the system inputs as following, using average travel speed (km/h) as the transport indicator, average supply per household (VA) as the electricity indicator, average data transfer capacity (kbps) as telecom indicator, and average discharge (litre/day) as water indicator.

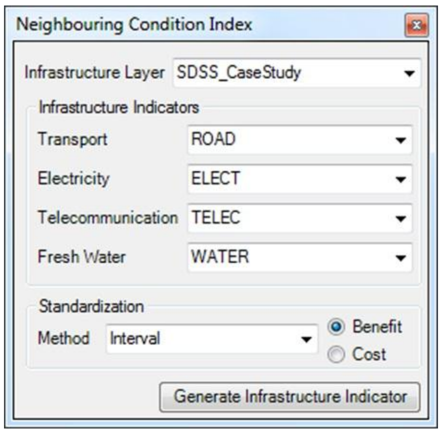
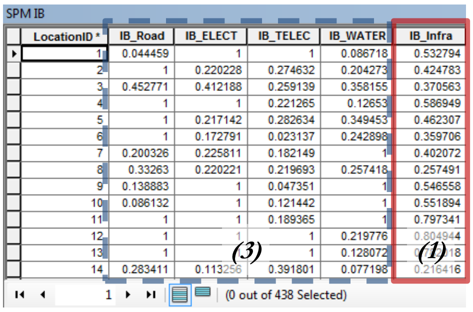


Figure 35: Neighboring Condition index tool

Thus the output map (Figure 36) represents the neighbouring condition classes based on the calculated existing infrastructure in (IB_Infra) attribute field. This is the main output for this step neighbouring condition:


SPM IB

LocationID *	IB_Road	IB_ELECT	IB_TELEC	IB_WATER	IB_Infra
1	0.044459	1	1	0.086718	0.532794
2	1	0.220228	0.274632	0.204273	0.424783
3	0.452771	0.412188	0.259139	0.358155	0.370563
4	1	1	0.221265	0.12653	0.586949
5	1	0.217142	0.282634	0.349453	0.462307
6	1	0.172791	0.023137	0.242898	0.359706
7	0.200326	0.225811	0.182149	1	0.402072
8	0.33263	0.220221	0.219693	0.257418	0.257491
9	0.138883	1	0.047351	1	0.546558
10	0.086132	1	0.121442	1	0.551894
11	1	1	0.189365	1	0.797341
12	1	1	1	0.219776	0.804944
13	1	1	1	0.128072	[illegible]
14	0.283411	0.113256	0.391801	0.077198	0.216416

(0 out of 438 Selected)

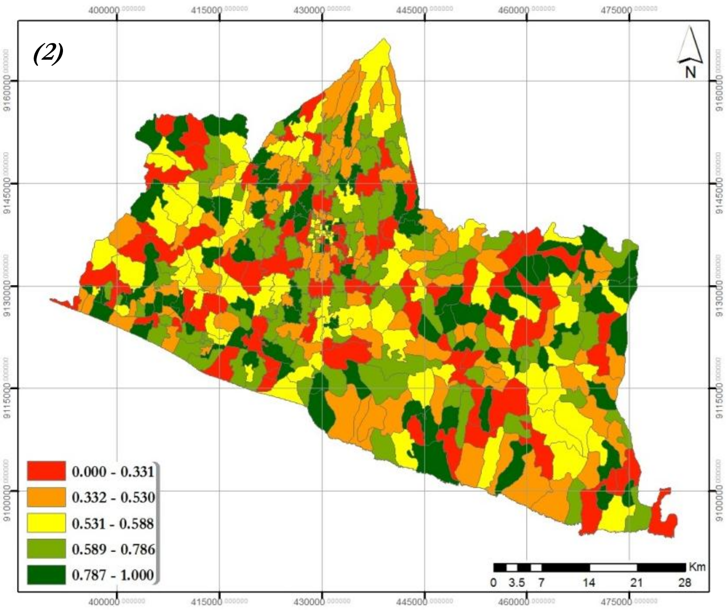


Figure 36: Existing infrastructure index - neighboring condition

(1) Calculated index (2) Classified Map (3) Infrastructure sectors score index

Note the attribute table for the output, four other fields (3) they represent each infrastructure sector score index and will use them in a later step.

5.2.2. Identify the priority targeting locations

The following map (Figure 37) showing the locations scored less than the identified poverty line value 0.4 (based on the calculated existing infrastructure neighbouring condition index) for the region, in order to identify the locations that required adding additional resources to meet the case infrastructure goal.

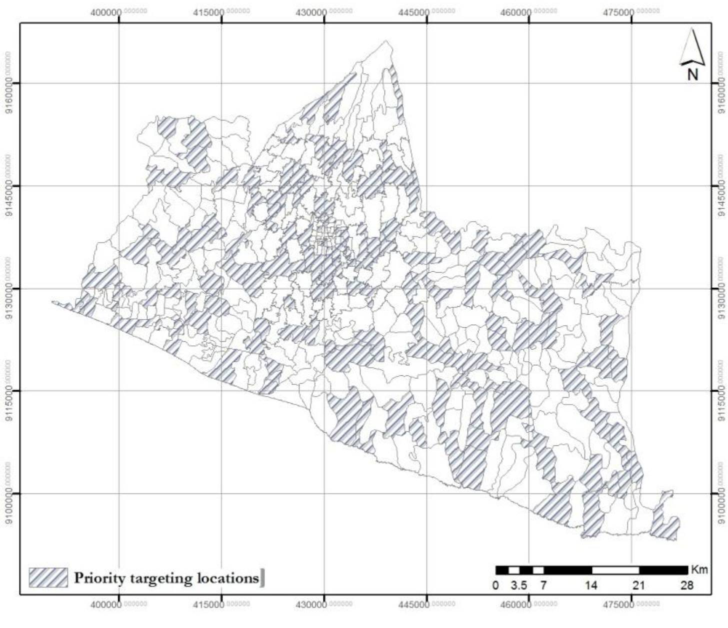


Figure 37: Priority targeting locations

5.2.3. Generate alternatives "The target situation"

Based on the identified poverty line for the infrastructure neighbouring condition index, this step illustrate alternative of the decision makers target situation, which is to improve the infrastructure score index in the locations (villages) scoring less than 0.4 to 0.4. The following map (Figure 38) shows the new infrastructure index.

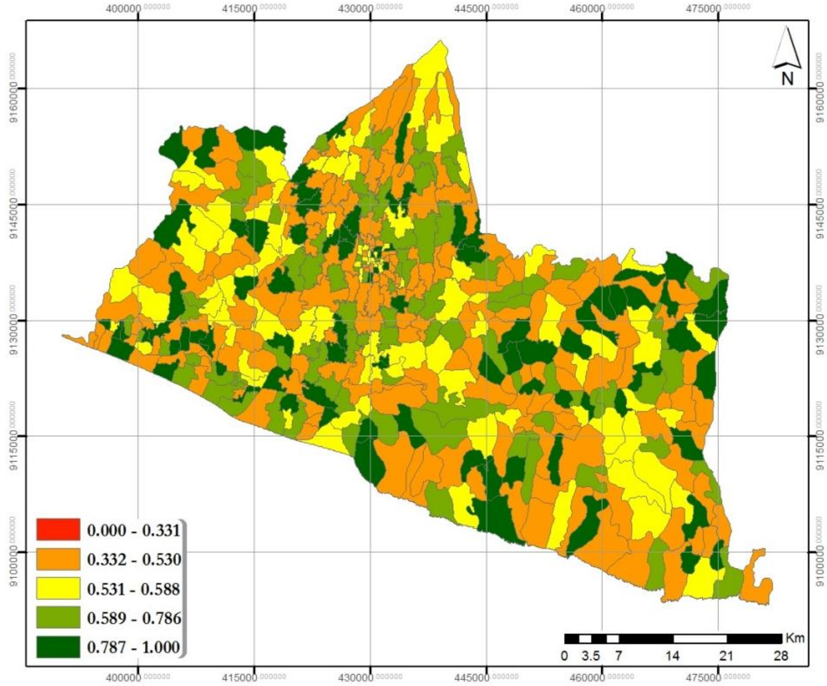


Figure 38: New infrastructure index

The above map shows the new infrastructure index classes after assigning the new index. As it can be seen the lowest class (RED) is no longer there in the map. The new map represents the improvement in the infrastructure index based on the priority target location condition (Figure 39).

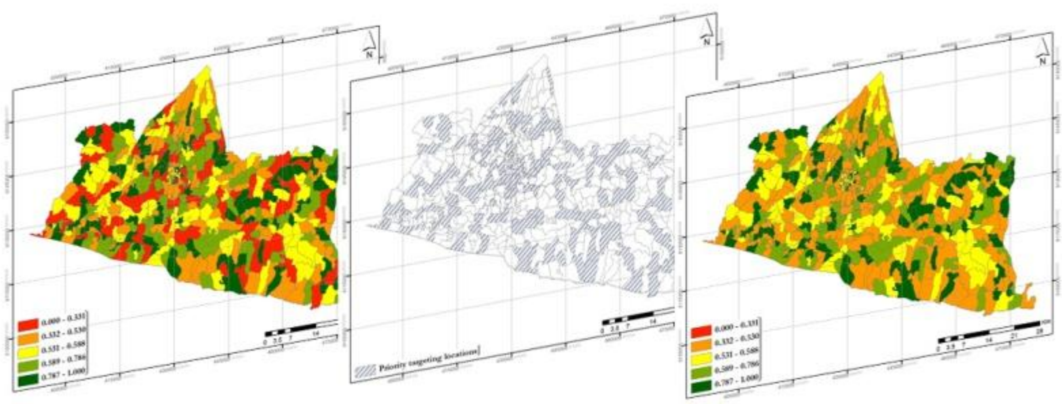


Figure 39: The new infrastructure index calculation

5.2.4. Evaluation

In this section, the decision makers will try to evaluate the alternative with the existing infrastructure situation. Based on resource allocation criteria addressed in this research, there are two evaluation methods. First The Spatial Autocorrelation Global Moran's I method to evaluate the equity from the spatial context and *Gini-Coefficient* of Inequality and Lorenz Curve for social context (Section 3.3.5).

5.2.4.1. Spatial Autocorrelation Global Moran's I

Moran's Index for the existing situation is -0.147 and for the new index situation is -0.131. Given both generated Moran's Index score of -0.147 and -0.131 for the existing and target situations, the Moran's Index did not give a significant result on which we can depend upon to evaluate which situation will more equitable infrastructure service level.

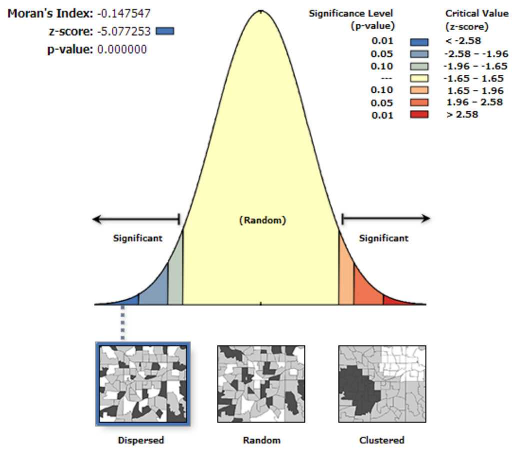


Figure 40: Existing - Global Moran's I score

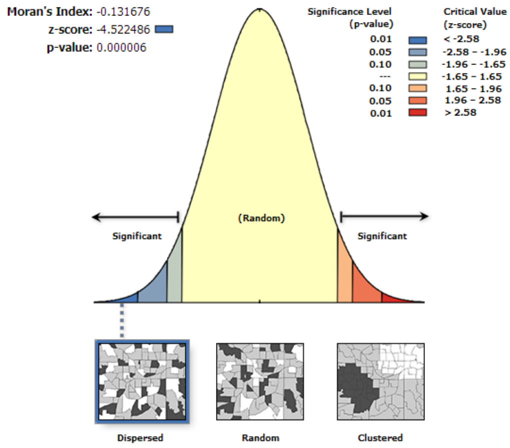


Figure 41: Alternative - Global Moran's I score

5.2.4.2. Gini-Coefficient of Inequality and Lorenz Curve

The following graphs showing Lorenz curve for both the existing situation (Figure 42) and the target situation (Figure 43) and it can be be seen that the target situation is closer to the perfect equality line.

Existing				
Infrastructure Service	**Cumulative**	**Villages %**	**Service Classes**	**Gini**
0.13	0.13	0	0	
0.3	0.43	10.00	2.36	
0.35	0.78	20.00	7.82	
0.42	1.2	30.00	14.18	
0.55	1.75	40.00	21.82	
0.58	2.33	50.00	31.82	**24.76**
0.66	2.99	60.00	42.36	
0.78	3.77	70.00	54.36	
0.79	4.56	80.00	68.55	
0.94	5.5	90.00	82.91	
		100.00	100	

Alternative				
Infrastructure Service	**Cumulative**	**Villages %**	**Service Classes**	**Gini**
0.4	0.4	0	0	
0.4	0.8	10.00	6.76	
0.4	1.2	20.00	13.51	
0.42	1.62	30.00	20.27	
0.55	2.17	40.00	27.36	
0.58	2.75	50.00	36.66	**17.30**
0.66	3.41	60.00	46.45	
0.78	4.19	70.00	57.60	
0.79	4.98	80.00	70.78	
0.94	5.92	90.00	84.12	
		100.00	100	

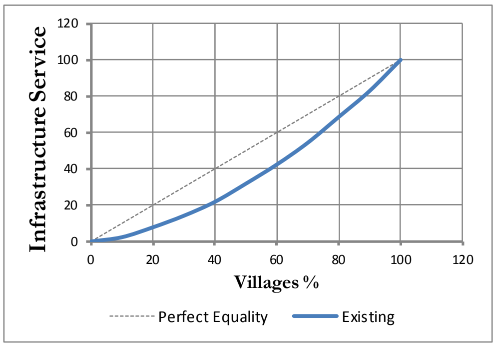


Figure 43: Existing situation Lorenz Curve

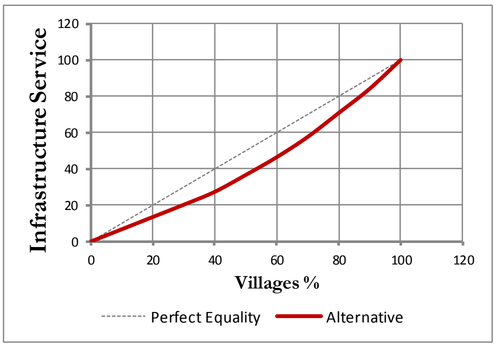


Figure 42: Target situation Lorenz Curve

Gini-Coefficient for the existing situation is 24.76 and for the new index situation is 17.30. From both generated Gini-Coefficient. Decision makers can address that it will increase the region's infrastructure level within the addressed policy to target the deprived area and achieve more equity distribution of the infrastructure service level.

As it can be seen in (Figure 44) the infrastructure service level increased for the first 30% of the number of villages after achieving the policy goal in the addressed case. In addition, from the tables in (Figure 43, Figure 42) the cumulative percentages of infrastructure service level distributed in more equitable way among the number of villages.

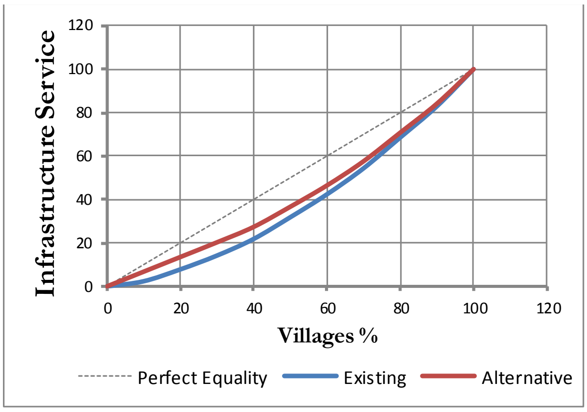


Figure 44: Evaluate existing and target situation Lorenz Curve

5.2.5. Selected alternative required additional resources

This section represents two main steps, firstly to determine the amount of resources that will be allocated in each location and secondly to distribute the assigned percentage over the four sectors of infrastructure.

5.2.5.1. Additional resources percentages

In this step, they will identify the percentage of resources they should allocate in each location (village) from the targeting locations in order to increase the score index to the poverty line value.

Identify the difference between the current infrastructure score index and the new assigned index for the target allocation and by using the weighted priority method for this score we can generate the additional resources required to reach this goal as shown in the above map (Figure 45).

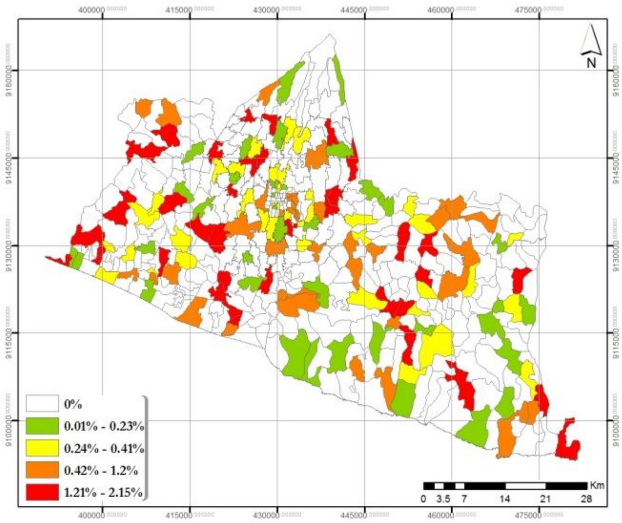


Figure 45: Percentages of additional resources required

5.2.5.2. Additional resources per sector

In This step, we will distribute the assigned additional amount of resources on each location (village) over the four different sectors of infrastructures based on the generated sector scores generated earlier with the existing infrastructure score index (section 5.2.1). As we can see in (Figure 36) the attribute table has been updated with four extra attributes along with the existing index. Based on the performance of each sector, additional resources will be distributed over all the sectors out of the total assigned percentage for each location as can be seen in (Figure 46).

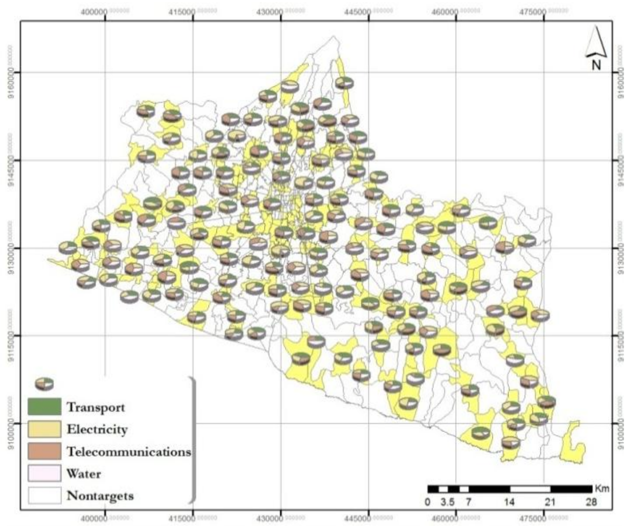


Figure 46: Additional resources per sector

5.3. Conclusion

This chapter illustrated applying the developed criteria and the implemented part of the spatial decision support system through simulating a real-world situation using actual spatial data in order to evaluate the system and investigate how the developed system can support the decision makers targeting the deprived areas to achieve equitable infrastructure service distribution.

Addressing the resource allocation decision scenario, problem, and exploring the available information to select the required information for the developed criteria to achieve equitable infrastructure service distribution. Then, following the criteria and the implemented part of the system (infrastructure index models) in order to achieve the addressed case scenario goal which is considered to (the infrastructure neighbouring condition index, poverty line = 0.4) improve the index for the villages with less than 0.4 to 0.4. Then, evaluating both the target and the existing situation using the two selected evaluators: (1) The Spatial Autocorrelation *Global Moran's I* (2) *Gini-Coefficient*. From the result of the the *Moran's Index* it did not provide significant results, which we can depend upon to evaluate which situation will achieve more equitable infrastructure service level. While *Gini-Coefficient and Lorenz Curve* displayed a difference between the two alternatives and provided significant results; in the *Gini-Coefficient value* and in the service level distribution amongst the villages showed in *Lorenz Curve*.

Thereafter, we start to determine the percentage of resources that should be added in each village in order to improve its existing index to the target index, and also using the infrastructure sectors (transport, water, electricity, telecommunication), neighbouring condition index, we distribute the allocated resources for each village among the four sectors.

6. CONCLUSION

This chapter concludes the aim of study to define criteria for infrastructure resource allocation to design a framework for spatial decision support system (SDSS), and this will be addressed by research achievements understood in terms of addressing research objectives and questions and limitations and further required research.

6.1. Reserch achievements

6.1.1. Review and analyze policies and methods

In order to achieve the first goal, the research discussed the Infrastructure resource allocation problem addressing various strategies to tackle the declining infrastructure investments worldwide taking into account the new emerged needs, population growth, expanding cities, social concerns as the need for more equitable infrastructure, and finally maintenance of existing infrastructure. Started by reviewing the various strategies that concern infrastructure resource allocation's decisions with different infrastructure goals to promote municipalities in assigning expenditures priorities on infrastructure needs.

This research addressed three current major policies (Pro-poor policy, Market Based, Environmental) effecting the process of municipalities, and the different methods (Economic Opportunities, Equity Based). Then analysing those policies and methods in order to select the adopted strategy for this research through reflecting the current investment strategies answering what is the current priority concern for policymakers? Based on priority concern for policymakers, which is achieving fair distribution of infrastructure investment resources, this research adopted the equity-based concept in the context of pro-poor redistributive policy, which reflects achieving our goal that is fair distribution of infrastructure investment resources.

6.1.2. Methods and factors guiding the process

Based on the adopted strategy, we started to identify the methods and factors that will guide the resource allocation process and achieving our infrastructure goal. Starting from introducing the equitable infrastructure investment and the equity and performance measurement, we addressed two approaches first, Capability approach which is the base measure to assess the social equity and the second approach, Spatial Autocorrelation as the base measure to assess the spatial equity and the main evaluator for the different alternatives suggested by the decision makers.

6.1.3. Identify the process of infrastructure resource allocation

Based on the selected methods and factors, link the identified methods and their required factors to illustrate the process workflow showing the decision tree of the steps that perform the adopted criteria by the decision makers. Then translate designed criteria (decision tree) into a conceptual framework for a spatial decision support system. In order to automate designed criteria decision-making process, we described the spatial decision support systems and their elements and components, which will define the decision support system.

6.1.4. Apply the developed criteria in a decision-making support system.

This was undertaken by identifying the spatial decision support system elements, then translating the designed criteria into a framework for a spatial decision support system, started from those two main elements the designed criteria and the spatial decision support systems characteristics. We started to address the workflow of the criteria in a form of process workflow recognizing the used methods as modules and the required factors as system input/output.

6.1.5. Implement the decision support system to a real case study.

For the implementation part, depending on the fact that the system will be developed within the ArcGIS environment, the focus of the implementation phase was mainly to the two identified models to generate the infrastructure score index, the Non-Spatial preference modelling which generates the unit (local) infrastructure index and Spatial preference modelling which generates the neighbourhood infrastructure index.

Then the criteria and the implemented part illustrated through simulating a real-world situation in order to operate the government/municipality using actual spatial data in order to evaluate the system and investigate how the developed system can support the decision makers. However, for the selected spatial autocorrelation method Global Moran's I it did not provide significant results, which we can depend on to evaluate which situation will achieve more equitable infrastructure service level. While Gini-Coefficient the second evaluator showed a reliable result.

6.2. Research limitations

For the allocation alternatives evaluation process, the research adopted two evaluators. The spatial autocorrelation method Global Moran's I and Gini-Coefficient. Global Moran's I did not produce a significant result while operationalizing the addressed case in the research.

6.3. Further research

The research put forth an initial step in development of a framework to assist decision makers achieve an equitable distribution of infrastructure service level, depending on on-going studies providing new methods to address the equitable distribution of infrastructure service including the spatial factor, so further research is required.

For the developed criteria translating the infrastructure index to percentages of resources and same used indicators units; it could be improved by adding an assessment module which can convert the required and added resources in a form of real investment unit (money) which will facilitate the decision process. Also, it can improve the methods used to evaluate the different alternatives, as the selected spatial evaluator did not produce a significant result on the case addressed in this research.

For the implementation phase, this research focuses on the infrastructure score index generation (Spatial – Non-spatial models) which represent an initial step implementing the main element in the process. Still further implementation is required allowing the different decision makers to use the system.

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APPENDIX A: Spatial Preference Modelling Variables

Case Study Existing Infrastructure Indicators							Spatial weights matrix			Spatial Lag			
Location ID	ROAD	ELECT	TELEC	WATER	HH	POP	Wij	N feats #	Nfeats OIDs	ROAD	ELECT	TELEC	WATER
1	21.00	854.90	76.60	85.50	2405	7194	0.13	8	21,17,11,7,5,4,3,2	21.08	734.66	12.18	96.90
2	25.70	676.30	2.20	67.60	2076	7607	0.25	4	13,7,6,1	25.43	729.28	23.20	98.72
3	18.00	485.40	1.60	72.80	803	3391	0.25	4	22,10,4,1	26.63	770.10	22.18	95.50
4	30.00	746.10	4.30	74.60	888	2713	0.25	4	10,5,3,1	23.63	689.78	21.90	83.98
5	30.00	703.90	3.90	70.40	1145	4011	0.25	4	17,10,4,1	24.80	797.05	32.17	99.53
6	33.00	674.70	2.70	101.20	2405	8764	0.25	4	13,9,8,2	26.23	691.40	3.45	140.20
7	12.70	696.50	7.30	104.50	2311	8819	0.20	5	31,13,11,2,1	22.30	772.96	20.66	100.64
8	20.50	679.40	3.00	101.90	1726	5790	0.25	4	20,12,9,6	31.65	684.55	4.25	147.63
9	23.70	718.90	2.40	287.60	2151	8743	0.20	5	25,20,13,8,6	26.96	654.48	4.30	98.18
10	25.50	714.90	5.50	107.20	2845	9658	0.14	7	36,29,22,17,5,4,3	26.90	711.40	20.03	96.36
11	19.30	900.00	10.70	135.00	1037	5038	0.20	5	40,31,21,7,1	14.38	770.32	28.16	107.00
12	42.40	710.70	7.00	106.60	1749	6120	0.25	4	24,23,20,8	21.75	624.08	3.55	129.95
13	35.00	691.00	6.20	103.70	2155	8991	0.14	7	37,31,25,9,7,6,2	20.34	688.86	4.89	119.04
14	18.80	526.80	0.40	52.70	1441	5102	0.25	4	39,27,19,16	38.30	556.38	4.23	55.65
15	18.80	568.80	28.50	56.90	1368	5111	0.50	2	33,18	20.20	719.40	1.80	71.95
16	34.50	553.80	2.50	55.40	2279	9189	0.33	3	27,26,14	31.20	529.50	2.47	61.27
17	22.70	872.30	42.30	130.80	1558	6023	0.20	5	29,21,10,5,1	23.20	754.30	38.64	97.56
18	21.70	652.10	1.80	65.20	1088	4019	0.33	3	33,19,15	30.33	665.47	12.83	66.57
19	53.50	640.90	8.20	64.10	1333	5426	0.25	4	39,33,18,14	20.10	608.57	1.73	60.87
20	27.50	633.90	4.90	95.10	2387	8842	0.17	6	32,25,24,12,9,8	24.52	651.47	3.80	127.67
21	10.20	796.80	25.10	119.50	1286	5363	0.20	5	40,29,17,11,1	21.96	817.80	47.18	114.12
22	30.00	764.50	2.30	114.70	2209	7670	0.20	5	38,36,30,10,3	22.48	666.12	3.18	99.92
23	20.00	581.50	4.50	232.60	1409	5427	0.33	3	28,24,12	29.13	623.07	3.27	93.47
24	19.00	601.50	1.80	90.20	1407	5046	0.17	6	35,32,28,23,20,12	26.68	620.03	3.88	117.23
25	18.80	593.40	4.70	89.00	2097	8275	0.14	7	46,37,34,32,20,13,9	21.69	669.99	16.97	116.01
26	30.80	499.60	3.70	74.90	2060	7858	0.17	6	58,56,51,42,27,16	28.65	590.37	3.60	79.25
27	44.00	562.10	3.30	56.20	1369	6034	0.17	6	58,45,39,26,16,14	27.90	513.60	3.22	64.13
28	26.00	557.00	1.00	83.60	1307	4024	0.25	4	42,35,24,23	20.88	610.75	2.98	127.95
29	29.30	701.00	82.10	105.20	2016	6944	0.17	6	41,40,36,21,17,10	19.73	778.32	18.78	116.73
30	26.30	694.60	2.90	104.20	1752	7345	0.25	4	57,49,38,22	26.25	711.72	3.15	106.78
31	10.50	742.60	7.60	111.40	1987	6992	0.14	7	61,50,40,37,13,11,7	20.07	757.96	21.20	103.26
32	22.70	604.90	3.90	90.70	3990	13436	0.13	8	48,47,44,35,34,25,24,20	26.75	599.18	9.81	85.79
33	18.70	786.70	1.80	78.70	1054	3920	0.14	7	53,45,43,39,19,18,15	30.11	555.34	7.17	59.33
34	15.60	617.60	51.00	92.60	3395	14528	0.25	4	48,46,32,25	18.10	638.98	14.60	78.88
35	21.50	632.20	2.00	94.80	1305	4866	0.20	5	44,42,32,28,24	26.54	598.98	3.10	89.86
36	28.30	706.60	3.70	106.00	2034	7252	0.14	7	57,52,41,38,29,22,10	29.33	729.24	18.89	109.40
37	18.00	719.60	7.30	72.00	2793	9595	0.20	5	61,46,31,25,13	20.32	694.96	17.76	89.78
38	14.30	729.10	2.20	109.40	1743	6755	0.20	5	57,49,36,30,22	29.06	703.80	3.40	105.58
39	21.20	468.70	2.90	46.90	1089	4207	0.17	6	53,45,33,27,19,14	34.48	592.62	3.00	63.68
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438	31.00	479.30	1.40	12.00	1339	4408	0.17	6	436,435,434,433,430,429	34.70	460.43	5.88	11.52

Case Study Existing Infrastructure Indicators							Standardization location $_i$ and its neighbouring units							
							Standardization x_i To X_i				Standardization x_{Lagi} To X_{Lagi}			
Location ID	ROAD	ELECT	TELEC	WATER	HH	POP	ROAD	ELECT	TELEC	WATER	ROAD	ELECT	TELEC	WATER
1	21.00	854.90	76.60	85.50	2405	7194	-0.717	1.620	2.852	-0.127	-0.711	0.663	-0.069	0.143
2	25.70	676.30	2.20	67.60	2076	7607	-0.327	0.198	-0.521	-0.552	-0.350	0.620	0.431	0.187
3	18.00	485.40	1.60	72.80	803	3391	-0.965	-1.322	-0.548	-0.429	-0.250	0.945	0.384	0.110
4	30.00	746.10	4.30	74.60	888	2713	0.029	0.754	-0.426	-0.386	-0.499	0.305	0.372	-0.163
5	30.00	703.90	3.90	70.40	1145	4011	0.029	0.418	-0.444	-0.485	-0.402	1.160	0.838	0.206
6	33.00	674.70	2.70	101.20	2405	8764	0.278	0.185	-0.498	0.245	-0.284	0.318	-0.464	1.171
7	12.70	696.50	7.30	104.50	2311	8819	-1.405	0.359	-0.290	0.324	-0.609	0.968	0.316	0.232
8	20.50	679.40	3.00	101.90	1726	5790	-0.758	0.223	-0.485	0.262	0.166	0.264	-0.428	1.347
9	23.70	718.90	2.40	287.60	2151	8743	-0.493	0.537	-0.512	4.668	-0.223	0.024	-0.426	0.174
10	25.50	714.90	5.50	107.20	2845	9658	-0.344	0.505	-0.372	0.388	-0.228	0.478	0.287	0.130
11	19.30	900.00	10.70	135.00	1037	5038	-0.858	1.980	-0.136	1.047	-1.265	0.947	0.656	0.383
12	42.40	710.70	7.00	106.60	1749	6120	1.057	0.472	-0.304	0.373	-0.655	-0.218	-0.460	0.927
13	35.00	691.00	6.20	103.70	2155	8991	0.444	0.315	-0.340	0.305	-0.771	0.298	-0.399	0.669
14	18.80	526.80	0.40	52.70	1441	5102	-0.899	-0.993	-0.603	-0.905	0.717	-0.757	-0.429	-0.835
15	18.80	568.80	28.50	56.90	1368	5111	-0.899	-0.658	0.671	-0.806	-0.783	0.541	-0.539	-0.449
16	34.50	553.80	2.50	55.40	2279	9189	0.402	-0.778	-0.508	-0.841	0.129	-0.971	-0.509	-0.702
17	22.70	872.30	42.30	130.80	1558	6023	-0.576	1.759	1.297	0.948	-0.534	0.819	1.131	0.159
18	21.70	652.10	1.80	65.20	1088	4019	-0.659	0.005	-0.539	-0.609	0.057	0.112	-0.039	-0.576
19	53.50	640.90	8.20	64.10	1333	5426	1.977	-0.084	-0.249	-0.635	-0.791	-0.341	-0.543	-0.711
20	27.50	633.90	4.90	95.10	2387	8842	-0.178	-0.140	-0.399	0.101	-0.425	0.000	-0.449	0.873
21	10.20	796.80	25.10	119.50	1286	5363	-1.612	1.158	0.517	0.680	-0.637	1.325	1.518	0.552
22	30.00	764.50	2.30	114.70	2209	7670	0.029	0.900	-0.517	0.566	-0.594	0.117	-0.477	0.215
23	20.00	581.50	4.50	232.60	1409	5427	-0.800	-0.557	-0.417	3.363	-0.043	-0.226	-0.473	0.062
24	19.00	601.50	1.80	90.20	1407	5046	-0.883	-0.398	-0.539	-0.016	-0.246	-0.250	-0.445	0.626
25	18.80	593.40	4.70	89.00	2097	8275	-0.899	-0.462	-0.408	-0.044	-0.660	0.148	0.149	0.597
26	30.80	499.60	3.70	74.90	2060	7858	0.096	-1.209	-0.453	-0.379	-0.083	-0.486	-0.458	-0.276
27	44.00	562.10	3.30	56.20	1369	6034	1.190	-0.711	-0.471	-0.822	-0.145	-1.098	-0.475	-0.634
28	26.00	557.00	1.00	83.60	1307	4024	-0.302	-0.752	-0.576	-0.172	-0.727	-0.324	-0.486	0.880
29	29.30	701.00	82.10	105.20	2016	6944	-0.029	0.395	3.101	0.340	-0.822	1.011	0.231	0.614
30	26.30	694.60	2.90	104.20	1752	7345	-0.277	0.344	-0.489	0.316	-0.282	0.480	-0.478	0.378
31	10.50	742.60	7.60	111.40	1987	6992	-1.587	0.726	-0.276	0.487	-0.794	0.848	0.340	0.294
32	22.70	604.90	3.90	90.70	3990	13436	-0.576	-0.371	-0.444	-0.004	-0.240	-0.416	-0.176	-0.120
33	18.70	786.70	1.80	78.70	1054	3920	-0.907	1.077	-0.539	-0.289	0.039	-0.765	-0.296	-0.748
34	15.60	617.60	51.00	92.60	3395	14528	-1.164	-0.269	1.691	0.041	-0.957	-0.099	0.041	-0.284
35	21.50	632.20	2.00	94.80	1305	4866	-0.675	-0.153	-0.530	0.093	-0.258	-0.418	-0.480	-0.024
:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
438	31.00	479.30	1.40	12.00	1339	4408	0.112	-1.371	-0.557	-1.871	0.419	-1.521	-0.354	-1.883

Case Study Existing Infrastructure Indicators							The gap between location $_i$ and its neighbouring units											
							Local Inequity (g_i)				Min (g_i) of neighbouring units				Max (g_i) of neighbouring units			
Location ID	ROAD	ELECT	TELEC	WATER	HH	POP	ROAD	ELECT	TELEC	WATER	ROAD	ELECT	TELEC	WATER	ROAD	ELECT	TELEC	WATER
1	21.00	854.90	76.60	85.50	2405	7194	0.006	-0.958	-2.920	0.270	-0.528	-1.033	-0.166	-0.789	0.975	2.267	1.282	0.739
2	25.70	676.30	2.20	67.60	2076	7607	-0.023	0.422	0.952	0.739	-1.215	-0.958	-2.920	-0.092	0.796	0.609	0.606	0.925
3	18.00	485.40	1.60	72.80	803	3391	0.715	2.267	0.933	0.539	-0.623	-0.958	-2.920	-0.351	0.116	-0.028	0.798	0.270
4	30.00	746.10	4.30	74.60	888	2713	-0.528	-0.449	0.798	0.222	-0.431	-0.958	-2.920	-0.257	0.715	2.267	1.282	0.691
5	30.00	703.90	3.90	70.40	1145	4011	-0.431	0.742	1.282	0.691	-0.528	-0.958	-2.920	-0.789	0.116	-0.028	0.798	0.270
6	33.00	674.70	2.70	101.20	2405	8764	-0.562	0.133	0.034	0.925	-1.215	-0.513	-0.060	-4.494	0.924	0.422	0.952	1.085
7	12.70	696.50	7.30	104.50	2311	8819	0.796	0.609	0.606	-0.092	-1.215	-1.033	-2.920	-0.664	0.793	0.422	0.952	0.739
8	20.50	679.40	3.00	101.90	1726	5790	0.924	0.041	0.057	1.085	-1.712	-0.690	-0.156	-4.494	0.270	0.140	0.086	0.925
9	23.70	718.90	2.40	287.60	2151	8743	0.270	-0.513	0.086	-4.494	-1.215	-0.017	-0.060	0.364	0.924	0.610	0.556	1.085
10	25.50	714.90	5.50	107.20	2845	9658	0.116	-0.028	0.659	-0.257	-0.793	-0.940	-2.870	-0.789	0.715	2.267	1.282	0.691
11	19.30	900.00	10.70	135.00	1037	5038	-0.408	-1.033	0.791	-0.664	-0.225	-0.958	-2.920	-0.193	0.975	0.609	1.001	0.270
12	42.40	710.70	7.00	106.60	1749	6120	-1.712	-0.690	-0.156	0.554	-0.247	0.041	-0.056	-3.301	0.924	0.331	0.094	1.085
13	35.00	691.00	6.20	103.70	2155	8991	-1.215	-0.017	-0.060	0.364	-0.562	-0.513	0.034	-4.494	0.796	0.610	0.952	0.925
14	18.80	526.80	0.40	52.70	1441	5102	1.616	0.236	0.173	0.070	-2.769	-0.386	-0.294	-0.077	1.101	0.987	0.005	0.398
15	18.80	568.80	28.50	56.90	1368	5111	0.116	1.199	-1.210	0.357	0.716	-1.843	0.243	-0.460	0.946	0.106	0.500	0.032
16	34.50	553.80	2.50	55.40	2279	9189	-0.274	-0.194	-0.002	0.139	-1.335	-0.386	-0.005	0.070	1.616	0.723	0.173	0.188
17	22.70	872.30	42.30	130.80	1558	6023	0.041	-0.940	-0.166	-0.789	-0.793	-0.958	-2.920	-0.257	0.975	0.742	1.282	0.691
18	21.70	652.10	1.80	65.20	1088	4019	0.716	0.106	0.500	0.032	-2.769	-1.843	-1.210	-0.460	0.946	1.199	0.243	0.357
19	53.50	640.90	8.20	64.10	1333	5426	-2.769	-0.257	-0.294	-0.077	0.716	-1.843	0.005	-0.460	1.616	0.987	0.500	0.398
20	27.50	633.90	4.90	95.10	2387	8842	-0.247	0.140	-0.050	0.773	-1.712	-0.690	-0.156	-4.494	0.924	0.610	0.556	1.085
21	10.20	796.80	25.10	119.50	1286	5363	0.975	0.167	1.001	-0.128	-0.793	-1.033	-2.920	-0.789	0.041	0.616	0.791	0.274
22	30.00	764.50	2.30	114.70	2209	7670	-0.623	-0.784	0.040	-0.351	-0.004	-0.201	0.011	-0.257	1.223	2.267	0.933	0.539
23	20.00	581.50	4.50	232.60	1409	5427	0.757	0.331	-0.056	-3.301	-1.712	-0.690	-0.156	0.554	0.637	0.428	0.094	1.052
24	19.00	601.50	1.80	90.20	1407	5046	0.637	0.148	0.094	0.641	-1.712	-0.690	-0.156	-3.301	0.757	0.428	0.268	1.052
25	18.80	593.40	4.70	89.00	2097	8275	0.239	0.610	0.556	0.641	-1.215	-0.513	-1.650	-4.494	0.948	0.170	0.474	0.773
26	30.80	499.60	3.70	74.90	2060	7858	-0.178	0.723	-0.005	0.103	-1.335	-0.461	-0.098	-0.206	0.851	0.912	0.108	0.306
27	44.00	562.10	3.30	56.20	1369	6034	-1.335	-0.386	-0.004	0.188	-0.890	-0.194	-0.098	-0.301	1.616	0.987	0.173	0.398
28	26.00	557.00	1.00	83.60	1307	4024	-0.425	0.428	0.090	1.052	0.418	-0.265	-0.056	-3.301	0.851	0.331	0.094	0.641
29	29.30	701.00	82.10	105.20	2016	6944	-0.793	0.616	-2.870	0.274	-0.225	-0.940	-0.166	-0.789	1.195	0.280	1.441	0.126
30	26.30	694.60	2.90	104.20	1752	7345	-0.004	0.136	0.011	0.061	-0.623	-0.784	0.040	-0.351	1.223	0.694	0.393	0.311
31	10.50	742.60	7.60	111.40	1987	6992	0.793	0.122	0.617	-0.193	-1.215	-1.033	-1.448	-0.664	0.796	0.609	0.791	0.422
32	22.70	604.90	3.90	90.70	3990	13436	0.336	-0.046	0.268	-0.117	-1.281	-0.320	-1.650	-0.326	0.637	1.335	0.556	0.773
33	18.70	786.70	1.80	78.70	1054	3920	0.946	-1.843	0.243	-0.460	-2.769	-0.257	-1.210	-0.301	1.101	1.199	0.500	0.398
34	15.60	617.60	51.00	92.60	3395	14528	0.207	0.170	-1.650	-0.326	0.149	-0.320	-1.173	-0.117	0.948	0.610	0.556	0.641
35	21.50	632.20	2.00	94.80	1305	4866	0.418	-0.265	0.050	-0.117	-0.425	-0.164	-0.091	-0.117	0.851	0.428	0.268	1.052
36	28.30	706.60	3.70	106.00	2034	7252	0.085	0.180	0.688	0.081	-3.217	-0.784	-2.870	-0.351	1.223	0.694	1.441	0.311
37	18.00	719.60	7.30	72.00	2793	9595	0.192	-0.196	0.474	0.422	-1.215	-0.292	-1.173	-0.193	0.948	0.610	0.617	0.641
38	14.30	729.10	2.20	109.40	1743	6755	1.223	-0.201	0.054	-0.091	-0.623	-0.784	0.011	-0.351	0.466	0.694	0.688	0.311
39	21.20	468.70	2.90	46.90	1089	4207	1.101	0.987	0.005	0.398	-2.769	-1.843	-0.294	-0.460	1.616	0.437	0.243	0.217
40	17.50	760.80	24.20	114.10	3608	14730	-0.225	0.280	0.757	0.126	-0.793	-1.033	-2.870	-0.664	1.195	0.616	1.441	0.274
41	14.20	818.50	11.90	122.80	3287	10399	1.195	-0.602	1.441	-0.269	-3.217	-0.172	-2.870	-0.243	0.915	0.616	0.757	0.274
42	23.00	627.80	3.60	94.20	2147	7767	0.851	-0.164	-0.028	-0.074	-2.532	-0.461	-0.091	-0.206	0.802	0.723	0.108	1.052
43	23.70	517.70	4.50	51.80	719	2958	0.203	1.044	-0.152	0.311	0.104	-1.843	0.113	-0.460	0.946	0.427	0.243	0.217
44	42.00	603.70	5.20	90.60	2474	9191	-0.232	0.009	-0.091	0.002	-2.532	-0.350	-0.040	-0.155	0.851	1.335	0.268	0.295
45	38.30	528.40	3.80	79.30	2698	10350	-0.890	0.437	-0.019	-0.301	-1.335	-1.843	-0.098	-0.460	1.189	0.987	0.243	0.539
46	9.30	704.00	43.10	70.40	3522	12760	0.948	-0.292	-1.173	0.153	-0.851	-0.320	-1.650	-0.326	0.239	0.610	0.556	0.641
47	48.00	457.50	2.20	68.60	2954	10398	-1.281	1.335	0.123	0.295	-1.416	-0.320	-0.091	-0.146	0.860	0.489	0.533	0.780
48	21.60	653.60	6.70	65.40	3180	11715	0.149	-0.320	0.533	0.235	-1.281	-0.292	-1.650	-0.326	0.948	1.335	0.500	0.780
49	26.70	703.80	4.90	105.60	3375	12933	0.466	0.096	0.051	0.042	-1.608	-0.409	-0.468	-0.232	1.223	0.694	0.393	0.311
:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
438	31.00	479.30	1.40	12.00	1339	4408	0.307	-0.150	0.203	-0.011	-1.324	-0.766	-0.522	-0.058	1.164	1.184	0.112	0.089

APPENDIX B: Spatial Preference Modelling Results

Case Study Existing Infrastructure Indicators							Maximum Standardization									
							Benefit					Cost				
Location ID	ROAD	ELECT	TELEC	WATER	HH	POP	ROAD	ELECT	TELEC	WATER	Infra	ROAD	ELECT	TELEC	WATER	Infra
1	21.00	854.90	76.60	85.50	2405	7194	0.001	1.000	1.000	0.046	**0.512**	0.999	0.000	0.000	0.954	**0.488**
2	25.70	676.30	2.20	67.60	2076	7607	1.000	0.173	0.393	0.200	**0.442**	0.000	0.827	0.607	0.800	**0.558**
3	18.00	485.40	1.60	72.80	803	3391	1.542	0.567	0.293	0.498	**0.725**	-0.542	0.433	0.707	0.502	**0.275**
4	30.00	746.10	4.30	74.60	888	2713	1.000	1.000	0.156	0.081	**0.559**	0.000	0.000	0.844	0.919	**0.441**
5	30.00	703.90	3.90	70.40	1145	4011	1.000	0.186	0.402	0.639	**0.557**	0.000	0.814	0.598	0.361	**0.443**
6	33.00	674.70	2.70	101.20	2405	8764	1.000	0.079	0.009	0.213	**0.325**	0.000	0.921	0.991	0.787	**0.675**
7	12.70	696.50	7.30	104.50	2311	8819	0.201	0.289	0.127	1.000	**0.404**	0.799	0.711	0.873	0.000	**0.596**
8	20.50	679.40	3.00	101.90	1726	5790	0.856	0.073	0.165	0.293	**0.347**	0.144	0.927	0.835	0.707	**0.653**
9	23.70	718.90	2.40	287.60	2151	8743	0.059	1.000	0.031	1.000	**0.522**	0.941	0.000	0.969	0.000	**0.478**
10	25.50	714.90	5.50	107.20	2845	9658	0.023	1.000	0.073	1.000	**0.524**	0.977	0.000	0.927	0.000	**0.476**
11	19.30	900.00	10.70	135.00	1037	5038	1.000	1.000	0.158	1.000	**0.790**	0.000	0.000	0.842	0.000	**0.210**
12	42.40	710.70	7.00	106.60	1749	6120	1.000	1.000	1.000	0.128	**0.782**	0.000	0.000	0.000	0.872	**0.218**
13	35.00	691.00	6.20	103.70	2155	8991	1.000	1.000	1.000	0.056	**0.764**	0.000	0.000	0.000	0.944	**0.236**
14	18.80	526.80	0.40	52.70	1441	5102	0.367	0.060	9.574	0.044	**2.511**	0.633	0.940	-8.574	0.956	**-1.511**
15	18.80	568.80	28.50	56.90	1368	5111	0.061	5.640	1.000	5.512	**3.053**	1.317	-4.640	0.000	-4.512	**-1.959**
16	34.50	553.80	2.50	55.40	2279	9189	1.000	1.000	1.000	0.247	**0.812**	0.000	0.000	0.000	0.877	**0.219**
17	22.70	872.30	42.30	130.80	1558	6023	0.009	1.000	1.000	1.000	**0.752**	0.991	0.000	0.000	0.000	**0.248**
18	21.70	652.10	1.80	65.20	1088	4019	0.252	0.030	0.685	0.030	**0.249**	0.748	0.970	0.315	0.970	**0.751**
19	53.50	640.90	8.20	64.10	1333	5426	1.000	1.000	1.000	1.000	**1.000**	0.000	0.000	0.000	0.000	**0.000**
20	27.50	633.90	4.90	95.10	2387	8842	1.000	0.038	1.000	0.119	**0.539**	0.000	0.962	0.000	0.881	**0.461**
21	10.20	796.80	25.10	119.50	1286	5363	4.709	0.054	0.253	1.000	**1.504**	-3.709	0.946	0.747	0.000	**-0.504**
22	30.00	764.50	2.30	114.70	2209	7670	1.000	1.000	0.009	1.000	**0.752**	0.000	0.000	0.994	0.000	**0.248**
23	20.00	581.50	4.50	232.60	1409	5427	0.397	0.258	1.000	1.000	**0.664**	0.603	0.742	0.000	0.000	**0.336**
24	19.00	601.50	1.80	90.20	1407	5046	0.140	0.058	0.059	0.102	**0.090**	0.860	0.942	0.941	0.898	**0.910**
25	18.80	593.40	4.70	89.00	2097	8275	0.036	0.512	0.168	0.119	**0.209**	0.964	0.488	0.832	0.881	**0.791**
26	30.80	499.60	3.70	74.90	2060	7858	1.000	0.132	1.000	0.056	**0.547**	0.000	0.868	0.000	0.944	**0.453**
27	44.00	562.10	3.30	56.20	1369	6034	1.000	1.000	1.000	0.079	**0.770**	0.000	0.000	0.000	0.921	**0.230**
28	26.00	557.00	1.00	83.60	1307	4024	1.000	0.324	0.237	0.411	**0.493**	0.000	0.676	0.763	0.589	**0.507**
29	29.30	701.00	82.10	105.20	2016	6944	1.000	0.367	1.000	0.362	**0.682**	0.000	0.633	0.000	0.638	**0.318**
30	26.30	694.60	2.90	104.20	1752	7345	1.000	0.049	0.007	0.049	**0.276**	0.000	0.951	1.018	0.951	**0.730**
31	10.50	742.60	7.60	111.40	1987	6992	0.143	0.029	0.111	1.000	**0.321**	0.857	0.971	0.889	0.000	**0.679**
32	22.70	604.90	3.90	90.70	3990	13436	0.066	1.000	0.060	1.000	**0.532**	0.934	0.000	0.940	0.000	**0.468**
33	18.70	786.70	1.80	78.70	1054	3920	0.123	1.000	0.070	1.000	**0.548**	0.877	0.000	0.930	0.000	**0.452**
34	15.60	617.60	51.00	92.60	3395	14528	0.055	0.070	1.000	1.000	**0.531**	0.985	0.930	0.000	0.000	**0.479**
35	21.50	632.20	2.00	94.80	1305	4866	0.098	1.000	0.037	1.000	**0.534**	0.902	0.000	0.963	0.000	**0.466**
36	28.30	706.60	3.70	106.00	2034	7252	0.010	0.037	0.068	0.037	**0.038**	0.990	0.963	0.932	0.963	**0.962**
37	18.00	719.60	7.30	72.00	2793	9595	0.041	1.000	0.154	0.132	**0.332**	0.959	0.000	0.846	0.868	**0.668**
38	14.30	729.10	2.20	109.40	1743	6755	0.526	1.000	0.016	1.000	**0.635**	0.474	0.000	0.987	0.000	**0.365**
39	21.20	468.70	2.90	46.90	1089	4207	0.114	0.377	0.003	0.306	**0.200**	0.886	0.623	0.997	0.694	**0.800**
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438	31.00	479.30	1.40	12.00	1339	4408	0.044	1.000	0.302	1.000	**0.587**	0.956	0.000	0.698	0.000	**0.413**

Case Study Existing Infrastructure Indicators							Interval Standardization									
							Benefit					Cost				
Location ID	ROAD	ELECT	TELEC	WATER	HH	POP	ROAD	ELECT	TELEC	WATER	Infra	ROAD	ELECT	TELEC	WATER	Infra
1	21.00	854.90	76.60	85.50	2405	7194	0.044	1.000	1.000	0.087	**0.533**	0.956	0.000	0.000	0.913	**0.467**
2	25.70	676.30	2.20	67.60	2076	7607	1.000	0.220	0.275	0.204	**0.425**	0.000	0.780	0.725	0.796	**0.575**
3	18.00	485.40	1.60	72.80	803	3391	0.453	0.412	0.259	0.358	**0.371**	0.547	0.588	0.741	0.642	**0.629**
4	30.00	746.10	4.30	74.60	888	2713	1.000	1.000	0.221	0.127	**0.587**	0.000	0.000	0.779	0.873	**0.413**
5	30.00	703.90	3.90	70.40	1145	4011	1.000	0.217	0.283	0.349	**0.462**	0.000	0.783	0.717	0.651	**0.538**
6	33.00	674.70	2.70	101.20	2405	8764	1.000	0.173	0.023	0.243	**0.360**	0.000	0.827	0.977	0.757	**0.640**
7	12.70	696.50	7.30	104.50	2311	8819	0.200	0.226	0.182	1.000	**0.402**	0.800	0.774	0.818	0.000	**0.598**
8	20.50	679.40	3.00	101.90	1726	5790	0.333	0.220	0.220	0.257	**0.257**	0.667	0.780	0.780	0.743	**0.743**
9	23.70	718.90	2.40	287.60	2151	8743	0.139	1.000	0.047	1.000	**0.547**	0.861	0.000	0.953	0.000	**0.453**
10	25.50	714.90	5.50	107.20	2845	9658	0.086	1.000	0.121	1.000	**0.552**	0.914	0.000	0.879	0.000	**0.448**
11	19.30	900.00	10.70	135.00	1037	5038	1.000	1.000	0.189	1.000	**0.797**	0.000	0.000	0.811	0.000	**0.203**
12	42.40	710.70	7.00	106.60	1749	6120	1.000	1.000	1.000	0.220	**0.805**	0.000	0.000	0.000	0.780	**0.195**
13	35.00	691.00	6.20	103.70	2155	8991	1.000	1.000	1.000	0.128	**0.782**	0.000	0.000	0.000	0.872	**0.218**
14	18.80	526.80	0.40	52.70	1441	5102	0.283	0.113	0.392	0.077	**0.216**	0.717	0.887	0.608	0.923	**0.784**
15	18.80	568.80	28.50	56.90	1368	5111	-1.300	0.781	1.000	0.830	**0.328**	2.300	0.219	0.000	0.170	**0.672**
16	34.50	553.80	2.50	55.40	2279	9189	1.000	1.000	1.000	0.196	**0.799**	0.000	0.000	0.000	0.804	**0.201**
17	22.70	872.30	42.30	130.80	1558	6023	0.094	1.000	1.000	1.000	**0.774**	0.906	0.000	0.000	0.000	**0.226**
18	21.70	652.10	1.80	65.20	1088	4019	0.313	0.214	0.392	0.201	**0.280**	0.687	0.786	0.608	0.799	**0.720**
19	53.50	640.90	8.20	64.10	1333	5426	1.000	1.000	1.000	1.000	**1.000**	0.000	0.000	0.000	0.000	**0.000**
20	27.50	633.90	4.90	95.10	2387	8842	1.000	0.106	1.000	0.157	**0.566**	0.000	0.894	0.000	0.843	**0.434**
21	10.20	796.80	25.10	119.50	1286	5363	0.424	0.146	0.211	1.000	**0.445**	0.576	0.854	0.789	0.000	**0.555**
22	30.00	764.50	2.30	114.70	2209	7670	1.000	1.000	0.006	1.000	**0.752**	0.000	0.000	0.994	0.000	**0.248**
23	20.00	581.50	4.50	232.60	1409	5427	0.351	0.305	1.000	1.000	**0.664**	0.649	0.695	0.000	0.000	**0.336**
24	19.00	601.50	1.80	90.20	1407	5046	0.159	0.125	0.099	0.151	**0.133**	0.841	0.875	0.901	0.849	**0.867**
25	18.80	593.40	4.70	89.00	2097	8275	0.096	0.235	0.148	0.139	**0.155**	0.904	0.765	0.852	0.861	**0.845**
26	30.80	499.60	3.70	74.90	2060	7858	1.000	0.144	1.000	0.101	**0.561**	0.000	0.856	0.000	0.899	**0.439**
27	44.00	562.10	3.30	56.20	1369	6034	1.000	1.000	1.000	0.117	**0.779**	0.000	0.000	0.000	0.883	**0.221**
28	26.00	557.00	1.00	83.60	1307	4024	1.000	0.291	0.242	0.276	**0.452**	0.000	0.709	0.758	0.724	**0.548**
29	29.30	701.00	82.10	105.20	2016	6944	1.000	0.213	1.000	0.194	**0.602**	0.000	0.787	0.000	0.806	**0.398**
30	26.30	694.60	2.90	104.20	1752	7345	1.000	0.156	-0.020	0.156	**0.323**	0.000	0.844	1.020	0.844	**0.677**
31	10.50	742.60	7.60	111.40	1987	6992	0.143	0.101	0.132	1.000	**0.344**	0.857	0.899	0.868	0.000	**0.656**
32	22.70	604.90	3.90	90.70	3990	13436	0.105	1.000	0.109	1.000	**0.554**	0.895	0.000	0.891	0.000	**0.446**
33	18.70	786.70	1.80	78.70	1054	3920	0.137	1.000	0.121	1.000	**0.565**	0.863	0.000	0.879	0.000	**0.435**
34	15.60	617.60	51.00	92.60	3395	14528	0.018	0.132	1.000	1.000	**0.538**	0.982	0.868	0.000	0.000	**0.462**
35	21.50	632.20	2.00	94.80	1305	4866	0.132	1.000	0.078	1.000	**0.553**	0.868	0.000	0.922	0.000	**0.447**
36	28.30	706.60	3.70	106.00	2034	7252	0.106	0.093	0.118	0.093	**0.103**	0.894	0.907	0.882	0.907	**0.897**
37	18.00	719.60	7.30	72.00	2793	9595	0.130	1.000	0.184	0.148	**0.365**	0.870	0.000	0.816	0.852	**0.635**
38	14.30	729.10	2.20	109.40	1743	6755	0.339	1.000	0.013	1.000	**0.588**	0.661	0.000	0.987	0.000	**0.412**
39	21.20	468.70	2.90	46.90	1089	4207	0.147	0.207	0.093	0.211	**0.165**	0.853	0.793	0.907	0.789	**0.835**
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438	31.00	479.30	1.40	12.00	1339	4408	0.109	1.000	0.191	1.000	**0.575**	0.891	0.000	0.809	0.000	**0.425**

Goal Values are reference values determine the minimum and maximum value acceptable by stakeholder.

G=0, Just to refine the new value to be more equal to the average of the neighbouring units

Indicators	Min Goal		Max Goal	
	Assumption	Value	Assumption	Value
ROAD	-	0.00	-	0.000
ELECT	-	0.00	-	0.000
TELEC	-	0.00	-	0.000
WATER	-	0.00	-	0.000

Case Study Existing Infrastructure Indicators							Goal Standardization									
							Benefit					Cost				
Location ID	ROAD	ELECT	TELEC	WATER	HH	POP	ROAD	ELECT	TELEC	WATER	Infra	ROAD	ELECT	TELEC	WATER	Infra
1	21.00	854.90	76.60	85.50	2405	7194	0.001	1.000	1.000	0.034	**0.509**	0.999	0.000	0.000	0.966	**0.491**
2	25.70	676.30	2.20	67.60	2076	7607	1.000	0.106	0.238	0.185	**0.382**	0.000	0.894	0.762	0.815	**0.618**
3	18.00	485.40	1.60	72.80	803	3391	0.179	0.567	0.233	0.135	**0.279**	0.821	0.433	0.767	0.865	**0.721**
4	30.00	746.10	4.30	74.60	888	2713	1.000	1.000	0.200	0.056	**0.564**	0.000	0.000	0.800	0.944	**0.436**
5	30.00	703.90	3.90	70.40	1145	4011	1.000	0.186	0.321	0.173	**0.420**	0.000	0.814	0.679	0.827	**0.580**
6	33.00	674.70	2.70	101.20	2405	8764	1.000	0.033	0.009	0.232	**0.318**	0.000	0.967	0.991	0.768	**0.682**
7	12.70	696.50	7.30	104.50	2311	8819	0.159	0.122	0.121	1.000	**0.351**	0.841	0.878	0.879	0.000	**0.649**
8	20.50	679.40	3.00	101.90	1726	5790	0.231	0.010	0.014	0.272	**0.132**	0.769	0.990	0.986	0.728	**0.868**
9	23.70	718.90	2.40	287.60	2151	8743	0.054	1.000	0.017	1.000	**0.518**	0.946	0.000	0.983	0.000	**0.482**
10	25.50	714.90	5.50	107.20	2845	9658	0.017	1.000	0.094	1.000	**0.528**	0.983	0.000	0.906	0.000	**0.472**
11	19.30	900.00	10.70	135.00	1037	5038	1.000	1.000	0.158	1.000	**0.790**	0.000	0.000	0.842	0.000	**0.210**
12	42.40	710.70	7.00	106.60	1749	6120	1.000	1.000	1.000	0.139	**0.785**	0.000	0.000	0.000	0.861	**0.215**
13	35.00	691.00	6.20	103.70	2155	8991	1.000	1.000	1.000	0.052	**0.763**	0.000	0.000	0.000	0.948	**0.237**
14	18.80	526.80	0.40	52.70	1441	5102	0.405	0.059	0.043	0.018	**0.131**	0.595	0.941	0.957	0.982	**0.869**
15	18.80	568.80	28.50	56.90	1368	5111	0.058	0.600	1.000	0.179	**0.459**	0.942	0.400	0.000	0.821	**0.541**
16	34.50	553.80	2.50	55.40	2279	9189	1.000	1.000	1.000	0.046	**0.762**	0.000	0.000	0.000	0.954	**0.238**
17	22.70	872.30	42.30	130.80	1558	6023	0.008	1.000	1.000	1.000	**0.752**	0.992	0.000	0.000	0.000	**0.248**
18	21.70	652.10	1.80	65.20	1088	4019	0.239	0.036	0.167	0.011	**0.113**	0.761	0.964	0.833	0.989	**0.887**
19	53.50	640.90	8.20	64.10	1333	5426	1.000	1.000	1.000	1.000	**1.000**	0.000	0.000	0.000	0.000	**0.000**
20	27.50	633.90	4.90	95.10	2387	8842	1.000	0.023	1.000	0.129	**0.538**	0.000	0.977	0.000	0.871	**0.462**
21	10.20	796.80	25.10	119.50	1286	5363	0.195	0.033	0.200	1.000	**0.357**	0.805	0.967	0.800	0.000	**0.643**
22	30.00	764.50	2.30	114.70	2209	7670	1.000	1.000	0.008	1.000	**0.752**	0.000	0.000	0.992	0.000	**0.248**
23	20.00	581.50	4.50	232.60	1409	5427	0.253	0.110	1.000	1.000	**0.591**	0.747	0.890	0.000	0.000	**0.409**
24	19.00	601.50	1.80	90.20	1407	5046	0.106	0.025	0.016	0.107	**0.063**	0.894	0.975	0.984	0.893	**0.937**
25	18.80	593.40	4.70	89.00	2097	8275	0.034	0.087	0.080	0.092	**0.073**	0.966	0.913	0.920	0.908	**0.927**
26	30.80	499.60	3.70	74.90	2060	7858	1.000	0.121	1.000	0.017	**0.534**	0.000	0.879	0.000	0.983	**0.466**
27	44.00	562.10	3.30	56.20	1369	6034	1.000	1.000	1.000	0.031	**0.758**	0.000	0.000	0.000	0.969	**0.242**
28	26.00	557.00	1.00	83.60	1307	4024	1.000	0.107	0.022	0.263	**0.348**	0.000	0.893	0.978	0.737	**0.652**
29	29.30	701.00	82.10	105.20	2016	6944	1.000	0.103	1.000	0.046	**0.537**	0.000	0.897	0.000	0.954	**0.463**
30	26.30	694.60	2.90	104.20	1752	7345	1.000	0.034	0.003	0.015	**0.263**	0.000	0.966	0.997	0.985	**0.737**
31	10.50	742.60	7.60	111.40	1987	6992	0.113	0.017	0.088	1.000	**0.305**	0.887	0.983	0.912	0.000	**0.695**
32	22.70	604.90	3.90	90.70	3990	13436	0.042	1.000	0.034	1.000	**0.519**	0.958	0.000	0.966	0.000	**0.481**
33	18.70	786.70	1.80	78.70	1054	3920	0.135	1.000	0.035	1.000	**0.543**	0.865	0.000	0.965	0.000	**0.457**
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438	31.00	479.30	1.40	12.00	1339	4408	0.051	1.000	0.034	1.000	**0.521**	0.949	0.000	0.966	0.000	**0.479**

APPENDIX C: Non-Spatial Preference Modelling Results

Case Study Existing Infrastructure Indicators							Maximum Standardization									
							Benefit					Cost				
Location ID	ROAD	ELECT	TELEC	WATER	HH	POP	ROAD	ELECT	TELEC	WATER	Infra	ROAD	ELECT	TELEC	WATER	Infra
1	21.00	854.90	76.60	85.50	2405	7194	0.318	0.950	0.506	0.270	**0.511**	0.783	0.192	0.496	0.752	**0.556**
2	25.70	676.30	2.20	67.60	2076	7607	0.389	0.751	0.015	0.213	**0.342**	0.712	0.391	0.987	0.808	**0.725**
3	18.00	485.40	1.60	72.80	803	3391	0.273	0.539	0.011	0.230	**0.263**	0.829	0.603	0.991	0.792	**0.804**
4	30.00	746.10	4.30	74.60	888	2713	0.455	0.829	0.028	0.236	**0.387**	0.647	0.313	0.974	0.786	**0.680**
5	30.00	703.90	3.90	70.40	1145	4011	0.455	0.782	0.026	0.222	**0.371**	0.647	0.360	0.976	0.799	**0.696**
6	33.00	674.70	2.70	101.20	2405	8764	0.500	0.750	0.018	0.320	**0.397**	0.602	0.392	0.984	0.702	**0.670**
7	12.70	696.50	7.30	104.50	2311	8819	0.192	0.774	0.048	0.330	**0.336**	0.909	0.368	0.954	0.692	**0.731**
8	20.50	679.40	3.00	101.90	1726	5790	0.311	0.755	0.020	0.322	**0.352**	0.791	0.387	0.982	0.700	**0.715**
9	23.70	718.90	2.40	287.60	2151	8743	0.359	0.799	0.016	0.908	**0.520**	0.742	0.343	0.986	0.113	**0.546**
10	25.50	714.90	5.50	107.20	2845	9658	0.386	0.794	0.036	0.338	**0.389**	0.715	0.348	0.966	0.683	**0.678**
11	19.30	900.00	10.70	135.00	1037	5038	0.292	1.000	0.071	0.426	**0.447**	0.809	0.142	0.931	0.595	**0.619**
12	42.40	710.70	7.00	106.60	1749	6120	0.642	0.790	0.046	0.337	**0.454**	0.459	0.352	0.956	0.685	**0.613**
13	35.00	691.00	6.20	103.70	2155	8991	0.530	0.768	0.041	0.327	**0.417**	0.571	0.374	0.961	0.694	**0.650**
14	18.80	526.80	0.40	52.70	1441	5102	0.285	0.585	0.003	0.166	**0.260**	0.817	0.557	0.999	0.855	**0.807**
15	18.80	568.80	28.50	56.90	1368	5111	0.285	0.632	0.188	0.180	**0.321**	0.817	0.510	0.814	0.842	**0.746**
16	34.50	553.80	2.50	55.40	2279	9189	0.523	0.615	0.017	0.175	**0.332**	0.579	0.527	0.985	0.847	**0.734**
17	22.70	872.30	42.30	130.80	1558	6023	0.344	0.969	0.279	0.413	**0.501**	0.758	0.173	0.723	0.608	**0.565**
18	21.70	652.10	1.80	65.20	1088	4019	0.329	0.725	0.012	0.206	**0.318**	0.773	0.418	0.990	0.816	**0.749**
19	53.50	640.90	8.20	64.10	1333	5426	0.811	0.712	0.054	0.202	**0.445**	0.291	0.430	0.948	0.819	**0.622**
20	27.50	633.90	4.90	95.10	2387	8842	0.417	0.704	0.032	0.300	**0.363**	0.685	0.438	0.970	0.721	**0.703**
21	10.20	796.80	25.10	119.50	1286	5363	0.155	0.885	0.166	0.377	**0.396**	0.947	0.257	0.836	0.644	**0.671**
22	30.00	764.50	2.30	114.70	2209	7670	0.455	0.849	0.015	0.362	**0.420**	0.647	0.293	0.987	0.659	**0.646**
23	20.00	581.50	4.50	232.60	1409	5427	0.303	0.646	0.030	0.734	**0.428**	0.798	0.496	0.972	0.287	**0.638**
24	19.00	601.50	1.80	90.20	1407	5046	0.288	0.668	0.012	0.285	**0.313**	0.814	0.474	0.990	0.737	**0.754**
25	18.80	593.40	4.70	89.00	2097	8275	0.285	0.659	0.031	0.281	**0.314**	0.817	0.483	0.971	0.740	**0.753**
26	30.80	499.60	3.70	74.90	2060	7858	0.467	0.555	0.024	0.237	**0.321**	0.635	0.587	0.978	0.785	**0.746**
27	44.00	562.10	3.30	56.20	1369	6034	0.667	0.625	0.022	0.177	**0.373**	0.435	0.518	0.980	0.844	**0.694**
28	26.00	557.00	1.00	83.60	1307	4024	0.394	0.619	0.007	0.264	**0.321**	0.708	0.523	0.995	0.757	**0.746**
29	29.30	701.00	82.10	105.20	2016	6944	0.444	0.779	0.542	0.332	**0.524**	0.658	0.363	0.460	0.689	**0.542**
30	26.30	694.60	2.90	104.20	1752	7345	0.398	0.772	0.019	0.329	**0.380**	0.703	0.370	0.983	0.692	**0.687**
31	10.50	742.60	7.60	111.40	1987	6992	0.159	0.825	0.050	0.352	**0.347**	0.942	0.317	0.952	0.670	**0.720**
32	22.70	604.90	3.90	90.70	3990	13436	0.344	0.672	0.026	0.286	**0.332**	0.758	0.470	0.976	0.735	**0.735**
33	18.70	786.70	1.80	78.70	1054	3920	0.283	0.874	0.012	0.249	**0.354**	0.818	0.268	0.990	0.773	**0.712**
34	15.60	617.60	51.00	92.60	3395	14528	0.236	0.686	0.337	0.292	**0.388**	0.865	0.456	0.665	0.729	**0.679**
35	21.50	632.20	2.00	94.80	1305	4866	0.326	0.702	0.013	0.299	**0.335**	0.776	0.440	0.989	0.722	**0.732**
36	28.30	706.60	3.70	106.00	2034	7252	0.429	0.785	0.024	0.335	**0.393**	0.673	0.357	0.978	0.687	**0.674**
37	18.00	719.60	7.30	72.00	2793	9595	0.273	0.800	0.048	0.227	**0.337**	0.829	0.343	0.954	0.794	**0.730**
38	14.30	729.10	2.20	109.40	1743	6755	0.217	0.810	0.015	0.345	**0.347**	0.885	0.332	0.987	0.676	**0.720**
39	21.20	468.70	2.90	46.90	1089	4207	0.321	0.521	0.019	0.148	**0.252**	0.780	0.621	0.983	0.873	**0.814**
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438	31.00	479.30	1.40	12.00	1339	4408	0.470	0.533	0.009	0.038	**0.262**	0.632	0.610	0.993	0.984	**0.804**

Case Study Existing Infrastructure Indicators							Interval Standardization									
							Benefit					Cost				
Location ID	ROAD	ELECT	TELEC	WATER	HH	POP	ROAD	ELECT	TELEC	WATER	Infra	ROAD	ELECT	TELEC	WATER	Infra
1	21.00	854.90	76.60	85.50	2405	7194	0.241	0.942	0.505	0.254	**0.485**	0.759	0.058	0.495	0.746	**0.515**
2	25.70	676.30	2.20	67.60	2076	7607	0.320	0.710	0.013	0.196	**0.310**	0.680	0.290	0.987	0.804	**0.690**
3	18.00	485.40	1.60	72.80	803	3391	0.191	0.463	0.009	0.213	**0.219**	0.809	0.537	0.991	0.787	**0.781**
4	30.00	746.10	4.30	74.60	888	2713	0.393	0.801	0.026	0.219	**0.360**	0.607	0.199	0.974	0.781	**0.640**
5	30.00	703.90	3.90	70.40	1145	4011	0.393	0.746	0.024	0.205	**0.342**	0.607	0.254	0.976	0.795	**0.658**
6	33.00	674.70	2.70	101.20	2405	8764	0.444	0.708	0.016	0.305	**0.368**	0.556	0.292	0.984	0.695	**0.632**
7	12.70	696.50	7.30	104.50	2311	8819	0.101	0.736	0.046	0.315	**0.300**	0.899	0.264	0.954	0.685	**0.700**
8	20.50	679.40	3.00	101.90	1726	5790	0.233	0.714	0.018	0.307	**0.318**	0.767	0.286	0.982	0.693	**0.682**
9	23.70	718.90	2.40	287.60	2151	8743	0.287	0.765	0.014	0.906	**0.493**	0.713	0.235	0.986	0.094	**0.507**
10	25.50	714.90	5.50	107.20	2845	9658	0.317	0.760	0.034	0.324	**0.359**	0.683	0.240	0.966	0.676	**0.641**
11	19.30	900.00	10.70	135.00	1037	5038	0.212	1.000	0.069	0.414	**0.424**	0.788	0.000	0.931	0.586	**0.576**
12	42.40	710.70	7.00	106.60	1749	6120	0.602	0.755	0.044	0.322	**0.431**	0.398	0.245	0.956	0.678	**0.569**
13	35.00	691.00	6.20	103.70	2155	8991	0.477	0.729	0.039	0.313	**0.390**	0.523	0.271	0.961	0.687	**0.610**
14	18.80	526.80	0.40	52.70	1441	5102	0.204	0.517	0.001	0.148	**0.217**	0.796	0.483	0.999	0.852	**0.783**
15	18.80	568.80	28.50	56.90	1368	5111	0.204	0.571	0.187	0.162	**0.281**	0.796	0.429	0.813	0.838	**0.719**
16	34.50	553.80	2.50	55.40	2279	9189	0.469	0.552	0.015	0.157	**0.298**	0.531	0.448	0.985	0.843	**0.702**
17	22.70	872.30	42.30	130.80	1558	6023	0.270	0.964	0.278	0.400	**0.478**	0.730	0.036	0.722	0.600	**0.522**
18	21.70	652.10	1.80	65.20	1088	4019	0.253	0.679	0.010	0.188	**0.283**	0.747	0.321	0.990	0.812	**0.717**
19	53.50	640.90	8.20	64.10	1333	5426	0.789	0.664	0.052	0.185	**0.423**	0.211	0.336	0.948	0.815	**0.577**
20	27.50	633.90	4.90	95.10	2387	8842	0.351	0.655	0.030	0.285	**0.330**	0.649	0.345	0.970	0.715	**0.670**
21	10.20	796.80	25.10	119.50	1286	5363	0.059	0.866	0.164	0.364	**0.363**	0.941	0.134	0.836	0.636	**0.637**
22	30.00	764.50	2.30	114.70	2209	7670	0.393	0.825	0.013	0.348	**0.395**	0.607	0.175	0.987	0.652	**0.605**
23	20.00	581.50	4.50	232.60	1409	5427	0.224	0.587	0.028	0.729	**0.392**	0.776	0.413	0.972	0.271	**0.608**
24	19.00	601.50	1.80	90.20	1407	5046	0.207	0.613	0.010	0.269	**0.275**	0.793	0.387	0.990	0.731	**0.725**
25	18.80	593.40	4.70	89.00	2097	8275	0.204	0.603	0.029	0.265	**0.275**	0.796	0.397	0.971	0.735	**0.725**
26	30.80	499.60	3.70	74.90	2060	7858	0.406	0.481	0.023	0.220	**0.283**	0.594	0.519	0.977	0.780	**0.717**
27	44.00	562.10	3.30	56.20	1369	6034	0.629	0.562	0.020	0.159	**0.343**	0.371	0.438	0.980	0.841	**0.657**
28	26.00	557.00	1.00	83.60	1307	4024	0.325	0.556	0.005	0.248	**0.283**	0.675	0.444	0.995	0.752	**0.717**
29	29.30	701.00	82.10	105.20	2016	6944	0.381	0.742	0.541	0.318	**0.496**	0.619	0.258	0.459	0.682	**0.504**
30	26.30	694.60	2.90	104.20	1752	7345	0.331	0.734	0.017	0.314	**0.349**	0.669	0.266	0.983	0.686	**0.651**
31	10.50	742.60	7.60	111.40	1987	6992	0.064	0.796	0.048	0.338	**0.312**	0.936	0.204	0.952	0.662	**0.688**
32	22.70	604.90	3.90	90.70	3990	13436	0.270	0.618	0.024	0.271	**0.296**	0.730	0.382	0.976	0.729	**0.704**
33	18.70	786.70	1.80	78.70	1054	3920	0.202	0.853	0.010	0.232	**0.324**	0.798	0.147	0.990	0.768	**0.676**
34	15.60	617.60	51.00	92.60	3395	14528	0.150	0.634	0.336	0.277	**0.349**	0.850	0.366	0.664	0.723	**0.651**
35	21.50	632.20	2.00	94.80	1305	4866	0.250	0.653	0.011	0.284	**0.299**	0.750	0.347	0.989	0.716	**0.701**
36	28.30	706.60	3.70	106.00	2034	7252	0.364	0.750	0.023	0.320	**0.364**	0.636	0.250	0.977	0.680	**0.636**
37	18.00	719.60	7.30	72.00	2793	9595	0.191	0.766	0.046	0.210	**0.303**	0.809	0.234	0.954	0.790	**0.697**
38	14.30	729.10	2.20	109.40	1743	6755	0.128	0.779	0.013	0.331	**0.313**	0.872	0.221	0.987	0.669	**0.687**
39	21.20	468.70	2.90	46.90	1089	4207	0.245	0.441	0.017	0.129	**0.208**	0.755	0.559	0.983	0.871	**0.792**
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438	31.00	479.30	1.40	12.00	1339	4408	0.410	0.455	0.007	0.017	**0.222**	0.590	0.545	0.993	0.983	**0.778**

Goal Values are reference values determine the minimum and maximum value acceptable by stakeholder.

Indicators	Min Goal		Max Goal	
	Assumption	Value	Assumption	Value
ROAD	Min (ROAD) + 10	10.21	Max (ROAD) + 50	###
ELECT	Min (ELECT) + 10	10.00	Max (ELECT) + 50	###
TELEC	Min (TELEC) + 10	10.46	Max (TELEC) + 50	###
WATER	Min (WATER) + 10	10.09	Max (WATER) + 50	###

Case Study Existing Infrastructure Indicators							Goal Standardization									
							Benefit					Cost				
Location ID	ROAD	ELECT	TELEC	WATER	HH	POP	ROAD	ELECT	TELEC	WATER	Infra	ROAD	ELECT	TELEC	WATER	Infra
1	21.00	854.90	76.60	85.50	2405	7194	0.043	0.883	0.347	0.196	**0.367**	0.957	0.117	0.653	0.804	**0.633**
2	25.70	676.30	2.20	67.60	2076	7607	0.091	0.663	-0.042	0.145	**0.214**	0.909	0.337	1.042	0.855	**0.786**
3	18.00	485.40	1.60	72.80	803	3391	0.013	0.428	-0.046	0.160	**0.139**	0.987	0.572	1.046	0.840	**0.861**
4	30.00	746.10	4.30	74.60	888	2713	0.134	0.749	-0.031	0.165	**0.254**	0.866	0.251	1.031	0.835	**0.746**
5	30.00	703.90	3.90	70.40	1145	4011	0.134	0.697	-0.033	0.153	**0.238**	0.866	0.303	1.033	0.847	**0.762**
6	33.00	674.70	2.70	101.20	2405	8764	0.164	0.661	-0.040	0.241	**0.257**	0.836	0.339	1.040	0.759	**0.743**
7	12.70	696.50	7.30	104.50	2311	8819	-0.040	0.688	-0.016	0.251	**0.221**	1.040	0.312	1.016	0.749	**0.779**
8	20.50	679.40	3.00	101.90	1726	5790	0.038	0.667	-0.038	0.243	**0.228**	0.962	0.333	1.038	0.757	**0.772**
9	23.70	718.90	2.40	287.60	2151	8743	0.070	0.715	-0.041	0.774	**0.380**	0.930	0.285	1.041	0.226	**0.620**
10	25.50	714.90	5.50	107.20	2845	9658	0.089	0.711	-0.025	0.258	**0.258**	0.911	0.289	1.025	0.742	**0.742**
11	19.30	900.00	10.70	135.00	1037	5038	0.026	0.938	0.002	0.338	**0.326**	0.974	0.062	0.998	0.662	**0.674**
12	42.40	710.70	7.00	106.60	1749	6120	0.259	0.705	-0.017	0.257	**0.301**	0.741	0.295	1.017	0.743	**0.699**
13	35.00	691.00	6.20	103.70	2155	8991	0.184	0.681	-0.021	0.248	**0.273**	0.816	0.319	1.021	0.752	**0.727**
14	18.80	526.80	0.40	52.70	1441	5102	0.021	0.479	-0.052	0.103	**0.138**	0.979	0.521	1.052	0.897	**0.862**
15	18.80	568.80	28.50	56.90	1368	5111	0.021	0.531	0.095	0.115	**0.190**	0.979	0.469	0.905	0.885	**0.810**
16	34.50	553.80	2.50	55.40	2279	9189	0.179	0.512	-0.041	0.110	**0.190**	0.821	0.488	1.041	0.890	**0.810**
17	22.70	872.30	42.30	130.80	1558	6023	0.060	0.904	0.167	0.326	**0.365**	0.940	0.096	0.833	0.674	**0.635**
18	21.70	652.10	1.80	65.20	1088	4019	0.050	0.633	-0.044	0.138	**0.194**	0.950	0.367	1.044	0.862	**0.806**
19	53.50	640.90	8.20	64.10	1333	5426	0.371	0.619	-0.011	0.135	**0.279**	0.629	0.381	1.011	0.865	**0.721**
20	27.50	633.90	4.90	95.10	2387	8842	0.109	0.611	-0.028	0.224	**0.229**	0.891	0.389	1.028	0.776	**0.771**
21	10.20	796.80	25.10	119.50	1286	5363	-0.065	0.811	0.077	0.294	**0.279**	1.065	0.189	0.923	0.706	**0.721**
22	30.00	764.50	2.30	114.70	2209	7670	0.134	0.772	-0.042	0.280	**0.286**	0.866	0.228	1.042	0.720	**0.714**
23	20.00	581.50	4.50	232.60	1409	5427	0.033	0.546	-0.030	0.617	**0.291**	0.967	0.454	1.030	0.383	**0.709**
24	19.00	601.50	1.80	90.20	1407	5046	0.023	0.571	-0.044	0.210	**0.190**	0.977	0.429	1.044	0.790	**0.810**
25	18.80	593.40	4.70	89.00	2097	8275	0.021	0.561	-0.029	0.206	**0.190**	0.979	0.439	1.029	0.794	**0.810**
26	30.80	499.60	3.70	74.90	2060	7858	0.142	0.445	-0.035	0.166	**0.180**	0.858	0.555	1.035	0.834	**0.820**
27	44.00	562.10	3.30	56.20	1369	6034	0.275	0.522	-0.037	0.113	**0.218**	0.725	0.478	1.037	0.887	**0.782**
28	26.00	557.00	1.00	83.60	1307	4024	0.094	0.516	-0.049	0.191	**0.188**	0.906	0.484	1.049	0.809	**0.812**
29	29.30	701.00	82.10	105.20	2016	6944	0.127	0.693	0.376	0.253	**0.362**	0.873	0.307	0.624	0.747	**0.638**
30	26.30	694.60	2.90	104.20	1752	7345	0.097	0.686	-0.039	0.250	**0.248**	0.903	0.314	1.039	0.750	**0.752**
31	10.50	742.60	7.60	111.40	1987	6992	-0.062	0.745	-0.014	0.270	**0.235**	1.062	0.255	1.014	0.730	**0.765**
32	22.70	604.90	3.90	90.70	3990	13436	0.060	0.575	-0.033	0.211	**0.203**	0.940	0.425	1.033	0.789	**0.797**
33	18.70	786.70	1.80	78.70	1054	3920	0.020	0.799	-0.044	0.177	**0.238**	0.980	0.201	1.044	0.823	**0.762**
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438	31.00	479.30	1.40	12.00	1339	4408	0.410	0.455	0.007	0.017	**0.222**	0.590	0.545	0.993	0.983	**0.778**

Location ID	Interval Standardization					Alternative					
	Benefit										
	ROAD	ELECT	TELEC	WATER	Existing Infra	Alternative IB_Infra	Alter_AR	AlterIB_RoadAR	AlterIB_ElectAR	AlterIB_TelecAR	AlterIB_WaterAR
1	0.044	1.000	1.000	0.087	**0.533**	0.533	0.000	0.000	0.000	0.000	0.000
2	1.000	0.220	0.275	0.204	**0.425**	0.425	0.000	0.000	0.000	0.000	0.000
3	0.453	0.412	0.259	0.358	**0.371**	0.400	0.002	30.546	27.808	17.483	24.163
4	1.000	1.000	0.221	0.127	**0.587**	0.587	0.000	0.000	0.000	0.000	0.000
5	1.000	0.217	0.283	0.349	**0.462**	0.462	0.000	0.000	0.000	0.000	0.000
6	1.000	0.173	0.023	0.243	**0.360**	0.400	0.002	0.000	39.376	5.272	55.352
7	0.200	0.226	0.182	1.000	**0.402**	0.402	0.000	0.000	0.000	0.000	0.000
8	0.333	0.220	0.220	0.257	**0.257**	0.400	0.008	32.295	21.381	21.330	24.993
9	0.139	1.000	0.047	1.000	**0.547**	0.547	0.000	0.000	0.000	0.000	0.000
10	0.086	1.000	0.121	1.000	**0.552**	0.552	0.000	0.000	0.000	0.000	0.000
11	1.000	1.000	0.189	1.000	**0.797**	0.797	0.000	0.000	0.000	0.000	0.000
12	1.000	1.000	1.000	0.220	**0.805**	0.805	0.000	0.000	0.000	0.000	0.000
13	1.000	1.000	1.000	0.128	**0.782**	0.782	0.000	0.000	0.000	0.000	0.000
14	0.283	0.113	0.392	0.077	**0.216**	0.400	0.010	32.739	13.083	45.260	8.918
15	-1.300	0.781	1.000	0.830	**0.328**	0.903	0.000	0.000	0.000	0.000	0.000
16	1.000	1.000	1.000	0.196	**0.799**	0.799	0.000	0.000	0.000	0.000	0.000
17	0.094	1.000	1.000	1.000	**0.774**	0.774	0.000	0.000	0.000	0.000	0.000
18	0.313	0.214	0.392	0.201	**0.280**	0.400	0.006	27.935	19.079	35.045	17.941
19	1.000	1.000	1.000	1.000	**1.000**	1.000	0.000	0.000	0.000	0.000	0.000
20	1.000	0.106	1.000	0.157	**0.566**	0.566	0.000	0.000	0.000	0.000	0.000
21	0.424	0.146	0.211	1.000	**0.445**	0.445	0.000	0.000	0.000	0.000	0.000
22	1.000	1.000	0.006	1.000	**0.752**	0.752	0.000	0.000	0.000	0.000	0.000
23	0.351	0.305	1.000	1.000	**0.664**	0.664	0.000	0.000	0.000	0.000	0.000
24	0.159	0.125	0.099	0.151	**0.133**	0.400	0.014	29.757	23.430	18.489	28.324
25	0.096	0.235	0.148	0.139	**0.155**	0.400	0.013	15.527	37.970	23.988	22.514
26	1.000	0.144	1.000	0.101	**0.561**	0.561	0.000	0.000	0.000	0.000	0.000
27	1.000	1.000	1.000	0.117	**0.779**	0.779	0.000	0.000	0.000	0.000	0.000
28	1.000	0.291	0.242	0.276	**0.452**	0.452	0.000	0.000	0.000	0.000	0.000
29	1.000	0.213	1.000	0.194	**0.602**	0.602	0.000	0.000	0.000	0.000	0.000
30	1.000	0.156	-0.020	0.156	**0.323**	0.578	0.000	0.000	0.000	0.000	0.000
31	0.143	0.101	0.132	1.000	**0.344**	0.400	0.003	38.066	26.805	35.129	0.000
32	0.105	1.000	0.109	1.000	**0.554**	0.554	0.000	0.000	0.000	0.000	0.000
33	0.137	1.000	0.121	1.000	**0.565**	0.565	0.000	0.000	0.000	0.000	0.000
34	0.018	0.132	1.000	1.000	**0.538**	0.538	0.000	0.000	0.000	0.000	0.000
35	0.132	1.000	0.078	1.000	**0.553**	0.553	0.000	0.000	0.000	0.000	0.000
36	0.106	0.093	0.118	0.093	**0.103**	0.400	0.016	25.881	22.701	28.733	22.685
37	0.130	1.000	0.184	0.148	**0.365**	0.400	0.002	28.180	0.000	39.868	31.952
38	0.339	1.000	0.013	1.000	**0.588**	0.588	0.000	0.000	0.000	0.000	0.000
39	0.147	0.207	0.093	0.211	**0.165**	0.400	0.013	22.358	31.454	14.057	32.131
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438	0.109	1.000	0.191	1.000	**0.575**	0.613	0.000	0.000	0.000	0.000	0.000