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Title: Indicator Based Assessment for Sustainability Benefits of Urban Light Rail Transport (A case study of Abuja, Nigeria)

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Indicator Based Assessment for Sustainability Benefits of Urban Light Rail Transport

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Summary

The common perception about the real sustainability benefits of the urban mass transport system are still poorly understood, especially in terms of how to quantify the determining indicators in specific and empirical terms to measure the extent of these benefits. Sustainability evaluation and enhancement can be accomplished in a scientific, reasonable and logical manner within the general planning paradigm as the beginning of improving progress toward sustainability development. Indicators such as travel time (timesaving), affordability, accessibility, employment, safety, congestion, modal shift, urban regeneration, air pollutant emissions, e.t.c.

The research objective is to assess the sustainability (economic, social and environmental) development benefits of the Abuja urban light rail transport system.

The research methods used are the questionnaire survey and experimental analysis.
The data collected from the questionnaire based on the ranking of indicators, is analysed quantitatively, using the descriptive statistics tools of excel, describing the rankings by the experts and stakeholders for their required rank score. The experiments performed were for the road and rail modes of transport along the same route.

The concepts of the conceptual framework of the sustainability diamond and multicriteria assessment are used in this research to compare transport route alternatives of the rail and their corresponding road routes, measuring the timesaving as an economic sustainability benefit. Analyses here revealed how the economic measurement indicator, i.e. timesaving, which was selected as the most ranked indicator that results into different empirical rate or level of contribution to sustainability benefit, thus answering the question, how are the Sustainability benefits of the urban light rail system assessed.

Based on the concepts of sustainability diamond and multicriteria assessment, this research approach selects a set of nine indicators from economic, social and environmental sustainability, based on highest common factor as used in the literature, especially as it relates to its applicability in a developing country. These selected nine indicators are scored by ranking, based on the most significant approach, by the participatory selection of experts. Thus, the first indicator with the highest rank scores amongst the selected is used for the quantitative assessment to empirically determine its level of sustainability benefit using geo-information system and quantification calculus approach.

The main findings show that Lot 1A along Kubwa to Idu rail route stations is faster as compared to the road route between the same locations by 8.4 minutes at off-peak hours and 38.4 minutes at peak hours. Lot 3A along Idu to Abuja metro route stations is less faster as compared to the road route between the same two locations by 1.6 minutes during the off-peak hours but faster by 28.4 minutes at peak hours. Lot 3B along Idu to Airport route stations is faster as compared to the road route between the same locations by 18.4 minutes during the off-peak period and 48.4 minutes during peak period.

Another interesting finding is that lot 3A gave a negative number of (-1.6minutes) during the off-peak hours. This can be taken into cognisance for further perceptions and re-planning, as a rail at 100km/hr compared to 75km/hr is ordinarily meant to get a commuter to its destination faster at peak or off-peak hours of the same route.

Therefore, the description in empirical terms the number of minutes gained or lost during the peak and off-peak periods provides precise answers to the research question on how the sustainability benefits of the urban light rail system on timesaving can be assessed. This is required to know in specific terms, to what extent a particular sustainability indicator will benefit an urban city when a rail transport infrastructure is provided.

In generating empirical and valid levels of benefit to sustainability development, the newly developed approach using the Geo-Information System (GIS) approach for the timesaving indicator, has shown to be capable of reliable assessment, through the integration with the conceptual framework to empirically ascertain the assessment of the sustainability benefits of the Abuja light rail. Thus, adding a new niche to the body of knowledge of the subject matter.

Keywords

Sustainability transport, urban light-rail, sustainability benefit, indicator assessment, GIS.

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Foreword

The provision of large-scale infrastructure without assessing its level of sustainability will result into challenges that may be of huge cost and negative effects to lives of the people. Understanding how best to practice sustainability and in what manner to fit in to the socio-economic and environmental condition of a specific jurisdiction, is of importance to the world, especially the developing countries who are still trying to manage many national issues.

Increasing the awareness of integrating sustainability development into local, state and national developmental projects is very crucial and should be given serious attention. However, the understanding of how sustainability development benefits a nation and the specific trade-offs among the components, provides important and adequate information for better decision-making, that guarantees the investments being made are worthwhile and choosing the efficient alternative.

Abbreviations

GIS	Geographic Information System
GPS	Global Positioning Systems
GCP	Ground Control Points
AOI	Area Of Interest
WGS	World Geodetic System
UTM	Universal Transverse Mercator
2D	2-Dimensional
PT	Public Transport
LRT	Light Rail Transport
MTS	Mass Transit Service
AMT	Abuja Mass Transit
Km/hr	Kilometre per hour
CBA	Cost Benefit Analysis
EIA	Environmental Impact Assessment
MCA	Multi-Criteria Analysis
VOC	Volatile Organic Compounds
NOx	Nitrous Oxide
CO	Carbon Monoxide
CO2	Carbon Dioxide
SO2	Sulphur Dioxide
NASRDA	National Space Research and Development Agency
PM	Particulate Matter
FCTA	Federal Capital Transport Authority
FCDA	Federal Capital Development Authority
FCT	Federal Capital Territory
FCC	Federal Capital City
AMAC	Abuja Municipal Area Council
EEA	European Environmental Agency
EU	European Union
WHO	World Health Organisation
UN	United Nations
OECD	Organisation for Economic Co-operation and Development

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Chapter 1: Introduction

This chapter introduces the thesis in general, the background of study, statement of problem, research objective, overall research question, significance of study, scope and limitation of study.

1.1 Background

Transportation plays a major role in recent times and it is a fundamental extension of almost any human activity. Concerns have increased over the role of transportation in greenhouse gas emissions, fuel resource depletion, toxic pollution, as well as issues relating to transportation costs and the equity impacts of transportation policy being formulated as a result of assessment for sustainability transportation. Thus, transportation sustainability must be addressed as a logical step toward overall sustainability development. The broad goals of sustainability transportation are the provision of safe, effective, and efficient access and mobility into the future while considering economic, social, and environmental needs (Ramani, Zietsman, et al., 2009).

During more than a century of development, light rail has proved itself an effective and efficient means of taking large numbers of passengers directly into and around the heart of a city, connecting communities and supporting businesses (Barrella, 2012). The urban transport in the European Union (EU) accounts for 80% of congestion costs, 15% of all greenhouse gas emissions, 20,000 road fatalities annually and upwards of 100,000 premature deaths each year from air pollution (May, Page, et al., 2008). There is thus ample evidence that European urban transport policies are currently far from sustainability.

In many cities, urban rail transportation projects, i.e. the light rail, metro and tram systems over the years demonstrated itself as the optimal solution in providing a sustainability mobility for the increasing urban population. This light rail also provides other benefits such as better comfort, medium-high carrying capacity, faster, more regular and safer. The light rail system is a large project that requires very high amount of investments, especially for the construction of infrastructure and maintenance costs. Apart from the economic benefits, the social and environmental improvement benefits are also derived from the rail system projects (Cascajo, 2004). Investing in transportation infrastructure does have continuing effects on both the transportation system and the sustainability system, i.e. economic, social and environmental, which interacts with transportation (Barrella, 2012).

A recent survey of tram schemes in France similarly notes that the French Internal Transport Law (LOTI) requires cities that implement major urban transport infrastructure schemes using public funds to evaluate the projects against criteria that can “verify the socio-economic efficiency of the investment.” These evaluations are, in essence, “before and after” studies of the projects from a socio-economic point of view (Gleave, 2005).

Transportation does have a very positive and transforming effect on our contemporary environment, redirecting the manner in which the built up area is been transformed to serve the public with a common good, thus providing economic, social and environmental benefits (Masud, Mohammed, et al., 2000).

There is presently a wide acceptance of the sustainability urban development notion, seeking to find accurate method to assess and measure comparative sustainability levels of existing and future developments, which has become an important issue. Indicators are derived from values and in turn create values. Therefore, the strong and unique advantage of an indicator based comparative urban sustainability assessment model is the quantifiability of the comparative sustainability levels. Considering the local perspective, sustainability indicators reflect large-scale environmental and economic aspects and local social issues relevant to urban sustainability. There is however a growing concern to balance environmental, economic and social dimensions of sustainability (Yigitcanlar and Dur, 2010).

The study area is located in Abuja, the Federal Capital Territory (FCT) of Nigeria, situated at 9.06° North latitude, 7.49° East longitude and 536 meters elevation above the sea level (National Space Research and Development Agency Nigeria, 2012). It has a population of 2,759,829 people, with a growth rate of 9.3% (United Nations Populations Fund). The study area was specifically chosen because it is the Federal Capital City with the first light rail transport to be implemented in the country (Federal Government Nigeria, 2013). The study on light rail was also chosen because it offers a good opportunity for an ex-ante research to be carried out i.e. research on a project yet to start or fully implemented, in order to deduce series of needs as it regards to the future benefits it will provide to public mass transportation and other important information it offers for better decision making. The fact that the Federal capital city in the capital possess urban environment characteristic as a fast growing city, also adds to the reasons it was chosen as a study area. The 280km Abuja Light Rail System (ALRS) is designed to carry commuters from satellite towns to the city centre in the capital. The large numbers who work in the Federal Capital Territory commute as much as 30km due to the high cost of accommodation in the metropolis. An estimated two million people will commute through the Abuja light rail project daily (Federal Government Nigeria, 2013). The Abuja Light Rail project has reached its final implementation take-off stage. The light rail system offers positive effects if well sustained, in terms of income generation, less carbon emissions from other sources of transport for climate change mitigation, better spatial coverage for higher en-mass mobility, reduction in traffic congestion, better land-use planning/value and inclusive transport, resuscitation of the Ajaokuta steel industry and other rail infrastructure parts-providing companies within the country.

The much awaited light rail is expected to provide the city with social, economic and environmental benefits which also needs to be assessed or measured using specified indicators that is related to ascertain its level of benefit to sustainability development. The scope and contents of local indicators differ from one large infrastructural investment to another. Nevertheless, the main intention of a sustainability assessment is to include the most prominent local indicators in the assessment model. An assessment model with a comprehensive inclusion of key issues provides findings that will be very beneficial to an inclusive decision making arena to support development of policies and effective measures for a more sustainability urban future (Yigitcanlar and Dur, 2010). Sustainability model is characterised with three main aspects, i.e., environmental, economic and social. It is not completely adequate just to gain the knowledge about the importance of indicators to achieve a sustainability transportation system. A framework in form of instruments is needed to determine if the transportation system is progressing towards sustainability. Therefore, a set of indicators is required to assess the progress in development of a sustainability urban transportation system, which may also serve many other purposes, such as benchmarking, evaluating effectiveness of policies and measures, comparing between two cities and monitoring the trend of progress towards sustainability development (Quaium, 2012). The two decades has witnessed a considerable change in the delivery of infrastructural services worldwide, with the developing countries, the World Bank and other donors disappointed with the sustainability of their investment in state-owned infrastructure services. These concerns are that investment was not having a long-term impact of the quality and extent of utility and transport services desired according to standards (Kenny, 2007).

1.2 Problem Statement

The common perception about the real and quantifiable sustainability benefits of the urban public transport system is still poorly understood, especially in terms of how to quantify and assess these benefits. Over the years, the sustainability of transportation infrastructures in Nigeria has suffered a serious setback due inadequate measures to assess its sustainability benefits for better decision making in the long term. The conventional methods of measuring the sustainability benefits of the light rail transport system are deeply rooted in the economic theory, depicting inadequacies in the perception of understanding by the local communities on the sustainability value of public transport.

This necessitates the development of a methodology to measure the social, economic and environmental effects and impacts generated by the urban transport investment projects. Various aspects of the ways indicators are selected and applied in practice were of concern to local authorities including their ability to reflect objectives, their use in developing targets and the ease with which they are understood in the monitoring process. Therefore, it is very important to identify specific indicators that are measurable in quantifying the sustainability benefits of the Abuja light rail and use them to assess the extent of its benefits. This provides an informed situation where decision makers understands the trade-offs between different scenarios of the economic, environmental and social benefits and how each of them has more weight of importance than the other, thereby providing empirical and provable reasons for crucial decisions to be implemented.

1.3 Research Objective

The main research objective is to assess the sustainability (economic, social and environmental) development benefits of the Abuja urban light rail transport system. This assessment provides empirical results that specify the rate at which a sustainability benefit contributes to the sustainability development expected by the provision of the large-scale infrastructure. Thus by providing these assessments in figures, it clearly shows its magnitude of benefit and directly answers the research question. Therefore, the specific objectives are:

- Identify the most significant indicators which are used in assessing the sustainability benefits of the urban light rail system
- Perform an ex-ante analysis for empirical assessment of the most ranked indicator

1.4 Research Question

In order to formulate a research question capable of achieving the above objective, the research question for this research is:

How can the sustainability benefits of the urban light rail system be assessed?

1.5 Significance of Study

This research offers an assessment methodology, which specifically provides the assessment of benefits from the light rail as a mass transportation programme. The purpose of economic, social and environmental sustainability assessment is not to attempt to take the decision in place of technical or political decision makers but to present them with the information they need to make an adequately well-informed decision. Assessments therefore need to be presented in a way that directs decision makers to the key factors to weigh in their decision, highlighting trade-offs, risks and uncertainties, rather than making judgments in place of the decision maker (Poutchy-Tixier, Bina, et al., 2004). Sustainability transportation can be considered as an expression and demonstration of sustainability development in the transportation sector. There is, therefore, a need to integrate sustainability transportation concerns into the activities of transportation agencies. In particular, it is of importance to develop methodologies that will address and evaluate sustainability transportation within the regular transportation-planning paradigm, considering the fact that asking for some trade-off in inter-generational equity becomes very challenging in developing countries where sustainability is an up-hill task (Zegras, 2006) .

Sustainability evaluation and enhancement can be accomplished in a scientific, reasonable, and logical manner within the general planning paradigm as a beginning to improving progress toward Sustainability development (Gleave, 2005). This will empower the local authorities to establish an effective set of core indicators which encompasses the objectives of stakeholders, are transparent and measureable, can be used for target setting and contribute to forecasting and appraisal. Examples of such important indicators are: transport demand, accessibility, safety, congestion, inclusiveness, air pollutant emissions, traffic levels noise and health impacts. LRT is not just about moving people from one point to another; it is also about building the community. If done properly, light rail systems will help communities fulfil their vision and their values, a complete application of a comprehensive and effective framework is needed for decision-makers when deciding on a sustainability transportation option (Marko, Soskolne, et al., 2004). Light rail, trams and other rapid transit systems can play a significant part in improving the attractiveness and quality of public transport in major conurbations by moving large numbers of passengers quickly, reliably and with less pollution than the car or bus (Chapman, 2007). This in turn can promote local economic growth and air pollutant emissions through modal shift. In addition, the research output from the use of an ex-ante research approach will also enhance better decision-making before a large transportation infrastructure is constructed and put into sustainability use.

The present dispensation in Nigeria is at a stage where every monetary budget to be released to fund large-scale infrastructures, needs adequate and informed reasons as facts used in convincing or supporting their requests from decision makers. Policy-makers such as the senate and house of parliament which always demand for facts of justification before budget is released and for bills to be successfully passed for infrastructural developments. This also promotes and provides informed decisions to policy makers on issues that necessitate actions such as benchmarking and regulation of price and tax when such infrastructures are in operation.

1.6 Scope and Limitation

The Abuja light rail system is in its completion stage, ready for operation in first quarter of 2015 (Federal Government Nigeria, 2013). That means the urban light rail is yet to start operation for now but will start in the year 2015.
Therefore, this ex-ante research will be carried out within the scope listed below and limitation observed.

Scope

- An ex-ante evaluation method will be applied for this research, using available developmental, planning and target objective data and provable simple mathematical calculus and spatial deductions for its operation.
- The sustainability assessment will be within three aspects of sustainability (economic, social and environmental).

Limitations

- Data gaps will be available by visibility study report, plan figures, logical assumptions and already programmed variables of the master plan of the light rail operation.
- Acquiring some ground control points was an up-hill task due to non-accessible roads to their positions during fieldwork.
- Timely access to vital documents such as the visibility study report, rail corridor master plan and other official government documents was a challenge due to government bureaucracy.
- Seventy percent of respondents had to be visited an average of four times before the completed questionnaires could be retrieved.

Chapter 2: Literature review

2.0 Introduction

The literature review identifies reviews, analyzes the body of works previously published by other scholars in the study area, and goes more in depth to the literatures that are more directly related to answer the needs of the study (Hofstee, 2006). The key words in this literature review are sustainability development, sustainability urban-transport, urban light rail, modal shift, transport sustainability benefits, indicator-based sustainability assessment. These key categories were selected based on their relevance to sustainability in transportation and indicator based assessment. The indicator based sustainability assessment review is the most in-depth amongst all the mentioned categories because it is more directly related to the main research focus as it relates to sustainability benefits of the urban light rail system.

2.1 Sustainability development

Sustainability development has over the years became a very important phrase in the present environmental and scientific horizon, due to the needs of the socio-economic systems to maintain a balance that is fair to the present and future generation. Therefore, for the purpose of this research, sustainability development can be defined in line with the Brundtland order, as a development that supports the requirements of the present without negatively affecting the capability of upcoming in-habitants to achieve their own desires (Robert, Parris, et al., 2005).

The European Union’s Sustainability Development Strategy defines transport sustainability as "the ability to meet the needs of society to move freely, gain access, communicate, trade and establish relationships without sacrificing other essential human or ecological values today or in the future" (Bojković, Macura, et al., 2011).

2.2 Sustainability Transportation

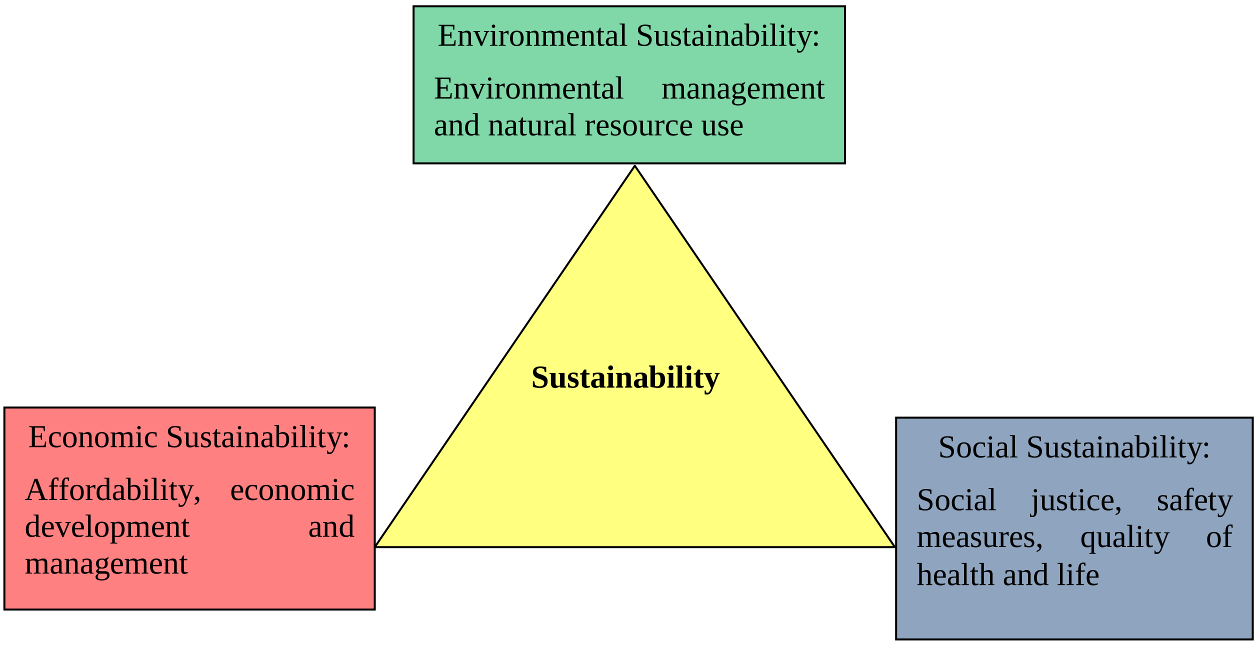
Sustainability in transportation strongly considers the specific resources of importance that the transport uses. These resources, such as biological habitats, energy, carbon and time are some of the depletable resources it consumes. Considering sustainability in transport therefore necessitates the optimization of the resource being used. In achieving sustainability transport, some needs are necessary, such as: healthy standards, equity, affordability, efficient transport operation, variety of alternative mode of transport, competitive market, reduction in emission within the earth's carrying capacity, reducing noise to healthy acceptable standards and using renewable energy less than its level of production (Goldman and Gorham, 2006).

Sustainability transport is a means of transport that aims to achieve the primary purpose of movement of people and goods, while simultaneously contributing to achieving environmental, economic and social sustainability (World Health Organisation, 2004) .

Several strategies have been proposed to implement a more sustainability transport system. Generally, a distinction can be made between behavioural and technological changes. Behavioural changes are aimed to reduce the level of car use, for example by shifting to less polluting modes of transport, changing destination choices, combining trips or reduce travelling. These strategies may improve environmental quality, destination accessibility and urban quality of life. While technological solutions are aimed towards reducing the negative impact per car and per kilometer. Examples are by increasing the energy efficiency of cars and developing new ways of road surface to reduce the level of traffic noise. These solutions do not appear to sufficiently reduce the problems of car use, such as making it compatible with sustainability (Steg and Gifford, 2005).

In order to attain sustainability in transportation, a coherent and comprehensive approach must be adopted towards mobility that integrates all modes of transport into a framework, namely walking, cycling, passenger transport, interlinked with areas such as the quality of life, the environment, health and safety in all transport movements and trips . The objectives of an urban transport plan within a pro-active governance should aim to include the following: Develop public transportation together with cheap means of transportation as well as those that are least polluting, example cycling and walking; Improve safety in all transport movements, organize parking facilities; Reduce car traffic; Introduce integrated tariff schedules and ticketing; Encourage firms and administrations to set up staff transport plans that promote greater use of public transport and car sharing; Re-organize goods transport and deliveries to reduce their impact on traffic flows and the environment.

Figure 1: Three Important Aspects of Transport System Sustainability



Source: (Jeon, Amekudzi, et al., 2010)

The figure above shows an integrated structure for synergizing sustainability importance in transport development and adequate decision-making process. It further depicts the fact that achieving adequate sustainability in transport is an all-encompassing process, which must put into consideration the environmental, economic and social aspects of sustainability for it to fulfill the mandate of efficient use of the present without or with very limited negative effect for the future generation.

This guides the identification of more relevant framework capable of delivering sustainability process that is capable of efficiently managing trade-offs among contending strategies.

2.3 Light Rail Transport

Light rail transport (LRT) system is a public transport system that uses rail-based technology and typically operates in urban settings. Vehicles are usually relatively lightweight, run on steel rails and are propelled by overhead electrical wires, some use a third rail such as the Docklands Light Railway (Marko, Soskolne, et al., 2004), while some use diesel as fuel such as the Abuja, Nigeria case study of this research.

LRT is designed to accommodate a variety of environments, including streets, freeway medians, railroad rights-of-way, operating or abandoned, pedestrian malls, underground or aerial structures, and even in the beds of drained canals (Transit, This Is Light Rail, 2000).
The LRT has the potential to open up a new market for public transport travel in our cities, which has largely remained untapped by bus and heavy rail passenger operations. Bus and heavy rail have clearly been a successful perception in the minds of the travelling public, not hindered by prior negative experiences that older bus and rail systems can integrate. Where demand can justify the volumes of patrons, a natural progression from a bus based system to LRT (modal shift) may occur on defined line haul routes. However, LRT are meant to complement existing public transport systems and not compete, if significant modal shifts towards urban public transport are to be achieved.

The success of light rail along defined corridors is attributed to its modern, reliability and effectiveness in moving commuters especially during peak periods to the central business district (CBD). As indicated in the introduction of chapter one, that most commuters in the study area lives in the suburbs due to high cost of living in the CBD, but needs to transport to the CBD daily to work. The LRT system of permanence encourages people to plan their lives around the system with confidence, which avails them with transport choices based on its availability. It also encourages businesses to develop along the routes, which in turn concentrates development, so that it can be more effectively served by public transport (Ramani, Zietsman, et al., 2013).

2.4 Transport Sustainability Benefits

The sustainability benefits of transportation are assessed within the sustainability triangle of the economic, social and environmental benefits as shown in figure 1. In achieving Sustainability benefits in the transport sector, it needs a strong drive towards better ease of access and mobility, efficient management of system performance, develop a defensive mechanism for the environment and improve the quality of life, advance various concepts of improving safety and security (Jeon, Amekudzi, et al., 2010).

In attaining a reasonable level of sustainability, it relies strongly on the integrated pattern of human actions, which therefore necessitates the coordination of deliberations between different actors, jurisdictions and sectors. This consequently strives to achieve consistency between the local short-term and global long-term targets. This is however different with the reductionist planning, that challenges are specifically given to an organization with narrow tasks and targets. In this regard, this kind of planning can result in solutions to a particular problem that can aggravate other problems confronting the society (Litman, 2007).

Therefore, achieving benefits in a sustainability manner in the transport sector requires a very holistic and critical dimension of integrating the necessary elements capable of consistent management of the developed process.

2.4.1 Social Benefit Sustainability Assessment in Transportation

In developing a variety of options for sustainability development, in order to achieve a better socially inclusive goal, there needs to be a synergy between related sectors and institutions having similar responsibility to pursue. These promotes the identification of different policy effects which are good for one sector but not really effective for the other, in consequence, agencies synergize their work together in a manner that will produce a comprehensive, integrated and long term solutions. Social sustainability urban transportation is described as the type of transport that integrates equitable rights which reduces social exclusion and improves the quality of life of an individual (Litman and Brenman, 2012).

Research in social sustainability comprises of social exclusion, social equity and quality of life. They are all associated with the common goal of equal distribution of the common-good benefits and challenges. Social exclusion is the outcome of individual challenges, spatial, monetary and value of life. All these, seeking to measure how these needs are adequately provided. On the other hand, equity refers to the equal distribution of resources, which may be inconsistent with the overall efficiency of the system. The social feature, common to the three aspects of social sustainability, is a challenging task for assessment by the transport organizations. The rationale for this may be due to the complexity of defining social sustainability or inadequate data to perform research that develops important information for better decision-making. Six main types of references and instruments are identified as relevant to social sustainability assessment: International Policy Frameworks, Codes of Conduct and Principles, Sustainability Reporting Frameworks, Sustainability Reporting Implementation Guidelines, Auditing and Monitoring Frameworks and Financial Indices (Barrella, 2012).

Developing indicators need the innovative use of data, as many variables can be put together into a quality life index, which helps to identify trade-offs amongst them. The experience in the United Kingdom (UK) shows how the use of conventional statistics, using socioeconomic or geographic statistics can provide a useful strategy for assessing social equity. This type of study would require census data, i.e., geopolitical boundaries, demographics, and available transportation statistics, which a Geographic Information System (GIS) could also support such analysis. The use of environmental justice and contextual sensitive solutions policies are some of the most common ways that the United States (US) agencies use to address social equity through consideration of the local context and a comprehensive public involvement process (Steg and Gifford, 2005). The Health Impact Assessment is an example of such method, which has started been put to use for transportation planning strategies both in the US and other countries. The Geographic Information System is one of the analytical tools used to assess sustainability in transportation plans (Macharis and Pekin, 2009), such as criteria selection, scenario building, healthy practices, green systems and climate support initiatives (Barrella, 2012).

2.4.2 Environmental Benefit Sustainability Assessment in Transportation

The environmental impacts of transport sustainability are geared towards attaining a reduction in local atmospheric pollution, global warming, negative impact on plants and animals, impact of waste disposal on environment, e.t.c. This over the years has given rise to developments such as technology for more efficient waste disposal methods to reduce the waste disposal effects and its use for alternative fuel to decrease dependence on non-renewable resources, also reduce pollution from the energy use of fossils. Sustainability

transport is connected to travel framework that can meet up with the transport requirements more efficiently, while also reducing the undesirable impacts and its related costs over the long term at different geographic locations (Whiteing and Stantchev, 2008).
In order to reduce carbon dioxide (CO_2) emissions from road transport, an initiative of a significant modal shift onto public transport is required. Trains and buses provide the obvious solution. This initiative also facilitates state policies like greenhouse gas budget (Barrella, 2012).

Climate change is the defining challenge of the 21st century. The Government is leading the charge internationally for global action on this key issue. It is also firmly committed to further action within the United Kingdom to reduce carbon emissions. The de-carbonisation of our transport networks will play a considerable part in meeting the challenging targets for carbon reduction. The United Kingdom's Climate Change Act 2008 is the world's first national long-term legally binding framework. It commits the Government to cut emissions by at least 80% by 2050. To ensure the United Kingdom is on a cost-effective trajectory to meet this target, the Act provides for a system of rolling, five-year carbon budgets for the United Kingdom. However, the delivery of carbon budgets will require action by businesses and individuals as well as Government, and local authorities will have an important role to play (Chapman, 2007). Investing in public transport, including light rail, can play a key part in meeting this challenge. This is why offering sustainability transport choices, at the local level is important, as short-distance, local trips are where the biggest opportunities for people to change the way they travel can be found given that two out of three journeys are under five miles. Light rail schemes in operation have contributed to the removal of car trips from overcrowded roads which have led to the reduction in the amount of pollution caused by car exhausts (Barrella, 2012).

Global warming refers to the measured increase in the Earths average temperature. This is caused by the build-up of key greenhouse gases in the atmosphere accumulated from combustion of fossil fuels and land use changes over the 20th century. The anthropogenic signal has now become increasingly evident in the climate record where the rate and magnitude of warming due to greenhouse gases is directly comparable to actual observed increases of temperature (Chapman, 2007).

2.4.3 Economic Benefit Sustainability Assessment in Transportation

A vital research aspect of transport is the ability of transport investment to advance economic growth at both the local and regional scales. The major transport benefit is been measured as travel-timesaving, other benefits exists such as employment generation and income for the government, which providing adequate measurement of these benefit has been of research importance (Banister and Berechman, 2001). How infrastructural investments advance economic development at different scales in time and space is a vital question decision maker strive to do in a logical manner.

However, policy instruments are very critical in achieving economic development gains from infrastructural ventures of the transport sector. In a democratic setting, it is important for the government to organize their process and arrange a framework, which includes policies capable of complementing other policies that will profit high economic advancement impacts from related capital investment categories.

In the contemporary world of the economics of geography, current developments have improved our understanding of how infrastructures in the transport sector have developed more markets, received profits from business, advance inter-regional amalgamation, which promotes factor markets. Achieving a balance amongst the market mechanisms and their structural processes to create a participatory economic impact, this generates a ripple effect capable of penetrating the broader economy for total factor productivity growth. Transport improvements also creates better economic mechanisms in broader urban active clusters related to spatial agglomeration gains and another connected with innovation and patent monetary benefits of new knowledge (Lakshmanan, 2011).

The economic aspect of sustainability assessment in transportation is very crucial because it provides the enabling environment for investments to meet its profit margin and maintain the system. The concept of cost benefit analysis and multicriteria analysis is very useful in this dimension, which also consequently determines the extent of funding instruments such as user-cost financing, public-private partnerships and tax (Barrella, 2012).

Economic sustainability maintains a distinction between growth (increased quantity) and development (increased quality), which focuses on social welfare outcomes rather than simply measuring material wealth, and questions common economic indicators such as gross domestic product, which measure the quality but not the quality of market activities (Litman and Burwell, 2006). Sustainability tends to show a conservation ethic, which means that production and consumption patterns are structured to minimize resource consumption and waste. This requires changing current economic policies that encourage inefficient production and consumption. Example, many countries minimize energy prices in order to keep utilities and driving affordable, and to encourage manufacturing. That reflects a consumption ethic. A conservation ethic might increase energy prices, may be through a carbon tax while implementing programmes to weatherize buildings, increase vehicle fuel efficiency, improve alternative modes, and increase industrial efficiency so that manufacturers and consumers can meet their needs with less resource consumption (Litman and Burwell, 2006).

2.5 The Role of Indicators in Assessing Sustainability Transport

The method that dictates how things are measured influences their perceived significance. A specific process or manner of approach may show the advantage part when measured in a particular manner. However, the same process may also show the disadvantage aspect when it is measured in a different way. That is why it is very important to understand the assumptions and effects of measurement varieties. Inclusive planning and sustainability development depend on measurable indicators. These indicators are of importance to planning and management. These indicators are used to develop baselines, discover trends, organize performance mandates, forecast problems and evaluate available options. The selected indicators are capable of affecting analysis outcome to a very reasonable extent. Therefore, a specific policy may rank very high during evaluation by using one set of indicators, while it may have a low result when ranked with another different set of indicators (Litman, 2007).

An indicator can be expressed as a variable chosen within a scope to measure the development towards an objective. A very important approach to measure and evaluate transport sustainability is the use of indicators. Definitions and characterization of sustainability transport systems help to define the scope of measurement using indicators. In the argument for using valid and reliable indicators for monitoring and evaluating transport, there are at least two issues to consider in identifying and using indicators for assessing the sustainability of transportation. These are validity and reliability. Validity means the accuracy with which the indicator measures the concept of interest, i.e. does accessibility and mobility through put, for example, validity represent sustainability transport.

Sustainability transport are measured by more traditional indicators (Litman, 2007), because they are more readily available, such as travel time and levels of service (LOS), and thus fall into the trap of defining the concept of interest based on what we can measure. The purpose of finding valid measurements remains a challenge. While Indicator reliability shows whether repeated measures of unchanged phenomenon using the same indicator will give us the same value (i.e. it is not affected by anything other than actual changes in what is measured). This can be influenced by our own subjectivity, if our judgement influences the indicator value, example good transportation quality and impression, which can be influenced for example by sample size, example when estimating travel demand. If we accept the idea that sustainability transportation has efficient accessibility, then a fundamental question arises; how do we measure accessibility? Despite some fifty years of history, calculating truly meaningful accessibility remains a challenge in practice. The most rigorous accessibility measures-those which capture the essence of the concept - are, naturally, complicated to implement, because they are data and computationally intensive.

However, the simpler measures, such as the infrastructure based measures (travel times/speeds etc) are biased fundamentally towards mobility (a capital drain), not accessibility parse. They are increasingly considered useful tools in the measurement and evaluation of transport sustainability performance towards established goals and objectives. Quantitative evaluation of transport activities in the major European transport indicator sets is carried out by the initiatives of the European Commission (EC) and its specialised agencies (Eurostat and European EEA) (Barrella, 2012).

In transportation, no single indicator is adequate to provide useful information for effective decision-making, therefore a set of indicators should be developed, reflecting various goals and objectives. The Vancouver principles of sustainability transportation is good a guideline for the selection and development of indicator framework to measure and assess sustainability of transport performance, which are generally reflected in most of the indicator initiatives of the Europoean Union (EU) and other international organisations (Bojković, Macura, et al., 2011).
Indicators are frequently defined as quantitative measures that can be used "to illustrate and communicate complex phenomena simply, including trends and progress over time" (EEA, 2005). During the last two decades measurement of sustainability issues by indicators has been widely used by the scientific community and policy-makers. Development of sustainability development indicators was first brought up as a political agenda issue at the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992. The UNCED policy declaration Agenda 21 requested countries at the national level and international governmental and non-governmental organizations at the international level to develop indicators in the context of improving information for decision-making (United Nations, 1992, Chapter 40). Since then, indicators are considered to be important tools for measurement of different aspects of Sustainability development, including transport related issues (Litman, 2007).

2.5.1 Criteria for selecting an Indicator

The selection of indicators are generally based on certain internationally established and commonly used quality criteria. This part of the research briefly outlines basic indicator quality criteria used by various European and other international organizations. Afterwards, quality criteria specific for transport indicators are defined. Quantitative policy targets for sustainability transport are presented as additional useful criteria for the selection of transport indicators. In general, indicator quality criteria reflected in the policy documents of the international organizations commonly state that indicators must be clear and understandable, policy relevant, accessible, and reliable and the indicator data must be accurate. Most of the organizations in the European Union and World Health organization (WHO) agree that indicators should be the representatives of selected geographical or political area (Litman and Brenman, 2012). Timeliness is an important indicator quality criterion for the EU, Eurostat, European Environmental Agency (EEA) and OECD. The EEA and the UN take into account the number of indicators as an important quality aspect. Cost efficiency of indicators plays an important role for the OECD and UN indicator selections (Litman, 2007).

The other indicator quality criteria of organizations reveal their individual differences in focus. For example, ethical value and usefulness of indicators are important criteria for the selection of WHO indicators. The EU considers balancing across different dimensions and mutual consistency within an indicator theme as important quality aspects. The EEA states that progress towards targets should be methodologically well founded and the UN organization outlines that indicators should be within the capability of national governments to develop (Litman and Burwell, 2006).

As suggested, indicators linked to transport activities should be balanced, reflecting a combination of economic, social and environmental objectives and can be applied at several levels (Litman, 2007) such as:

- Planning process - to assess planning and investment practices
- Options and incentives - to examine consumers options and markets
- Travel behaviour - to assess vehicle ownership, vehicle travel, mode split, etc.
- Ecological effects - assessing pollutant emissions, accident intensity and land degradation.
- Effects on people and the environment - to measure mortality, morbidity, environmental degradation, etc.
- Effects on economy - monetization of costs, valuation of properties and productivity
- Targets for performance - Set up a system to ascertain the level at which desired standards and mandates are achieved.

In the area of transport, as in many other fields, indicators play a useful role in highlighting problems, identifying trends, contributing to priority setting, policy formulation and evaluation and monitoring of process, in this way informing the public and decision-makers.

In addition, comprehensive criteria defining sustainability transport system may help to define the scope of indicators for measurement of transport sustainability performance and may provide with the more complete overview of various aspects of transport sector (Barrella, 2012). On the basis of Vancouver principles (Organisation for Economic Co-operation and Development, 1996) Sustainability transport can be defined by the following criteria: Access, equity, health and safety, individual responsibility, integrated planning, Pollution prevention, land and resource use, education and public participation and more comprehensive cost accounting.

2.6 Evaluating the Real Sustainability Benefits of Urban Transportation

The urban public transportation investments have increased over the years, with a common perception about its real benefits, which its quantification and assessment are still not well understood. The conventional methods of measuring these benefits are deeply rooted in the economic theory, depicting inadequacies in the perception of understanding by the local communities on the value of public transport. This necessitates the development of a new methodology to measure the social, economic and environmental effects and impacts generated by the urban transport investment projects (Barrella, 2012).

In many cities, urban rail transportation projects, i.e. the light rail, metro and tram systems over the years demonstrated itself as the optimal solution in providing mobility for the increasing urban population, considering sustainability as a core issue of relevance. This light rail also provides other benefits such as better comfort, medium-high carrying capacity, faster, more regular and safer. The light rail system is a large project that requires very high amount of investments, especially for the construction of infrastructure and maintenance costs. Investing in such a large project is far more expensive than the alternative transport mode of a new bus line, which indicates that the low financial profitability of the rail transport. Apart from the economic benefits, the social and environmental improvement benefits also derived from the rail system projects.

2.6.1 Existing Assessment Techniques for Sustainability Benefits of Urban Rail Transport

Complementarities of Methods and Instruments
Over the years, France has accumulated a wide array of methods and instruments to assist in decision-making for the sustainability development of transport. This aid consists in data analysis and trend modelling, upstream assessment of the impacts of decisions, dialogue with stakeholders and the introduction of subsidiary through contract-based policies. Presented in this order, these methods and instruments flow from the technician to the decision-maker and are generally used in both a complementary and subsidiary manner to help the decision maker reach a decision. Such subsidiary is essential, first to compensate for and revitalise hierarchical structures founded solely upon monetary criteria (analysis of returns on investment or value analysis) that cannot account for aspects to which a monetary value cannot be assigned; and secondly, to allow the decision-maker to set priorities on the basis of disparate, unrelated criteria or indicators (multi-criteria analysis, indicator-based methods) whose accumulation precludes both an integrated vision and creative synergies (May, Page, et al., 2008) .

However, in view of the growing complexity and interrelationship of the issues at stake for future generations, one of the major problems regarding sustainability development that decision-makers in France currently face is the ranking of issues in terms of their legitimacy and their economic, social and environmental relevance, both in the short term and in the long run. This need to rank is an issue of direct concern to a civil society that is currently undergoing radical change and that has no hesitation in challenging the legitimacy and not the legality of decisions, particularly those concerning transport, in cases where economic criteria take precedence over the well-being of the population and natural balances (Kenny, 2007).

In order to provide a better insight into the complementarities between approaches, methods and instruments, the following presentation progresses from the perspective of the decision-maker to that of the technician by starting with approaches to ranking and then moving on successively to partnership-based approaches, dialogue and compulsory purchase processes, preliminary assessment methods, and analytical tools (Marko, Soskolne, et al., 2004).

The measurement using the monetary value shows more objectivity than the MCA, but does not factor in the non-monetized effects, such as the social and environmental which are more difficult to monetize, making the CBA approach non-useful in the transport assessment that includes the social and environmental objectives. While the MCA assesses collectively, the objective achievement through impact quantification, which is qualitative and quantitative, this have to be in monetary values. The MCA approach for measuring the criteria has its level of subjectivity but accommodates the use of both the quantitative and qualitative indicators. Another important method is the multi-criterion decision-making method, Elimination Et Choix Traduisant la Realite (ELECTRE), developed by Bernard Roy in 1991 in an effort to solve the inadequacies of the existing decision making techniques. The ELECTRE comprises of two main concepts, namely the threshold of indifference/preference and outranking relations that seeks to develop an outranking relation using thresholds. Considering these three methods, the MCA is still a more suitable technique to assess transport investment for the benefit of sustainability development, which takes into consideration the socio-economic and environmental factors (Cascajo, 2004).

2.6.2 Comparison in the Evaluation of Methodologies in EU countries:

The ex-ante evaluation method is used as the framework to assess infrastructure, prioritizing and phasing of projects at the national level (Cascajo, 2004).

Table 1: Comparison of assessment methodology within the EU countries

Source: (Cascajo, 2004)

Country	Method of Assessment	Status	Use
Netherlands	CBA	Categorization of direct, indirect and external impacts	No measurement of non-monetizable effects
United Kingdom	CBA and EIA	Supporting evaluation	Schemes involving more than one mode
Germany	CBA and Qualitative evaluation	Evaluation divided in themes	Regional and national level
Austria	CBA and Cost-effectiveness and Open dialogue	3 aspects of criteria	Non for environmental effects
Spain	CBA and MCA	Complementary	Theoretical approach

The number of effects integrated into the assessment is variable; There is a convention in the use of CBA for the assessment of public transportation infrastructure investments, generally

an international assessment is complemented with a MCA or a qualitative procedure (Cascajo, 2004).
In table 1, the method of assessment in the Netherlands uses the cost benefit analysis, which categorizes the direct, indirect and external impacts that limits its application to measure the non-monetizable effects. The UK compliments the CBA with Environmental Impact Assessment (EIA) in order to be able to assess the non-monetizable projects. In Germany, qualitative evaluation is added to support CBA method both at the regional and national level. All these methods are used to ensure efficient implementation and later operation of infrastructural project, avoiding loss of monetary values and faulty long-term plans.

2.7 Conceptual Framework

2.7.1 The Sustainability Diamond

The understanding of trade-offs amongst criteria to be selected and finally selecting according to priority of needs in our contemporary world is an up-hill task that requires advanced methods to achieve valid and reliable results. The sustainability diamond is one of the concepts used to assess and evaluate transportation strategies, policy instruments and other alternatives that needs critical evaluation, in order to make a more productive and efficient decision.

Sustainability diamond is a compound indicator for combining many performance measures into a single rate, demonstrating the extent which every single alternative contributes to comprehensive sustainability goals. This produces an index of evaluative procedures for economic sustenance, environmental reliability, value of life, social fairness, efficient transportation structure and healthy ecological balance. This dimension is also capable of selecting the vital decision indicators for implementation, generates data for the measures, normalizes and quantifies the strategies according to their respective significance in the decision making process, identifies relevant performance strategies for each assessment criterion. The indicator points are plotted and assessed for variety of needs, which can be contextualized to suit local scenario through the development of goals and performance methods to reveal the sustainability challenges of a region.

The methodology associated with the sustainability diamond is set up to accomplish the following:

1. Categorize important sustainability challenges or mandates, related to the three aspects of sustainability, i.e. environmental, social and economic.

2. Classify critical performance methods for every goal for the basic reason of evaluating the extent that the planning scenarios accomplish the sustainability goals.

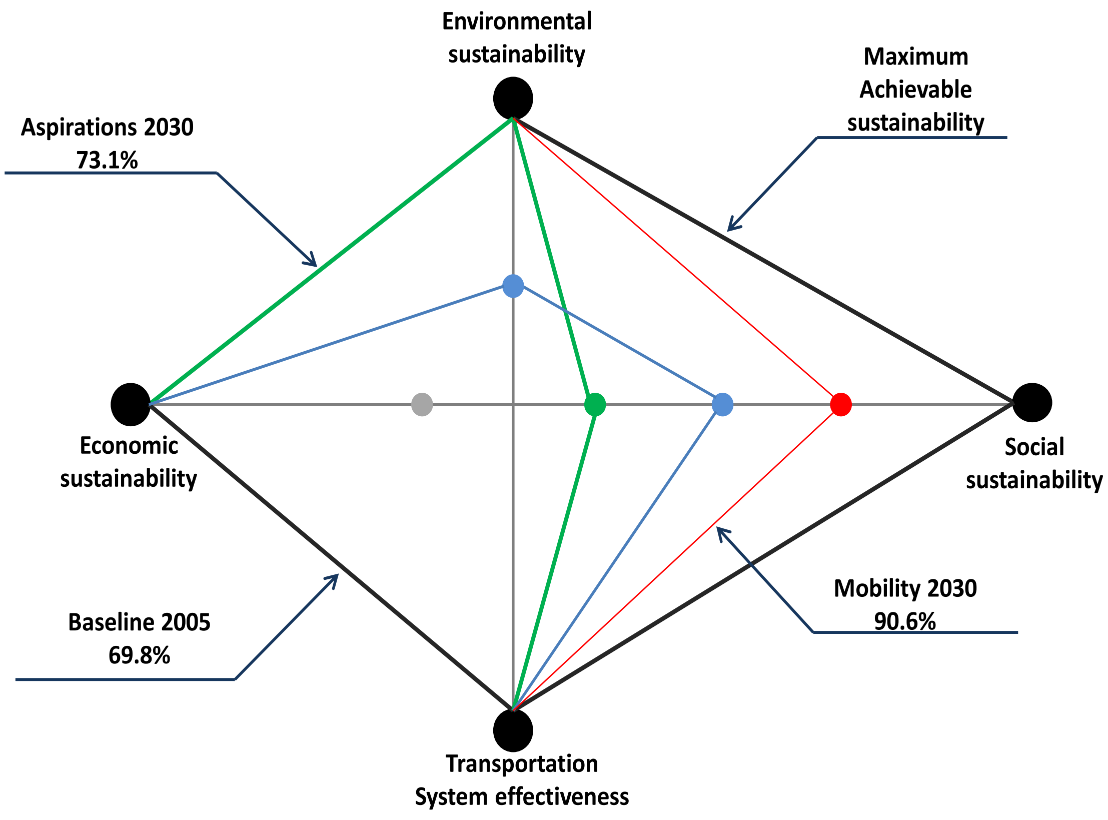
3. Evaluate and measure the effects of variety of strategies. This is achieved by allocating an index for every aspects of sustainability. Every performance indicator is allocated a value, which is divided by the highest or lowest value to generate a normalized value. As it is done when trying to achieve minimum level of pollution, the least level of pollution is divided by each value to develop normalized values.

4. Construct a composite sustainability index, characterized by significant criteria and parameter of weightings. This allocates weights to the measures that reveal the relative importance of each related mandate to city sustainability. To assign weight is a subjective method, which can follow different dimensions and requires the consensus of decision makers. Therefore, an index will equate summation of normalized value multiplied by the allocated weight. (Barrella, 2012).

5. A very important aspect of the sustainability diamond is its use for trade-offs management amongst sustainability indexes as unified development tool for choosing among multiple plan or project varieties. This shows the comparative impacts of alternative strategies on, the financial system, system performance, and social equity in order to select the prevailing choice, seen as possessing more advantage than others, based on every assessment criteria. In some cases, an alternative may be stronger than the other on environmental issues while weaker in economic terms or vice-versa depending on the scenario.

In conditions when there is no major option available, sustainability diamond assist policy-makers to have adequate understanding of the situation and also envisage trade-offs among the aspects of transport sustainability for every available preference.

Figure 1: Sustainability Diamond: Use of sustainability diamond to compare the three Atlanta area plan alternatives



Source: (Barrella, 2012).

As shown in figure 1 below, the sustainability diamond is used to compare the three Atlanta regional alternatives. The sustainability diamond in this regard was able to measure the different levels of attainment by environmental, social and economic aspects of sustainability.

Also with respect to the base line 2005, the maximum achievable sustainability, mobility and their aspirations where determined for its transportation system effectiveness

In comparison with the baseline for 2005 to aspirations 2030, economic sustainability and transportation effectiveness both had almost equal scores. However, it is pertinent to note that aspiration 2030 did much better than baseline 2005 on environmental impact, but baseline 2005 generated a higher social sustainability index (Barrella, 2012).

Table 2: Measures for Performance corresponding to each objective/ goal and sustainability dimension

Sustainability Dimension	**Goals/Objectives**	**Performance Measures**
Transportation System Effectiveness	A1. Improve Mobility A2. Improve System Performance	A11. Average freeway speed A21.Vehicle-miles travelled per capita
Environmental Sustainability	B2. Minimize Air Pollution	B21. Volatile Organic Compounds (VOC) emissions B23. Nitrous Oxide (NOx) emissions
Economic Sustainability	C1. Maximize Economic Efficiency	C12. Total time spent in traffic
Social Sustainability	D1. Maximize Equity D2. Improve Public Health	D12-1. Equity of VOC exposure D12-2. Equity of NOx exposure D21-1. Exposure to VOC emissions D21-2. Exposure to NOx emissions

Source: (Barrella, 2012)

Table 2 shows the relationship between the goals/objectives as linked to its performance measures on each of its sustainability dimension it tends to achieve over time in terms of transport system effectiveness, environmental, economic and social sustainability. For example in the transportation system effectiveness, to achieve the goal of improved mobility and system performance, the indicators to be measured for its performance are the average freeway speed and vehicle per miles travelled per capita.

Table 3: Performance Measure for Criteria

Performance Measures	Unit	Baseline 2005	Mobility 2030	Aspirations 2030
A11. Average freeway speed	miles/hour	47.12	42.21	42.21
B23. NOx emissions	ton/day	209.64	38.33	38.33
C12. Vehicle hours traveled per capita	minute/person	9.26	8.95	8.95
D12-1. Equity of VOC exposure (S)	Spatial Equity Index	19.1	23.45	23.45
D12-2. Equity of NOx exposure (S)	Spatial Equity Index	20.02	23.56	23.60
D12-3. Equity of VOC exposure (I)	Income Equity Index	10.74	55.95	427.17
D12-4. Equity of NOx exposure (I)	Income Equity Index	1354.56	54.97	364.93
D21-1. Exposure to VOC emissions	Human Impact Index	9.57	467.48	4134.47
D21-2. Exposure to NOx emissions	Human Impact Index	2269.79	318.92	2766.65

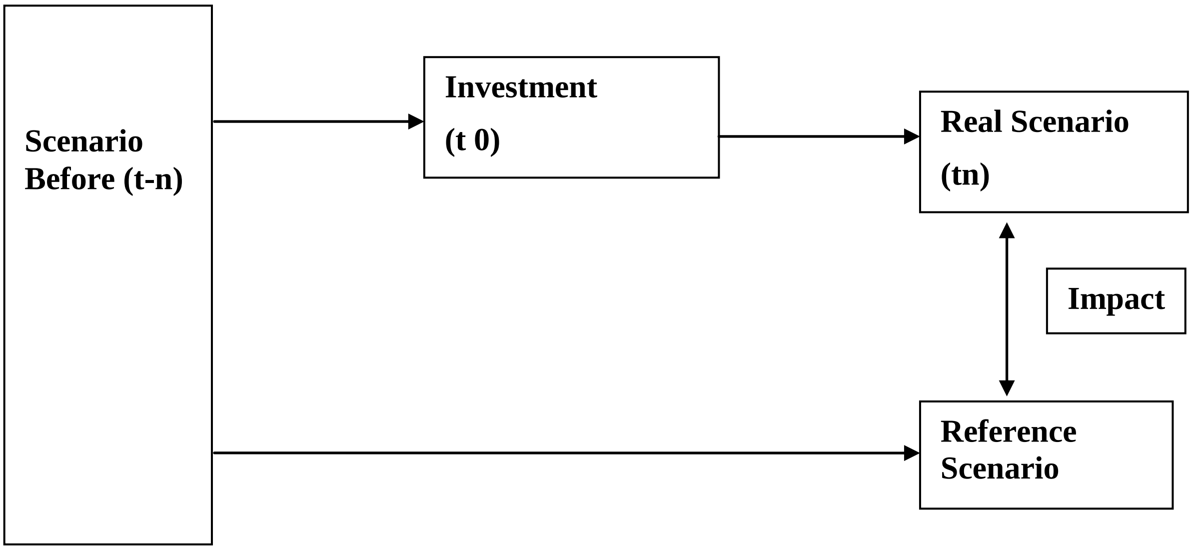
Source: (Cascajo, 2004)

In the table 3 above, the performance measures with their specific unit has a base line in the year 2005. The mobility in 2030 shows the model of what will be obtained if specific parameters of increasing or decreasing specific phenomena as a benefit. This measured result in mobility is compared to the aspirations, i.e. the extent of desired goal, in which their comparison brings about level of achievement towards set targets. As seen above some performance measures such as the exposure to VOC emissions does not meet up with the desired aspiration, while the NOx emissions was able to meet the desired aspiration of reduction in year 2030. This process is very important because it guides different actors and sectors to understand where there are challenges in meeting up with the desired targets, in a way that each actor is able to recognize where to put more efforts and in cases of already succeeding performance, methods of consistent and improved success are introduced to avoid any inadequacy.

2.7.2 Multicriteria Assessment Methodology

This approach is demonstrated also with the three aspects of sustainability development, namely environmental, social and economic benefits to be assessed. The evaluation carried out for transport investment is dependent in their comparison in different scenarios. In this method, the benefits will be evaluated by the difference between the reference scenario, i.e. scenario without the plan and the real scenario with the plan which both scenarios are referred to as the evaluation year, as shown in figure 2 below (Cascajo, 2004).

Figure 2: Evaluation Scenarios



(Cascajo, 2004)

In figure 2 above, considering the fact and taken into cognisance that a specific number of objectives are to be evaluated, each objective will be evaluated in the two scenarios by one or even more criteria, which earns a value through one related indicator. This criterion is either qualitative or quantitative, measured with a proper indicator in numeric figures to ascertain its level of impact. These defined indicators quantify the criteria and are calculated in the reference and real scenario situation, to depict the final impact of a ratio of difference between reference and real scenarios. The second level in this approach is to allocate the homogenised indicators to every criterion to represent its relative importance to the overall objective of sustainability (Cascajo, 2004). Thus, the final impact will be calculated as the weighted sum of all indicators multiplied with the weight allocated to its related criterion.

Further assessment is prepared with respect to the objective of the three aspects of sustainability development, i.e. social, economic and environmental. This will produce an overview of its contribution to global sustainability in transport developments. To do this, a set of criteria is developed and its relevant indicators to measure it as well. Table 5 shows some criteria and their indicators defined. The table depicts eleven criteria, nine of them measured by quantitative indicators, while qualitative indicators measured two, haven gone through a consultation process with some principal actors of various cities participating. In achieving this, a semi-structured questionnaire is developed and respondent's feedback coded in numeric value for assigning a final score to the qualitative indicators (Cascajo, 2004).

Table 5: Objectives, Criteria and Indicators for the overall assessment

Sub-objectives	**Criteria**	**Indicators**	**Quantitative/ Qualitative Assessment**
Economic Benefits	Reduction of travel time	Total travel time saved by the project in both, public and private transport, between the scenarios	Quantitative
	Economic Efficiency	Difference between 'Fare revenues' and 'Operation costs'	Quantitative
	Employment Generation	Additional Regional Employment	Quantitative
	Economic Growth	Economic Development Effect	Quantitative
Social Benefits	Social Equity	Quantified questionnaire responses	Qualitative
	Increase in the use of PT	Increase in public transport (PT) trips per day	Quantitative
	Urban regeneration	Urban regeneration in the vicinity of PT	Qualitative
Environmental Improvements	Air Pollution	Reduction of pollutant emissions (Tons/year of CO, SO_2, NO_x, lead, PM)	Quantitative
	Greenhouse effect	Reduction of emission of CO_2 (tons/year)	Quantitative
	Safety improvements	Reduction of accident costs per year (Euro/car-km.)	Quantitative

Source: (Cascajo, 2004)

In the table above the sub-objectives, which are in form of economic, social and environmental benefits are measured using measurable indicators with specific units to attain categories of criteria, using the qualitative and quantitative approaches. As seen above, the social equity and urban regeneration as a social benefit, has a qualitative approach, while all others have the quantitative approach.

Chapter 3: Research Approach and Techniques

3.0 Introduction

This research methodology is aimed at answering the research question; how can the sustainability benefits of the urban light rail system be assessed?

This is an experimental type of research, which starts by exploring the roles and uses of indicators in assessing the sustainability benefits of the light rail transport. This research then continues with experiments using the light rail and the road means of transport in different ways thereby quantifying the sustainability benefits of transportation of the light rail in specific and empirical terms.

This chapter describes in specific terms, the research approach and techniques, operationalization of variables and indicators, sample size and selection, validity and reliability, types of data, data collection methods and data analysis methods.

3.1 Research Methods

The research methods are the questionnaire survey and the experimental analysis. The questionnaire survey presents a set of nine indicators for prioritization by the light rail experts, allocating a rank score to each indicator. These selected nine indicators are scored for ranking based on the most significant approach, by the participatory selection of experts. This ranking of each indicator is separately under its sub division of economic, social and environmental which were selected from the already existing indicators in literature based on highest common factor, especially as it relates to its applicability in a developing country like Nigeria. Thus, the first with the highest ranked score amongst the indicators is used for the experimental analysis for quantitative assessment to empirically determine its level of contribution to sustainability. While the second ranked indicator is discussed to understand the viability of its assessment.

The experts on the light rail development are the target group for the questionnaire administration. The private experts involved in the project are the indigenous consultants employed for contract by the government to supervise the activities of the rail construction. While the other experts are related to federal government ministries such as the Ministry of Transport Authority (FCTA) and Federal Capital Development Authority (FCDA), Transport Secretariat, Department of Urban and Regional Planning, Abuja Urban Mass Transport Company and Surveying/Mapping Department.

These experts were selected for the participatory indicator selection because of their relationship with this light rail infrastructural development as one of the major working group. Their knowledge and experience during the planning and implementation is useful in administering the questionnaire, scoring the indicators, thereby giving them ranks.

3.2 Sample Size and Selection

The selected sample size for the experts is 62. The type of sampling used is the stratified random sampling. This sample size was initially meant to be 60, but 62 respondents ended up filling the questionnaire out of the 85 copies distributed due to the fear of limited return rate in past research.

Out of the total 62 questionnaire's that was administered, 61% (38 respondents) are the engineer's (civil, mechanical and electrical/electronic engineers) working on a daily routine at the rail sites. The urban planners are 20% (12 respondents) involved in the planning of the light rail with regards to the city. Railway administrators are 8% (5 respondents), who are in top railway administrative positions as decision makers, such as directors and head of departments. Land surveyor are 5% (3 respondents) working as indigenous consultants on the rail project. Environmentalist are 3% (2 respondents), into the earth works related to the project and the transport planners are 3% (2 respondents) working as indigenous staff. Each expert within these stakeholders has a very high level of understanding concerning the recent developments on the urban light rail.

These chosen 62 respondents within these different but interlinked experts were selected because each of the questionnaires administered is done under an organization that has a common goal and objective, i.e. mandate as a purpose to achieve that, which is directly related to their important roles in the light rail mass transportation project. This selection is also because it is mainly the technical and top ranking officials of the related organizations in Nigeria that are involved in such technical oriented infrastructural projects. These technical staff directly involved with a specific project at a time is usually not more than 15 to 30 in each organization, who have the technical information on the existing project, therefore it necessitates the selection method to rank the criteria and their respective indicators according to its importance.

It is recommended in the literature that selecting the most appropriate individuals can also be achieved through nomination process within each stakeholder organization (Sandford, 2007). The top ranking technical officers also nominated some of their technical staff known to them, working on the light rail project to respond to the questionnaires.

3.3 Validity and Reliability

3.3.1 Validity

The instruments for use in this research will measure the required indicators, aiming to empirically assess their sustainability benefits, because the instruments are geared directly towards answering specific requirements that eventually leads to adequate measurement of the indicators to answer the research question in concrete and specific terms.

3.3.2 Reliability

The extent, to which the instruments for measuring the indicators, such as the questionnaire, excel software for descriptive statistics and GIS in this research will produce the same result on repeated trials, is reliable. This generates stability of scores overtime or across raters.

3.4 Operationalization of variables and indicators

Nine variables and their indicators were selected for ranking. While two out of these nine indicators with the highest rank score is operationalized and measured in order to quantify their sustainability benefits. Two of out of nine were selected because there the most important as ranked by the experts and due to time constraint all the indicators cannot be ranked at the same time within the specified period. The experiment is performed on the first indicator, while the second indicator is discussed to understand its viability in assessment.

These nine indicators and their variables are as follows:

Table 6: Operationalization of variables and indicators

SN	Variables	Indicators	Instrument of Measurement for Analysis
Economic Sustainability			
1	Reduction of travel time	Total travel time saved in between scenarios by the project in both the public and private transport	Geographical Information System (GIS) and simple calculus
2	Employment Generation	Additional city employment	Scenario modelling and simple calculus using with and without situations of the light rail
3	Transport fare affordability	Difference between the proposed rail fare and present vehicle transport fare	Scenario modelling and simple calculus using the rail transit access fee as compared to the vehicle road transport
Social Sustainability			
4	Increase in the use of mass transport (modal shift)	Increase in public transport trips per day, based on better timing and periods of availability	Scenario modelling and simple calculus using with and without situations of the light rail
5	Proximity of settlements to rail stations	Accessibility without extra cost	GIS for Spatial Analysis
6	Reduction in road congestions	Better time management and ease flow of traffic during transit due to reduction in vehicle use on roads (modal shift)	Scenario modelling and simple calculus using with and without situations of the light rail
7	Safety improvements	Reduction of accidents per year and death rate from vehicle accidents	Scenario modelling and simple calculus using with and without situations of the light rail
Environmental Sustainability			
8	Urban regeneration	Urban regeneration in the vicinity of light rail transport	GIS for Spatial Analysis for land use changes
9	Air Pollution affecting air quality	Pollutant emissions reduction in CO, SO2, NOx, lead, PM per tons/year of reduced vehicles compared to pollutant emitted by the light rail.	Scenario modelling for level of diesel fuel consumption per cycle, per day to be used and pollutant emissions expected.

3.5 Data Collection Methods

The sources of data for this research are the primary and secondary data.

3.5.1 Secondary data

1. Most significant sustainability indicators from literature review.
2. Feasibility study report of conceptual design of lots 1, 2 and 3 by the of the Abuja Mass Transit System.

3.5.2 Primary data

1. Questionnaire response from experts.
2. NigeriaSat-X satellite imagery of 22m resolution (November 2011) covering the Federal Capital Territory (FCT) and Quick-bird satellite imagery of 0.65 resolution (2006) covering phase one of Federal Capital City. This shows all the spatial coverage of the rail corridor.
3. Line data for roads in Abuja.
4. Geographic positioning systems (GPS) location of rail stations and ground control points (GCP).

Table 7: Sources of data and their respective collection methods in summary

SN	**Data**	**Collection Methods**
1	Sustainability Indicators	Review of relevant literature related to urban light rail transport assessment using sustainability indicators
2	Conceptual design of lots 1, 2 and 3	Data base creation by vector data extraction using digitization from the feasibility study report
3	Ranking of specified indicators	Questionnaire response for indicator scoring by experts
4	NigeriaSat-X satellite imagery of 22m resolution and Quick-bird satellite imagery of 0.65m resolution	Satellite image interpretation and groundthruting
5	Line data for roads	Vector data extraction of road line features by digitizing from the high resolution quick-bird image
6	Location of rail stations	GPS location of point data for rail stop stations

The data collection methods in the table above are further explained in details as follows:

A Ranking of Indicators

The sixty-two experts scored the nine selected indicators in order to rank, using the most significant approach. This scoring matrix produced the data to be used for analysis.

B Satellite Image Interpretation

The line features such as the lot 1, 2, 3-rail line and roads are interpreted and extracted by digitizing. The point data such as the rail stations, settlements and airport are also interpreted and extracted by digitizing. Digitization is the act of extracting an interpreted feature into a line, point or polygon. Lines represent line features like roads and rail lines, points represents features like rail stations and polygon represents features like an area of settlement, districts or cadastral layouts.

C Ground-truthing

The GPS points of rail line lot 3A was acquired on ground and plotted on the image as longitude (X) and latitude (Y) to ground-truth (confirm) the position of the acquired points on the satellite imagery. The GPS points collected for the purpose of ground truthing are:

Table 4: GPS points for Ground control purpose obtained on ground

SN	Point	GPS Reading
1	Ring road two	N 09.03077° E 007.42278°
2	National Park Rail Station	N09.04043° E 007.44143 °
3	Rail track behind Stadium	N09.04356° E007.44626°
4	Pedestrian bridge after ring road two	N09.03729° E007.43612°

Photograph 1: GPS point acquired at Ring Road Two

The 2D differental Garmin GPS used to acquire the point at the ring road two rail station on the 14th July 2013, at 1:52 pm, reading N 09.03077° E 007.42278° as seen on the GPS and as shown in the table above. This point is used as one the ground control points for geo-referencing the rail track master plan to the correct referencing in positioning the rail track map and image map to its precise location with respect to the world.

D Database creation

The data are spatially created to its specific referenced location and their attributes are generated as a database that can be queried and spatially analyzed and saved in the GIS analysis environment (ArcGIS9.3) software.

The database created are distances from different rail stations, measured using the ArcGIS measuring tool in order to assess its extent of benefit for timesaving for 100km/hour, while compared to the road vehicle at 75km/hour, at different scenarios by settlement of living of some respondents, peak and off-peak periods, head way time and rail stoppage time.

3.6 Data Analysis Methods

3.6.1 Descriptive Statistics Analysis from Questionnaire results

The data collected from the questionnaire is analysed first of all by using the excel descriptive statistics software to generate the bar chart, representing the differences in the ranked scores of the indicators according to the most significant.

The excel descriptive statistics is also used to generate a pie chart representing the percentage participation of the experts who administered the questionnaire. The information gathered from the questionnaire is based on figures to rank scores regarding the economic, social and environmental sustainability as listed in table 6 above.

3.6.2 Geospatial Analysis from Satellite Imagery and Light Rail Master Plan

The satellite imagery showing the spatial coverage of the rail corridor settlements and the whole study area is acquired and used to extract relevant features such as roads, lot 1, 2 and 3 of the rail line corridors, rail station points and settlements with over lay analysis before further analysis is carried out.

Data processing is a vital step to geo-spatial analysis, in this case, the satellite imagery is geo-referenced using the acquired Ground Control Points (GCP's) of already geo-referenced image of the same study area and confirmed with the four GCP's acquired with the GPS during fieldwork. The geo-referencing is the first important stage that ensures that the area of interest (AOI) is accurately referenced (registered) to its proper position with respect to the world, which also ensures that all positions of features extracted from the satellite imagery are in their accurate positions to avoid over or under shoot errors. The AOI is spatially geo-referenced to the projected coordinate system of WGS-84, Universal Transverse Mercator (UTM) zone 32 north. The data are spatially created to its specific referenced location and their attributes are generated as a database that can be queried and spatially analyzed and saved in the GIS environment (ArcGIS9.3) software.

Thus, after data processing, the travel time data analysis is done by measuring the rail distances along rail lots 1A, 3A and 3B. The road route linking the rail lots to their respective interchange station from one another are also measured using the ArcGIS measuring tool for further analysis.

Figure 2: Summary of methodology

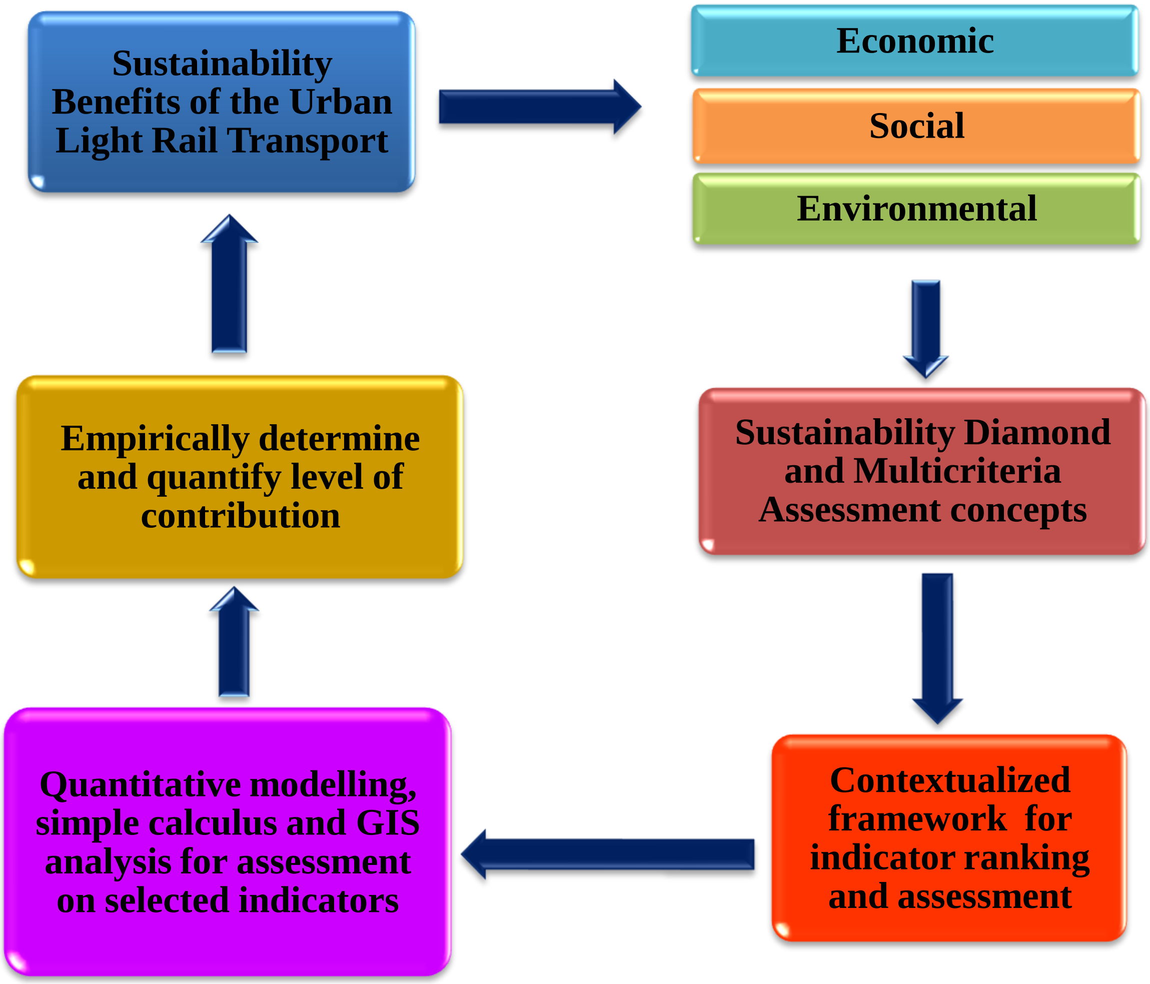


Figure two above shows the summary of methodology. The application of a new methodology as an instrument for measuring the indicators and operationalize the variables, have led to the specific collection of the primary and secondary data which also uses the data analysis method of the geo-information system for spatial analysis. The Sustainability benefits of the light rail were identified in the economic, social and environmental sustainability. These were viewed under the sustainability diamond analysis concept, which evaluates and compares project alternatives in various sustainability parameters and transportation strategies. The sustainability diamond and multi criteria concepts are being used to merge many performance measures into one value, capable of demonstrating how better each alternative performs in contributing to the local, national and international sustainability goals. In this thesis, the sustainability diamond and multicriteria assessment are used to bring together various sustainability benefit criteria and their respective measuring indicators to measure in empirical terms their rate of contribution to sustainability development. The sustainability concept that is further contextualized into a framework that ranks the indicators based on their perceived importance by experts, as a sustainability benefit to the country by the light-rail transport infrastructure. The quantitative modelling, simple calculus and Geographic Information System (GIS) are used for the analysis of assessment for the selected indicators, to empirically determine the level of contribution to the sustainability benefits of the Urban Light Rail Transportation.

Chapter 4: Research Findings

4.0 Introduction

In this chapter, the concepts in the conceptual framework of the sustainability diamond and multicriteria that is concerned with selecting the best alternative criteria, based on how high or low it is been measured or rated with a related indicator. This framework is further contextualized to develop an approach that uses certain measurable indicators that are useful in assessing the sustainability benefit of the Abuja urban light rail system. Thus, the sustainability benefit of the travel timesaving is used to develop different scenarios about the rail travel time and the road use travel time. The analysis carried out in these scenarios clearly shows valid and provable results of the extent of benefit the travel timesaving has added to the sustainability benefit.

The characteristics of the base line study area of the capital city are first explained in reasonable details, especially as it relates to transportation. This is followed by the results of ranking the indicators by the respondents and the outcomes of the results are shown. Contributions to the study by the respondents through the questionnaire are also presented and explained. The results generated with excel statistical tool and GIS is depicted and explained. The results of finding on the most ranked indicator and how it can be assessed is presented and explained in details.

4.1 Federal Capital Territory Abuja

The Abuja Federal Capital City (FCC) is located at the heart of Nigeria on Latitude 9° 12' North, Longitude 7° 11' East of the Equator. It has population of about 1.5 million (National Population Commission, 2006). The development of Abuja is divided into 3 Phases for an orderly and coordinated development. At present, the city growth has reached Phase 3, though the phase 1 and 2 are not yet fully developed. The Phase 1 of the city is where the population is concentrated and the actions of urban managers are most required. The FCC Phase 1 comprises of five (5) districts (Central area, Garki, Wuse, Maitama, and Asokoro) (National Space Research and Development Agency Nigeria, 2012) .

The FCT falls within the Savannah zone vegetation of the West African sub-region with patches of rain forest around the Gwagwa plains. These areas of the FCT form one of the surviving mature forest vegetation in Nigeria. Abuja in particular and the Federal Capital Territory in general have experienced a huge population growth. It has been reported that some areas around Abuja have been growing at 20 – 30% from the 2006 population census.

Abuja is one of the fastest growing cities in the sub-Saharan Africa. The city lacks the modern infrastructural management techniques required for an effective management of a modern city. Cities of the developed world are managed with the intelligence provided by geospatial information using Geographic Information Systems (GIS) and Remote Sensing (RS) as tools and benefits from advances made in this field in the last four decades particularly since the availability of very high resolution images provided by the new generation satellites – Nigeria-Sat- 2 and X, Quick-Bird, IKONOS (Agbaje, Adepoju, et al., 2008) etc.

The creation of Abuja was guided by a master plan that set out the design of the city to meet a fast growing population and to ensure that Abuja would provide leadership to Nigeria in many different ways, such as proper planning and provision of basic infrastructures. The layout of the city was specifically designed to accommodate mass transit infrastructures.

Although most elements of the master plan have been implemented and although most of the intentions and dreams of the founders of Abuja have been realized, the city lacks a mass transit system capable of reducing congestion on roads, providing affordable transportation and re-engineering the whole city business and architecture through mass transit infrastructure.
Abuja is a very young city. The city was planned in the late 1970s and is one of the few cities in the world that was completely planned prior to construction and planned specifically to be a national capital. It was planned after the construction of Brasilia and Canberra, the capitals of Brazil and Australia respectively; indeed, the designs of those two cities gave both inspiration and "lessons learned" to the designers of Abuja.

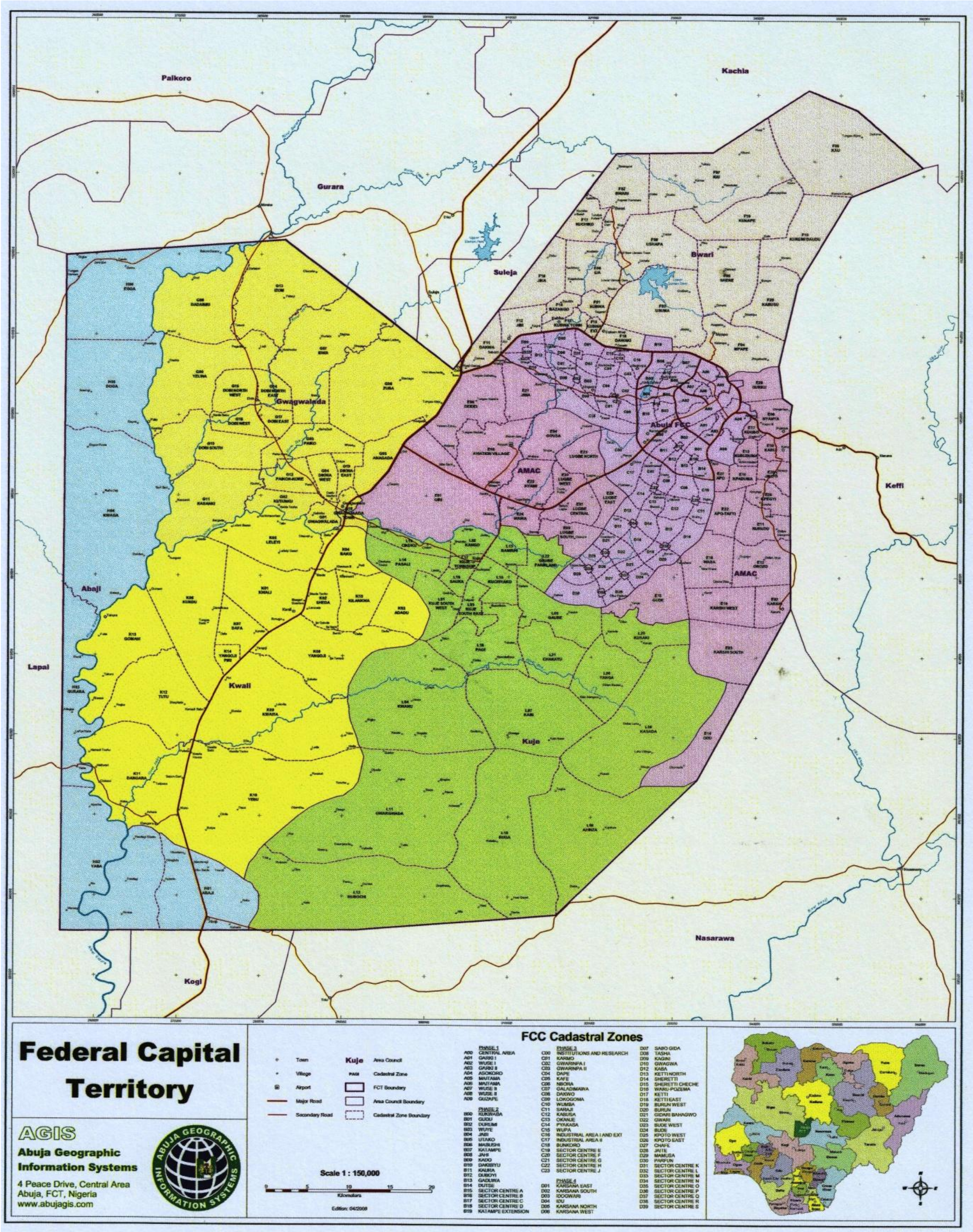
The design concept of Abuja is a linear form, curved roughly into a crescent shape. The linear plan is evident here, as it is the fact that this city was planned with urban transit top of mind. The proposed transit ways runs through approximately 19 community sites; private vehicular traffic was not intended for these routes. The rectangle at the city centre is the main government/embassy/ministry district. The community sites are separated by a linear park, which is bisected by a parkway, intended for mixed vehicle (motorized) traffic. The city has been built quite faithfully to the original plan; however, there are several exceptions to that statement. The city was originally planned for a maximum population of 1.6 million but the population is now expected to be much larger. The proposed transit system has not yet been implemented, which means people working in the city must find their way to work by private vehicles or informal buses and motorcycles (CPCS Transcom Limited, 2009).

Map 1: Administrative Map of Nigeria showing the location of Abuja at the center in red colour as FCT

Source: National Space Research and Development Agency (NASRDA), 2013

Map 1 shows the administrative map of the country Nigeria, with the study area, Abuja FCT located right in the center of the country in red colour. The administrative map of Nigeria as a country shows 36 states and Abuja, the Federal capital territory. Thus Abuja, been in the center serves as an equidistance location to most states of the federation.

Map 2: Administrative Map of Federal Capital Territory Abuja



Source: Abuja Geographic Information Systems (AGIS), 2013

Map 2 shows the administrative map of Abuja as the Federal Capital Territory (FCT), the Federal Capital City (FCC) and its cadastral zones and the area councils. While the specific study area comprises of the Abuja Municipal Area Councils (AMAC) and Abuja FCC which consists of FCC phase 1, 2 3 and 4 all in purple colour polygons. These areas consisting of the FCC are the most developed urban areas in the city. This is because the concentration of government activities is predominantly there, therefore given rise to more infrastructural developments and built-up areas. This area has continued to expand very fast, given rise to high cost of rent, leading to people living in the suburbs but working inside the FCC.

Image Map 1: Federal Capital Territory Abuja Showing Study Area and settlements on the Nigeria Sat-X Image

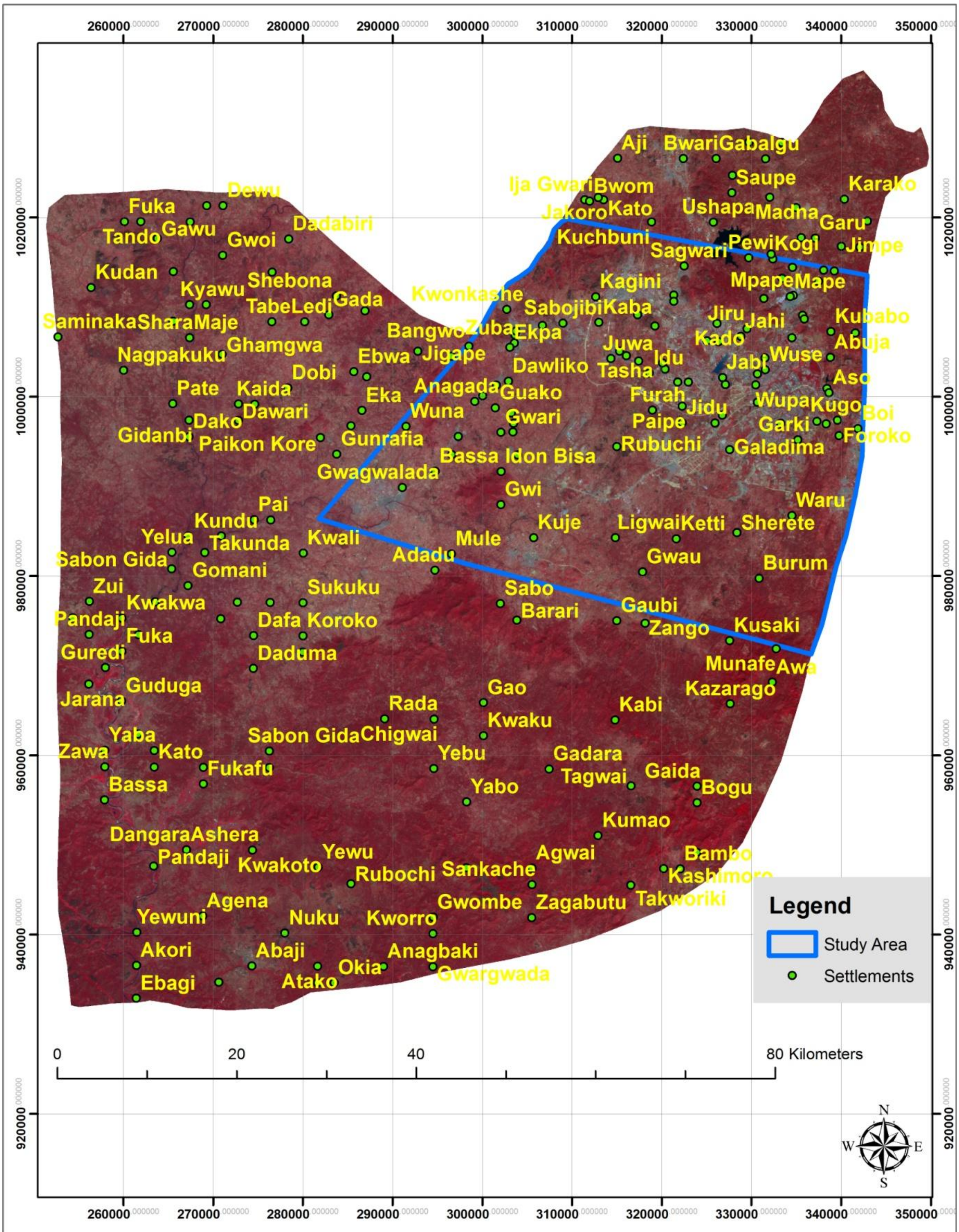


Image Source: NASRDA, 2011

The image (22m resolution Nigeria-Sat X) of Abuja above shows the specific study area at the top right hand corner within the blue polygon as the study area. Within this blue polygon lies the most built-up part of the FCT, which explains the reason why it is the Federal Capital City (FCC) within the FCT, possessing most of the large infrastructures and settlements (urban and built up areas), as seen with more concentration of settlements than other parts of the Federal Capital Territory. The red, blue and green of band 1,2 and 3 respectively means that the image is reflecting with this colours (spectral signatures), depicting different features with different colours including black.

4.2 Abuja Light Rail Visibility Plan for Baseline Study

The visibility study plan provided some baseline information, figures and benchmark statistics, which were used as a baseline during the scenario building process.

4.2.1 Demand for Transit Services

The initial demand study and demand modeling exercise were undertaken for the Abuja MTS project in late 2006 and early 2007, in order to determine the likely ridership of Lots 1, 2 and 3 of the MTS, at inception and 20 years in the future, as well as the appropriate fare levels.
The demand estimates are based on the population estimates/projections, household survey that gathered a sample size of 2,657 households in the Abuja region that include the information concerning 5,888 persons and 8,055 rips frequently made by these persons, traffic data analysis. The initial demand study presented in the above-mentioned Working Paper was carried out based on the initial transit way alignments as outlined in the Abuja Master Plan. Since then, a number of changes have taken place on the alignments, and the demand projections have been adjusted appropriately.

Based on the anticipated travel demand and assuming that 40% of the peak period passengers travel in the peak hour, 20,650 passengers will use lot 1A and 1B corridor in one hour. Six-car, 1,800 passenger capacity trains are required to run every five minutes for Sector Centre M to Sector Centre C. 6,300 passengers will use the Kubwa to Junction Station corridor and a train every 15 minutes is required. Using the round trip times identified above, the total number of trains required is 17 for Gwagwa to Sector Centre C and 3 for Kubwa to Junction. In lot 3A and 3B, based on the anticipated demand, 5,000 passengers will use this corridor in the peak hour, therefore six car, 1,800 passenger capacity trains are required to run every 20 minutes and using the round trip time identified above, four trains are required for this section (CPCS Transcom Limited, 2009).

4.2.1 Service Demand

The initial travel demand analysis as documented in the working paper on demand for transit services was carried out based on initial transit way alignments as outlined in the Abuja master plan. The study of opportunities to integrate the proposed alignments with the existing and future development proposals for road infrastructure identified a number of changes that were required to the previously identified alignments. It is important to note that the development potential in and adjacent to the proposed transit ways remain unchanged from that identified when the initial analysis of travel demand was undertaken. However, the current transit alignment(s) in addition to shifting LOT 1A further to the northwest also included the extension of LOT 2 to connect with LOT 1A.

The travel demand trip matrices previously established for the base year (2010) and planning horizon (2030) remain unchanged and are based on the previously identified growth projections. These trip matrices reflect the projected distribution and pattern of development within Abuja as well as the impact of future growth projections of neighbouring satellite towns (CPCS Transcom Limited, 2009).

4.2.2 Real Estate Revenue Potential

It has been well established internationally that the development of mass transit corridors encourages commercial development, particularly in the vicinity of stations. Some transit operators have integrated commercial development into their overall business strategy. The most notable example is the Hong Kong Mass Rapid Transit System, where almost one-third of total revenues are generated from this source. Other revenue sources include commercial development initiatives such as leases to small businesses and advertising in stations. In the case of AMT, it is recommended that the operator be granted access to exploit opportunities within stations. This may include concessions to food operators and other vendors, as well as advertising. The Abuja MTS Financial Model assumes that the operator generates revenue from these sources in an amount equal to 6% of annual passenger revenues. This is consistent with mass transit operations in other parts of the developed and developing world. For this assumption to be realistic however, the FCTA must grant the concessionaire the right to develop, exploit and collect revenues for these real estate ventures. The actual degree to which commercial development within stations occurs will depend on the creativity of bidders and the flexibility of the Government to provide property rights. All other real estate should be developed by entities other than the concessionaire and revenue should accrue to the Government. Specifically the Government has the ability to earn ongoing revenues from its real estate portfolio around proposed Abuja MTS stations (CPCS Transcom Limited, 2009).

4.3 Conceptual Design of the Light rail

In order to meet the demand and train frequency, the built infrastructure should be constructed to the following standards and the trains provided by the operating concessionaire should meet the minimum performance criteria,. As demand increases more trains or longer trains may be required and the headways will be decreased to provide additional service. The maximum capacity of the system is defined by the signaling system and the performance of the trains. The proposed minimum headway for the system is five minutes. Other conceptual parameter relevant to this researh are as follows:

- Design Speed – 100 km/hr
- Minimum Radius – 700 metres with an absolute minimum of 400m in exceptional cases
- Formation shall be designed to accommodate 2 parallel tracks with 100 km/hr design speed.
- Communication, Signals and Power Supply shall be as per the National Railway Contract with a minimum headway of 5 minutes.
- On-line Station: This type of station will have commuter rail platforms only, passengers walking to, bicycling to or being dropped off at the station by private vehicle. Minor provisions for transfers to or from buses or other transit services may be provided. This will typically happen on the adjacent local road rather than within the Transit way corridor.

- Bus Transfer Station: This type of station will typically have all of the features of the online station in addition to dedicated facilities for passengers to transfer to buses or other transit services. These additional facilities will include one or more passenger platforms for bus passenger boarding and alighting.
- Rail Transfer Station: This type of station will provide facilities for passengers to transfer between two or more rail services. It will also likely incorporate all of the facilities provided by the other two station types.

4.4 Benefits to Abuja of Investing In Public Transport Through Integrated Network And Service Planning

The result of Abuja's population and employment growth, changing demographics and land use patterns is that travel growth continues to outstrip population growth. This means more cars, more drivers, more congestion, longer travel times and overcrowding on some public transport services. Public transport investments will have a vital part to play in addressing these challenges to protect Abuja's lifestyle.

Some of the benefits of Abuja investing in an integrated transport network are:

Efficient public transport

- Deliver fast, frequent and reliable services and good quality infrastructure, making it easier to get to more destinations; and making public transport easier to use and understand

Greater accessibility:

- Provide fair, equitable and safe public transport to enable people to access the places, goods and services they need.
- Providing mobility to people who have no other form of transportation.
- Meeting minimum standards for service coverage, frequency and operating hours across all urban areas.
- Making destinations more accessible, including Abuja itself, satellite townships, key activity centers (such as major sporting venues) and local shops.

Supporting the economy:

- Connecting people to goods and services and places of employment, education and training.
- Moving large numbers of people more efficiently and effectively to key centres and employment nodes.
- Reducing car use and congestion, which can reduce business costs.
- Creating jobs in infrastructure provision and ongoing service delivery.

More efficient use of resources:

- Making trains, buses and para-transit work together to provide efficient and cost effective access to more destinations.
- Restructuring and consolidating services in key areas to reduce overlap between services and operators.
- Making the transport system more efficient by getting more people to catch public transport to major destinations rather than drive.
- Achieving significant gains in patronage, which can defer the demand for road funding.

Fewer car trips, less congestion and less time spent in traffic:

- Providing quality public transport that attracts people out of their cars, resulting in less vehicle travel overall, fewer trips by car and less congestion.

Lower energy consumption, air pollution, greenhouse gases and noise

- Reducing car use and congestion, which can reduce non-renewable resource consumption and emissions of noise, air pollutants and greenhouse gases.

Less urban space taken by transport

Encouraging more people to catch public transport because it can move more people, in fewer vehicles and less space; and Reducing Abuja's reliance on cars, which can free up valuable road space, delay the need to construct new roads, and reduce the space needed for car parking.

Improved community health

- Reducing car use and congestion, which can reduce air pollution and its impacts on human health.
- Reducing car use, which can reduce accidents and improve road safety.

Better growth management and land use outcomes

- Supporting the preferred pattern of Abuja's development by making the region's major destinations more accessible.
- Providing quality infrastructure and services to encourage land use decisions that support good public transport outcomes.

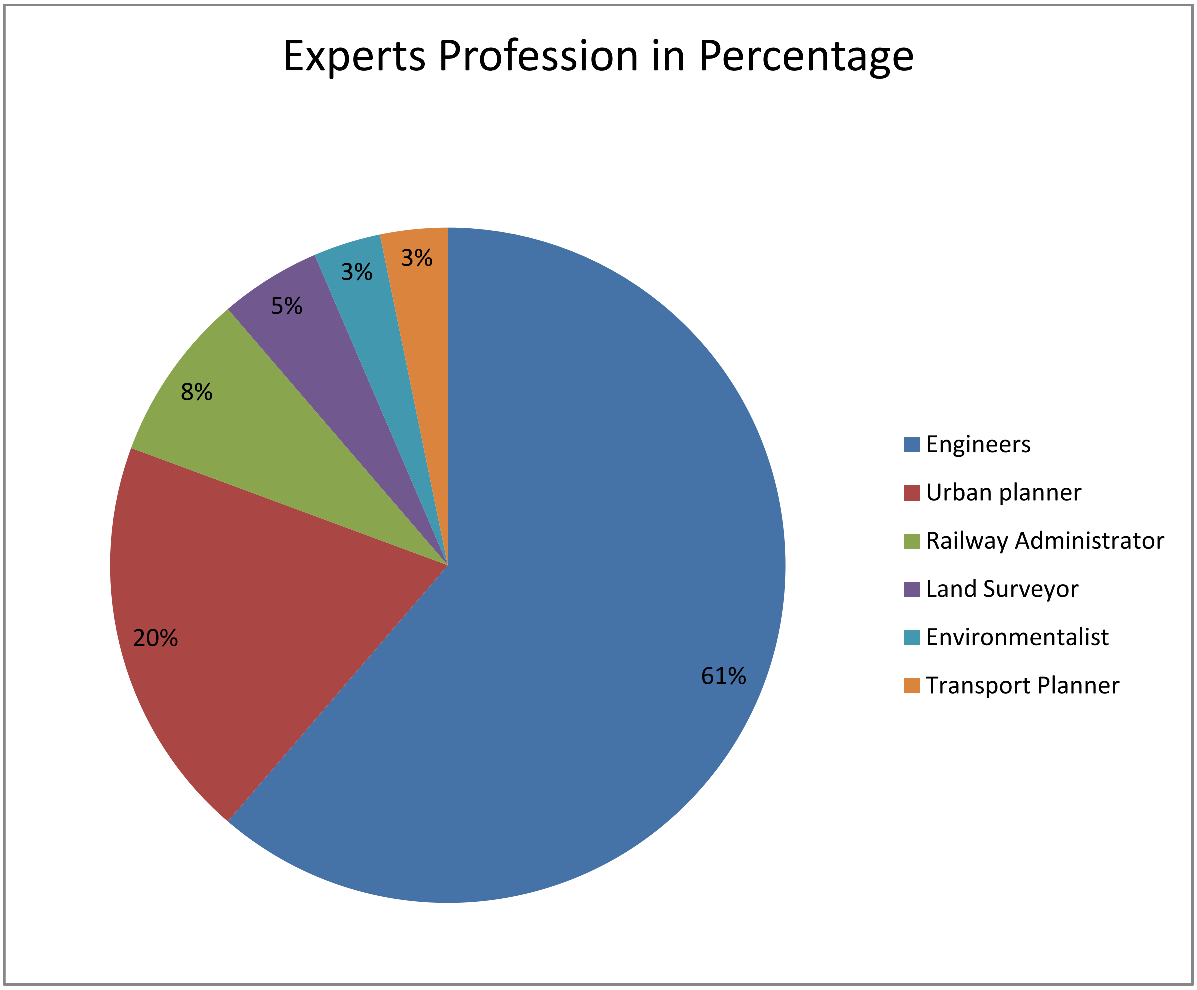
4.5 Rankings for Economic, Social and Environmental Sustainability Indicators by Respondents

Percentage of Respondents per Profession

The nine indicators were ranked by the sixty-two respondents, which produced the summary in table 5 below. As seen in chart 1, from the 62 respondents that were administered, three percent were environmentalists and transport planners respectively, five percent are land surveyors, eight percent are railway administrators, twenty percent are urban planners and the larger part by sixty-one percent are engineers.

Photograph 2: Myself and some of the engineers as experts who responded to the questionnaire

Chart 1: Pie Chart showing the percentage of 62 expert's profession as respondents

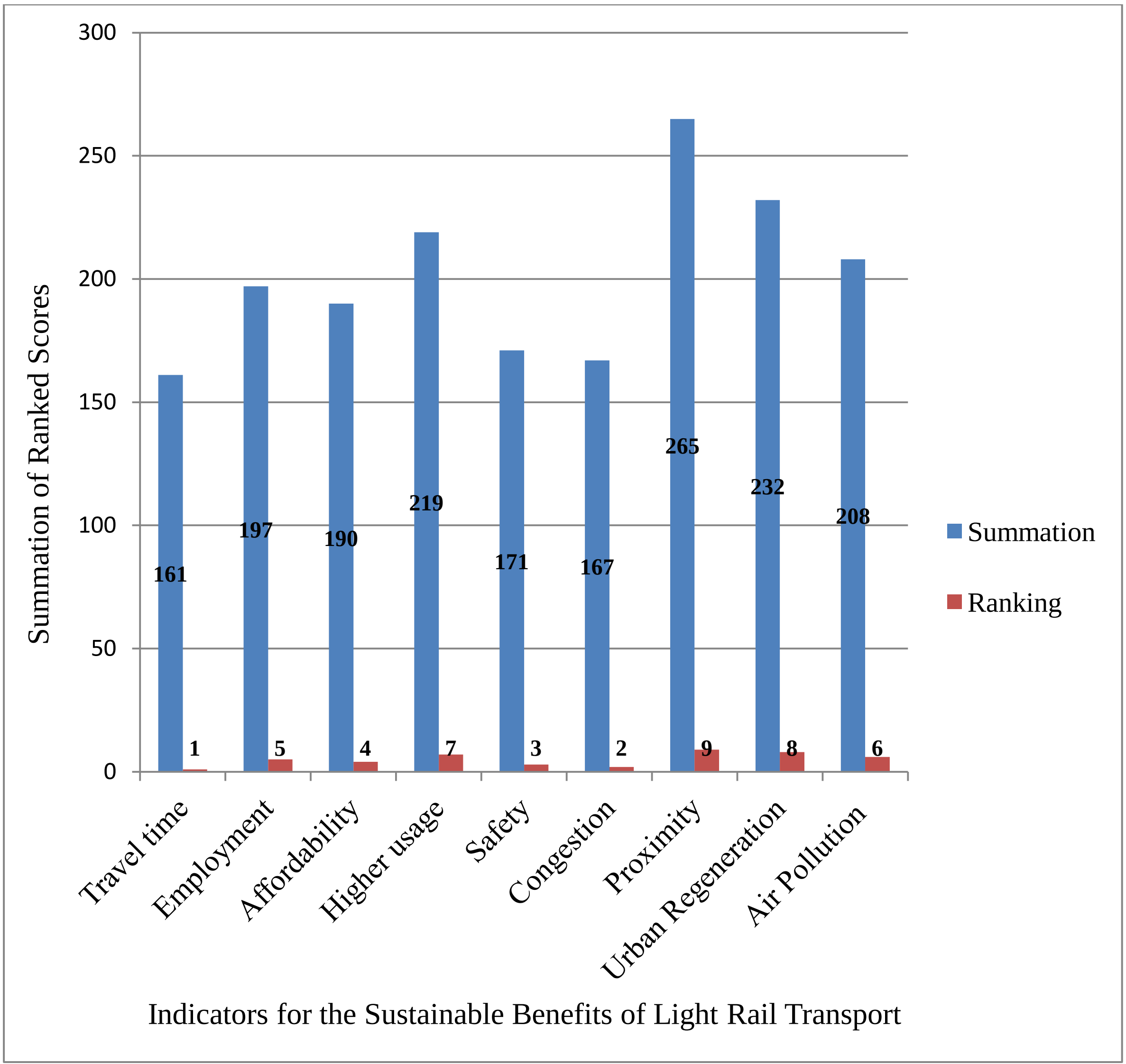


The table 5 below shows that travel time as an economic sustainability indicator and congestion as a social sustainability indicator are the first and second most ranked score. Therefore based on the ranking of travel time and congestion as the most ranked indicator respectively, this research will be based on the experimental approach assessment of the travel time and discussion on the viability of assessing the congestion indicator for sustainability benefits of the urban light rail.

Table 5: Summary of the nine indicators, the total sum of the scores and their rank scores with the 1st, 2nd, up to the 9th position

	Travel Time	Employ ment	Afford ability	Modal Shift	Safety	Cong estion	Proxi mity	Urban Regene-ration	Air Pollu tion
Summ ation	161	197	190	219	171	167	265	232	208
Rank Score	1	5	4	7	3	2	9	8	6

Chart 2: Summation and rank scores for nine indicators



Note: The lower the summation of a rank score, the higher the rank position, e.g. 161 has the lowest summation, due to addition of numbers one and it is highest ranking position as 1st.

In chart 2 above, travel time (timesaving) took the 1st rank position as the indicator with the most ranked figures of the minimum summation of scores, i.e. all addition of number one equals 161 and congestion is the 2nd rank position with 167 summation of its scores. Safety indicator is 3rd position with 171 summation of ranked scores, affordability is 4th position with 190 summation, employment generation is 5th position with 197 summation scores, reduction in air-pollution is 6th with 208 summation of scores, 7th position with 219 summation of scores, urban regeneration is 8th position with 232 summation of scores and proximity as the 9th position with 265 summation scores.

Therefore, it implies that most of the respondents believe and chose travel timesaving as their first choice by ranking it as one in the questionnaires and reduction in congestion as their second ranked choice to sustainability benefit of the Abuja light rail. While the least of them chose proximity from the settlements to the nearest rail station. These rankings as first and second for the travel timesaving and reduction in congestion are the two indicators that will form the basis for the rest of the research.

Table 6: The two of the nine indicators with the highest rank score were selected and defined in a tabular format, showing its variable and instrument of measurement

SN	Variables	Indicators	Instrument of measurement
1	Reduction in travel time	Total travel time saved by the project in both, public and private transport, between both scenarios	Geographical Information System (GIS) and simple calculus
2	Reduction in road congestion	Better time management and ease flow of traffic during transit due to reduction in vehicle use on roads (modal shift)	Scenario modelling and simple calculus using with and without situations of the light rail

The first most ranked indicator therefore qualifies for assessment and the second for discussion on viability of assessment, since all the indicators cannot be assessed due to limited research period and there is a need to know and understand the most important indicators.

4.5 Assessing the Sustainability benefit of total travel time saved by the light rail as compared to road vehicle transport scenarios

The design speed of the light rail is 100km/hour (CPCS Transcom Limited, 2009) therefore the travel time of the light rail is compared with the travel time of the road vehicle at 75km/hour, at peak and off-peak periods for lots 1A, 3A and 3B and the road along the same routes.

Table 7: The key operating assumptions are as follows:

Source: Feasibility Study and Conceptual Design, CPCS Transcom, 2009

SN	Assumptions	Default Level
1	Peak Hours per Day	6
2	Non-Peak Hours per Day	14
3	AM Peak Hours	3
4	PM Peak Hours	3
5	AM Peak Hourly Passengers as a percentage of Daily Peak Period	40%
6	PM Peak Hourly Passengers as a percentage of Daily Peak Period	40%
7	Service Days per Year	360

Table 8: Overview of Technology Specifications for Financial Analysis

SN	Train Specification	Unit	Lot 1	Lot 1A	Lot 2	Lot 3
	Locomotives	#	1 small	1 small	1 small	1 small
	Coaches	#	8 cars	6 cars	6 cars	6 cars
	Passengers	#	2400	1800	1800	1800
	Run Time	Minutes	38.1	15.3	44.3	27.8
	Cycle Time	Minutes	90.2	44.6	102.6	69.5
	Fuel Consumption per Cycle	Liters	350	160	390	250

Source: Feasibility Study and Conceptual Design, CPCS Transcom, 2009

Image Map 2: Measurement of Lot 1A Rail Track

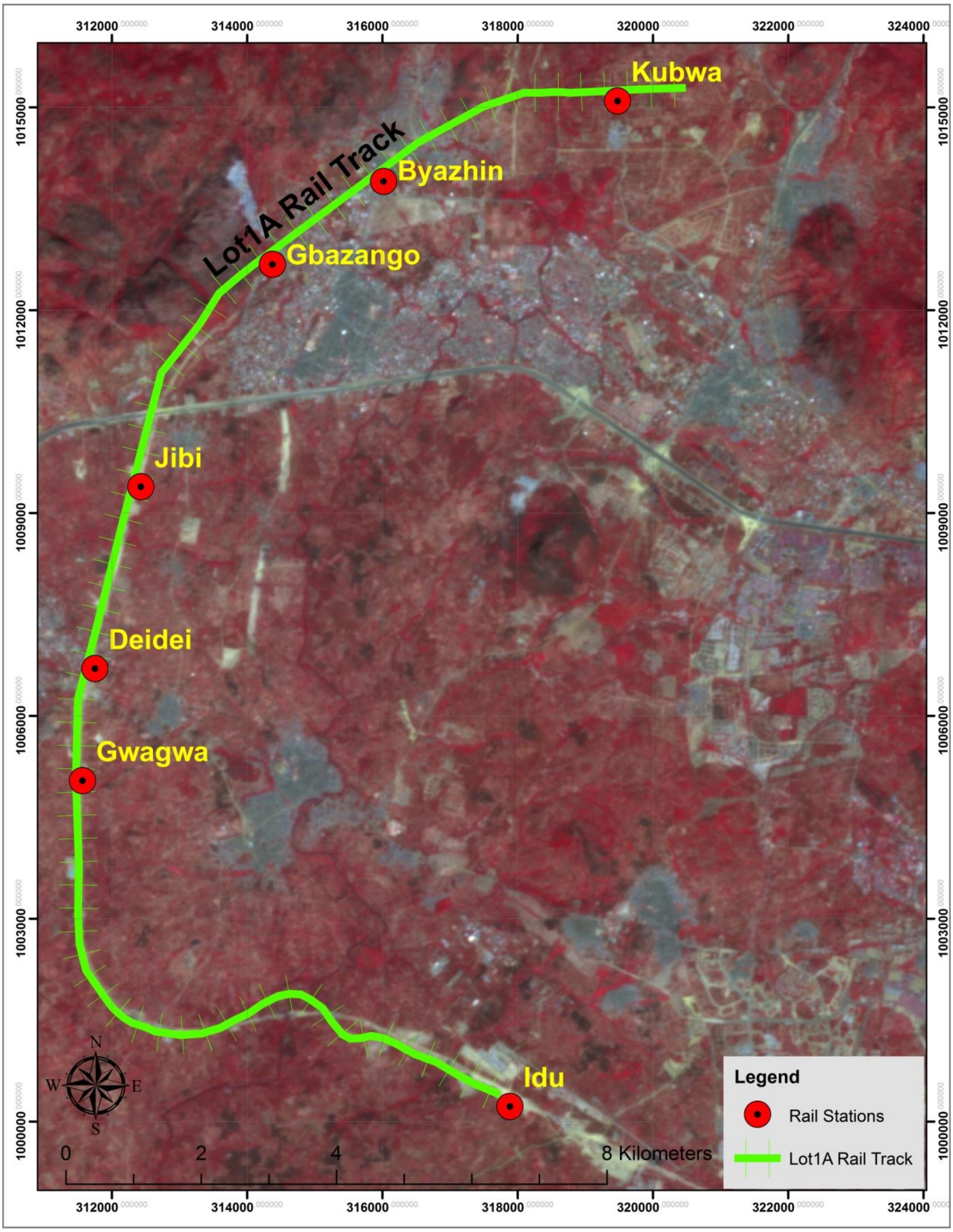
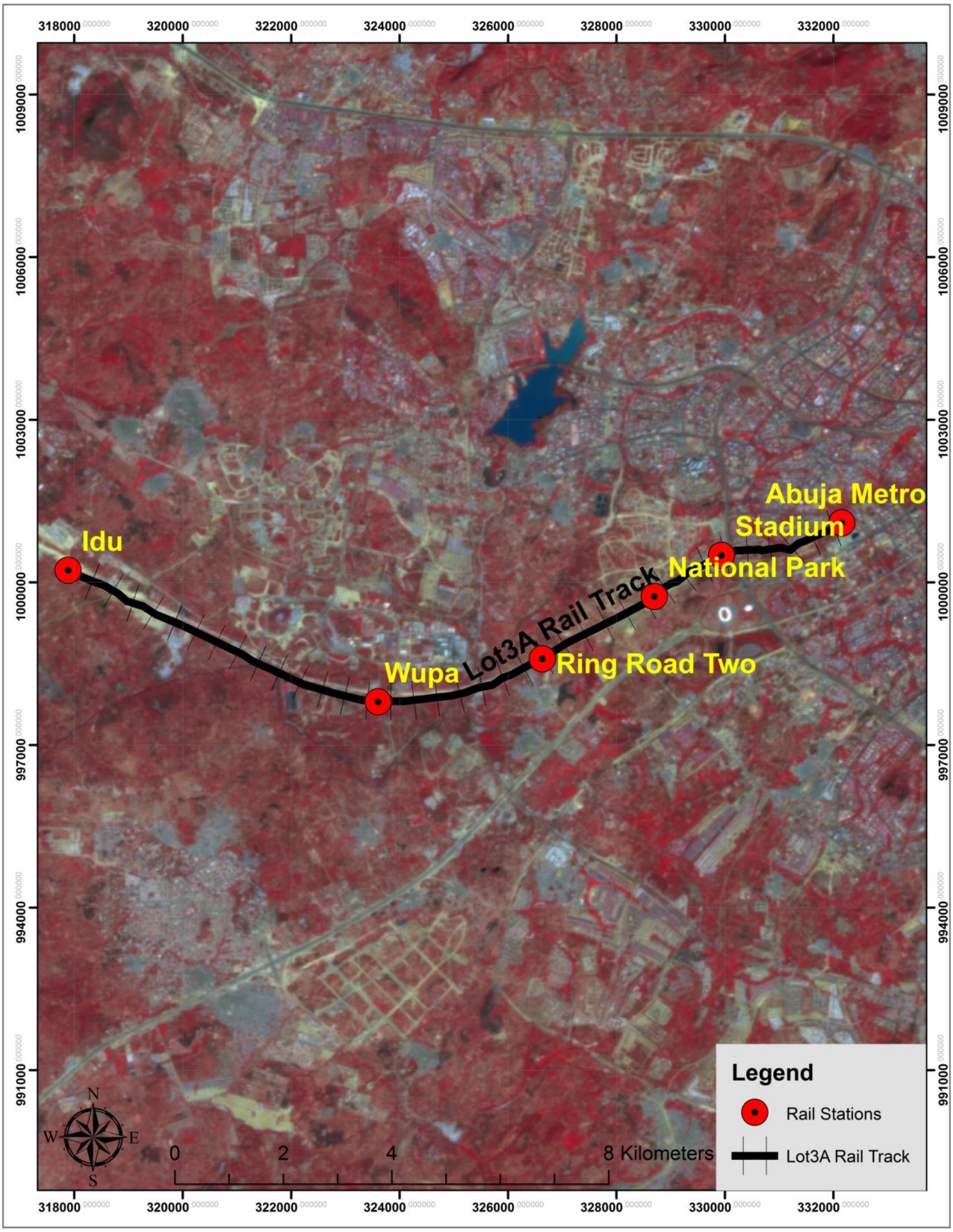


Image Source: NASRDA, 2011

The above image map 2 shows the lot 1A rail track in green line colour from Idu to Kubwa rail stations as 23.9 km, using route measurement tool of the ArcGIS software. This is measured by using this tool to know the specific rail track route length as seen on the Nigeria-sat X satellite imagery and also as seen by the digitized line through the overlay analysis of the revised master plan on the satellite imagery.

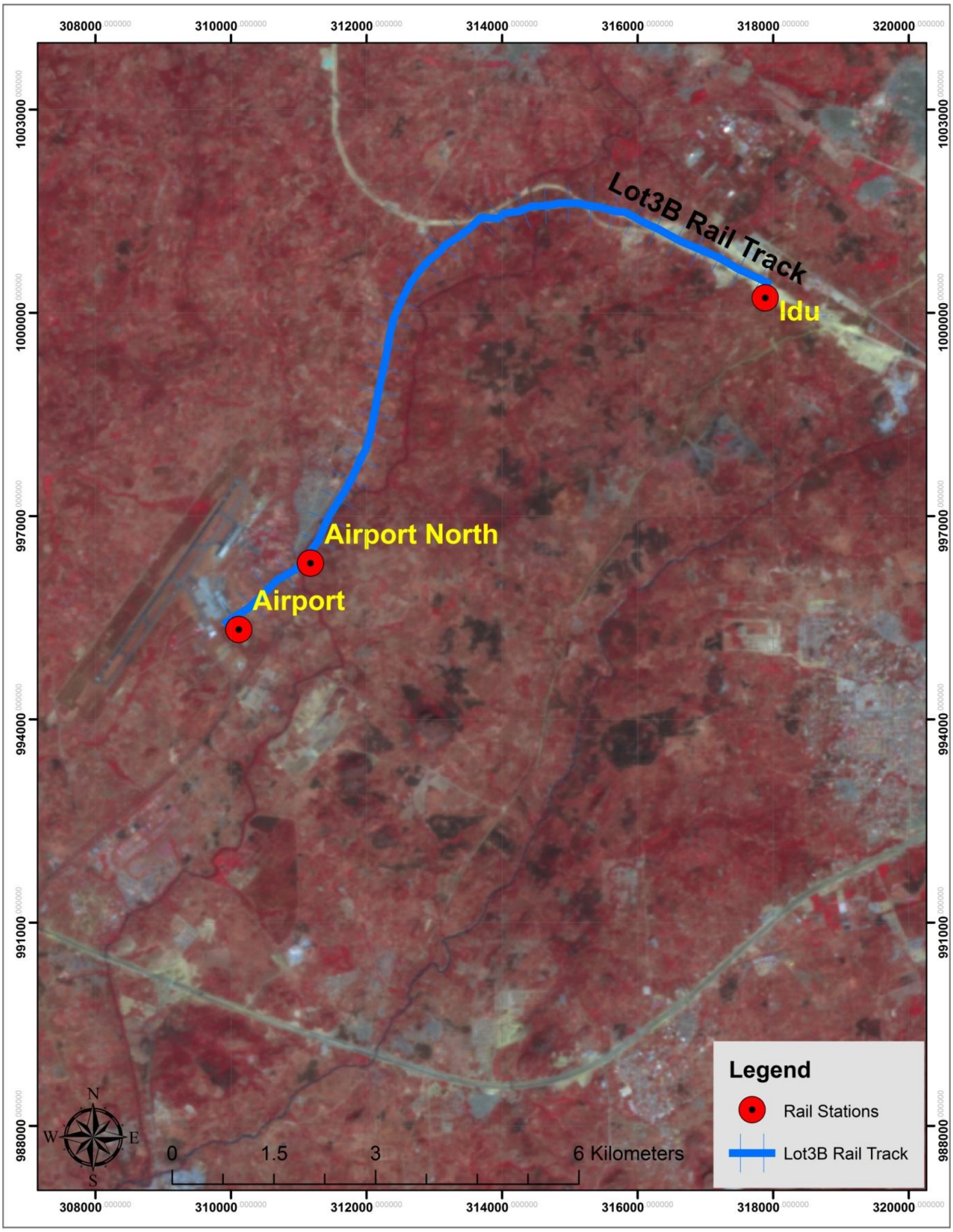
Image Map 3: Measurement of Lot 3A Rail Track



Source: NASRDA, 2011

The above image map 3 shows the lot 3A rail track in black line colour from Idu to Abuja metro rail stations as 15.61 km, using route measurement tool of the ArcGIS software. This is measured by using this tool and digitizing the specific rail track route as seen on the Nigeria-sat X satellite imagery and also as seen by the digitized line through the overlay analysis of the revised master plan on the satellite imagery. There are more settlements along this rail lot.

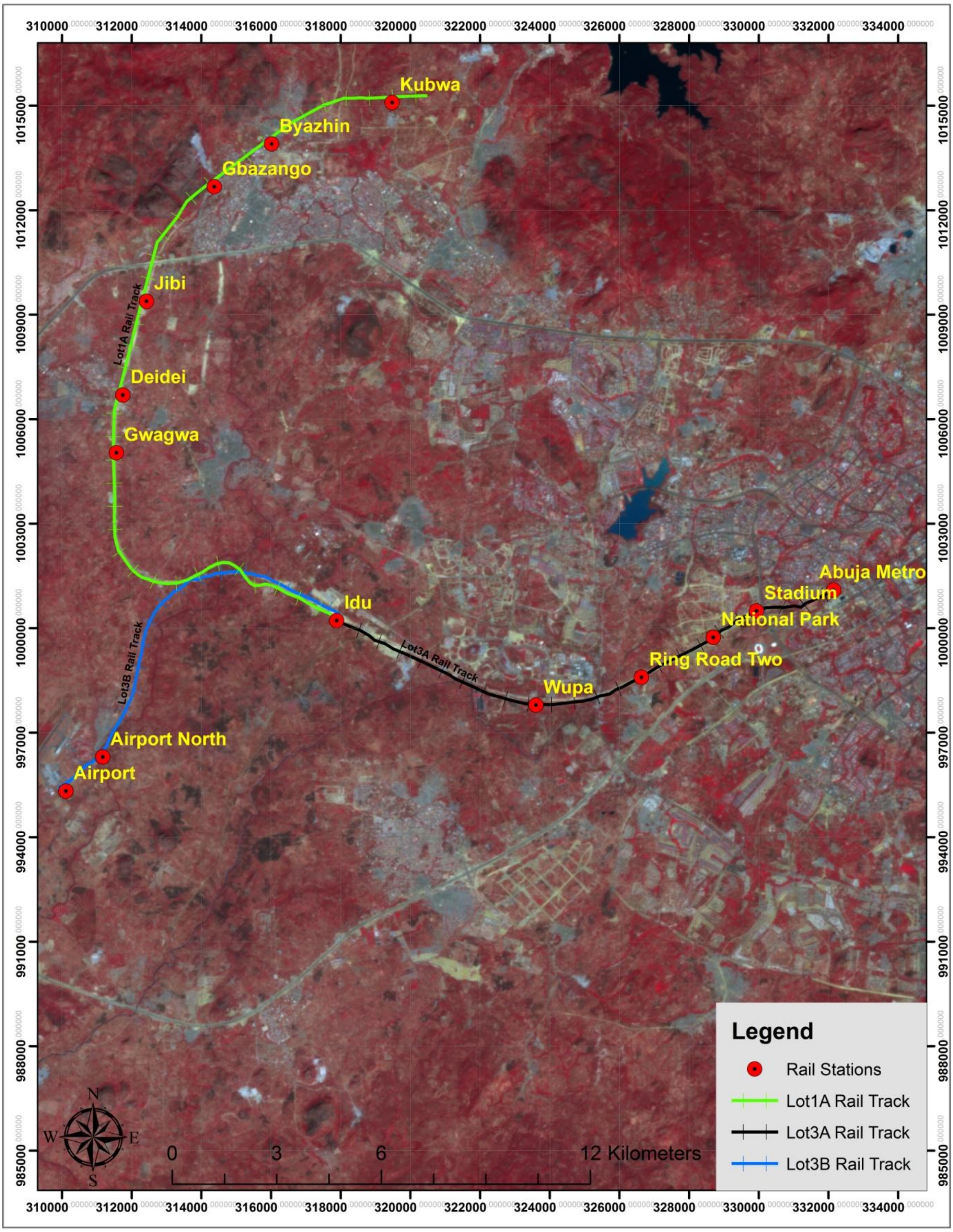
Image Map 4: Measurement of Lot 3B Rail Track



Source: NASRDA, 2011

The above image map 4 above shows the lot 3B rail track in blue line colour from Idu to Airport rail stations as 11.3 km, using route measurement tool of the ArcGIS software. This is measured by using this tool and tracing the specific rail track route as seen on the Nigeria-sat X satellite imagery and also as seen by the digitized line through the overlay analysis of the revised master plan on the satellite imagery.

Image Map 5: Lots 1, 3A and 3B Rail tracks and their 16 Rail Stations



Source: NASRDA, 2011

Image map 5 above shows lots 1A, 3A and 3B in rail track lines colour green, black and blue respectively, to depict all the 16 rail stations in red colours with a common change over rail station at Idu. This is carried out by digitizing the rail tracks line by line, with critical attention to end and start points to avoid the under shoot (digitizing below expected line length) or over shoot (digitizing beyond the expected line length) errors.

Table 9: Distances Measured with GIS and segmentation programme, Number/Name of stations aInter-change stations and minutes of stoppage time

	Rail Lot 1A	Rail Lot 3B	Rail Lot 3A
Distances as measured with GIS (Km)	23.90	11.3	15.61
Distance by Segmentation Implementation Programme (Km)	23.7	11.18	15.60
Number of Stations	7	3	6
Name of Stations	Kubwa, Byazhin, Gbazango, Jibi, Deidei, Gwagwa and Idu	Airport, Aiport-North, Idu	Abuja-Metro, Stadium, Nationalpark, Ringroad-II, Wupa and Idu
Inter Change Station	Idu	Idu	Idu
Minutes of Stoppage time	5minutes headway plus 5mins stoppage at each 5stops (1minute each) = 10minutes	5minutes headway plus 1minute stoppage time at 1 stop (1 minute each) = 6minutes	5 minutes headway plus 4minutes stoppage time at 4stops (1minute each) = 9minutes

Table 9 shows the distances as measured with the route measurement tool of the ArcGIS 9.3 software for the rail lot 1A, 3A and 3B, as compared to the distance already measured by the segmentation implementation programme. Slight (less than 0.5 km) differences were observed due to image rectification and registering by geo-referencing errors.

Thus, a total of sixteen rail stations are available for the three lots 1A, 3A and 3B, all having a major interchange at Idu station. There is a five minutes headway time and addition of one-minute stoppage time at each rail station, appreciating to its total minutes of stoppage time at each rail lot. The more the rail stations ahead at each rail lot, the more the stoppage time of one minute each at the rail stops, for example as seen in rail lot 3B with the least rail stops and least stoppage time of six minutes. While at rail lot 1A, it has seven rail stations and ten minutes stoppage time. As the rest of the six rail lots are built, more directions will be introduced with different interchange and more or less stoppage time.

Image Map 6: Road length measurements from Kubwa to Idu 40.9km, Idu to the international wing of the Abuja Airport 39km and Idu rail station to Abuja-metro station 20.9km

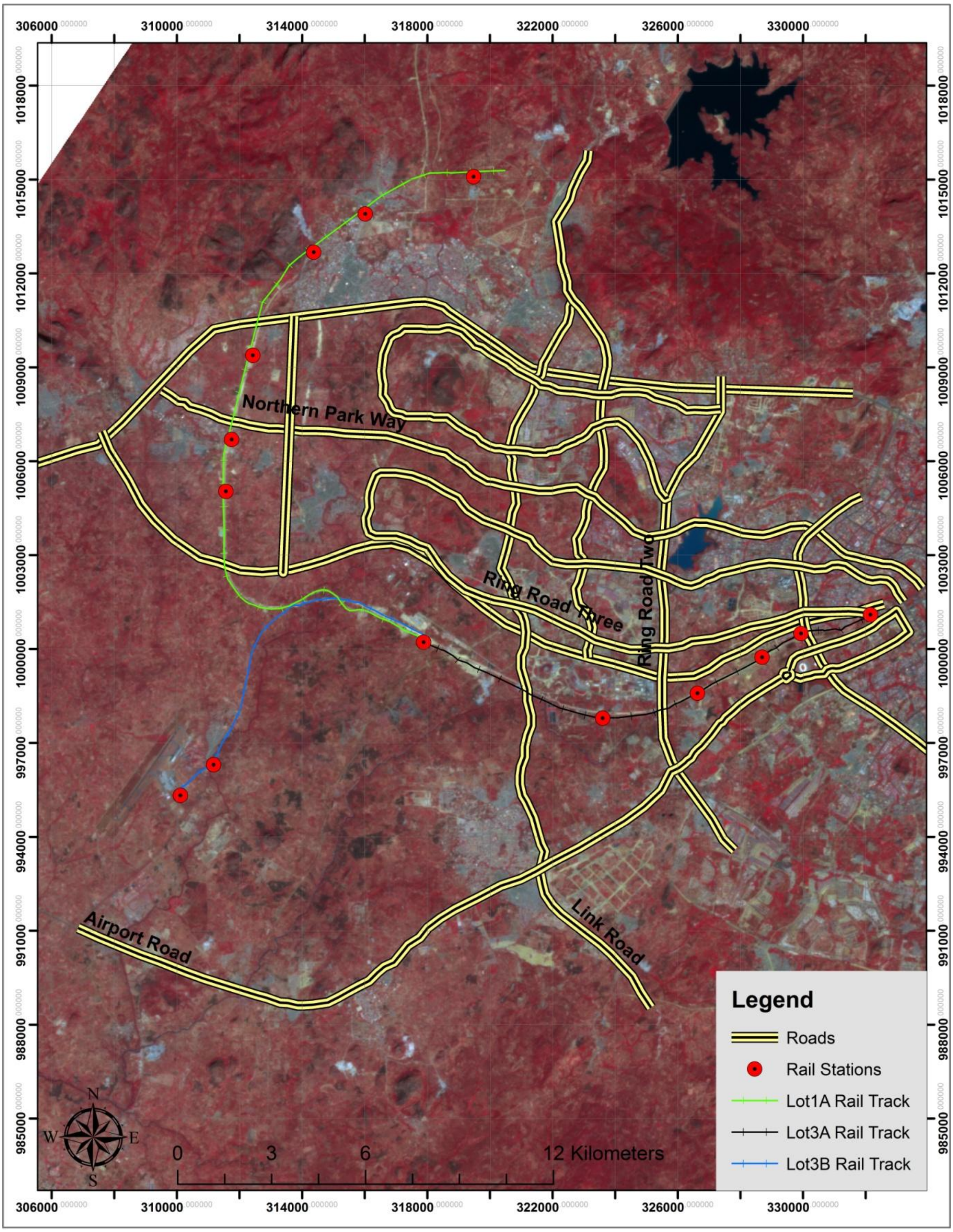


Image Source: NASRDA, 2011

Image 6 shows the road measurements of the available road routes the commuters presently use in the absence of the rail in operation is measured using the ArcGIS measurement tool. The results of the measurements are: Kubwa to Idu is 40.9km, this is done by measuring the road from kubwa through the expressway, and through the ring road-two express way down to Idu. At present this is the only tarred road route available for this link on the road from Kubwa to Idu. Thus, it further shows that using this road, the motorists' needs to connect to other major high ways before finally getting to the Idu destination.

Idu to Airport as 39km, the route goes through from Idu back to Ring road-two, through the Airport road to the Airport. There is only one airport road from ring road two that leads to the airport. More settlements are really being built, not too far from the airport, due to more commercial activities attributed to the airport, informing more travel demand in the nearest future, as some passengers using the plane from the airport will also start using the light rail due to its benefit for timesaving and less cost .

Idu to Abuja Metro Station is 20.9 km. The road is measured from Idu through the Constitutional Avenue expressway at the central area district to the Abuja-metro station. Most civil servants work in this axis of Abuja Metro, which means there will be higher travel demand during the peak hours of 7-10am and 4-6pm, when the workers will be resuming and closing from their offices respectively.

Table 10: Timesaving Benefit for Lot rail 1A from Gbazango rail station at Kubwa to Idu station at Idu

Lot1 A Rail Gbazango at Kubwa to Idu station at 100km/hr	Minutes spent by Rail plus 10 minutes (5 minutes headway and 5 minutes of stoppage time at each 5stops)	Kubwa to Iju settlement by road at 75km/hr	Minutes spent by road vehicle	Time Saved by Rail at off peak hours	Time saved by Rail at peak hours of road vehicle at 75km/hr
23.90km	23.90X3600/100 =860.4/60 =14.34mins +10mins	40.9km	40.9X3600/75 =1963.2/60	32.72-24.34	8.38mins + 30mins
Total	24.34mins	40.9km	32.72mins	8.38mins	38.38mins

Table 10 shows timesaving benefit for Lot rail 1A from Gbazango rail station at kubwa to Idu station at Idu.

This further shows the minutes spent by rail and the minutes spent by road. The time saved by both scenario is also calculated. The rail saved as a time benefit 8.38 minutes during off peak hours and saved 38.38 minutes during peak hours. This means there is quite a reasonable difference of timesaving between the light rail and road for the peak and off peak periods.

Table 11: Timesaving Benefit for Lot 3A rail from Idu to Abuja Metro

Lot3A Rail at 100km/hr	Minutes spent by Rail plus 9 minutes	Idu settlement to Abuja Metro station by road at 75km/hr	Minutes spent by road vehicle	Time Saved by Rail at off peak hours	Time saved by Rail at peak hours of road vehicle at 75km/hr
15.61km	15.61X3600/100 =561.96/60 =9.36 mins +9mins	20.9km	21X3600/75 = 1008/60 =16.8mins	-1.56mins	-1.56mins +30mins
Total	18.36mins	21km	16.8mins	-1.56mins	28.4mins

Table 11 shows timesaving benefit for Lot rail 3A from Idu rail station at Idu to Abujametro station at Central Area district. This further shows the minutes spent by rail and the minutes spent by road. The time saved by both scenario is also calculated. The rail lost time of (-1.56) minutes at off peak hours and saved 28.4 minutes during peak hours. This implies that, at the off-peak periods, using the road at 75km/hr will gain 1.56 minutes and the rail lost the same 1.56 minutes, that is why it is in the negative figure of (-1.56).

Table 12: Timesaving Benefit for Lot 3B rail from Idu to Airport

Lot3B Rail at 100km/hr	Minutes spent by Rail plus 6 minutes	Idu settlement to Airport rail station by road at 75km/hr	Minutes spent by road vehicle	Time Saved by Rail at off peak hours	Time saved by Rail at peak hours of road vehicle at 75km/hr
11.31km	11.31X3600/100 =407.16/60 =6.8mins +6mins	39.01	39X3600/75 = 1872/60	18.4mins	18.4mins +30mins
Total	12.8mins	39km	31.2mins	18.4mins	48.4mins

Table 12 shows timesaving benefit for Lot rail 3B from Idu rail station at Idu to the Airport station at the Airport. This further shows the minutes spent by rail and the minutes spent by road. The time saved by both scenarios is also calculated. The rail saved as a time benefit is 18.4 minutes during off peak hours and saved 48.4 minutes during peak hours.

Table 13: Summary of Timesaving by Lots 1A, 3A and 3B compared to their Road Routes

	Lot 1A	**Lot 3A**	**Lot 3B**
Rail route at off peak hours of road transport	8.38mins	-1.56mins	18.4mins
Rail route at Peak hours of road transport	38.38mins	28.4mins	48.4mins

Table 13 shows the summary of timesaving as a benefit and its specific contribution to sustainability development. Lot 3B gained most at both the off peak and peak hour of road transport by 18.4 minutes and 48.4 minutes respectively. Followed by Lot 1A, which gained as a time benefit, 8.38 and 38.38 minutes at off peak and peak hours of road transport respectively. While Lot 3A, lost (-1.56) minutes at off peak hours and gained 28.4 minutes at peak hours of road transport.

Parameters Used

- 1 minute stoppage time at each rail station and 5minutes headway from start = 10 minutes added time to Lot 1A, 9 minutes added to lot 3B and 6 minutes added to lot 3B.
- The number of added minutes depends on the number of rail stations after take-off and the station before the last stop.
- Minutes spent at peak hours (8-10am or 4-6pm) (Omidiji, 2010) on the road
- = 30minutes on the average. Extreme conditions last up to 90 minutes. 120 minutes or more but not included in this case.
- 3600seconds =1hour, 60seconds =1minute

Chart 3: Summary of Timesaving by Lots 1A, 3A and 3B compared to their Road Route

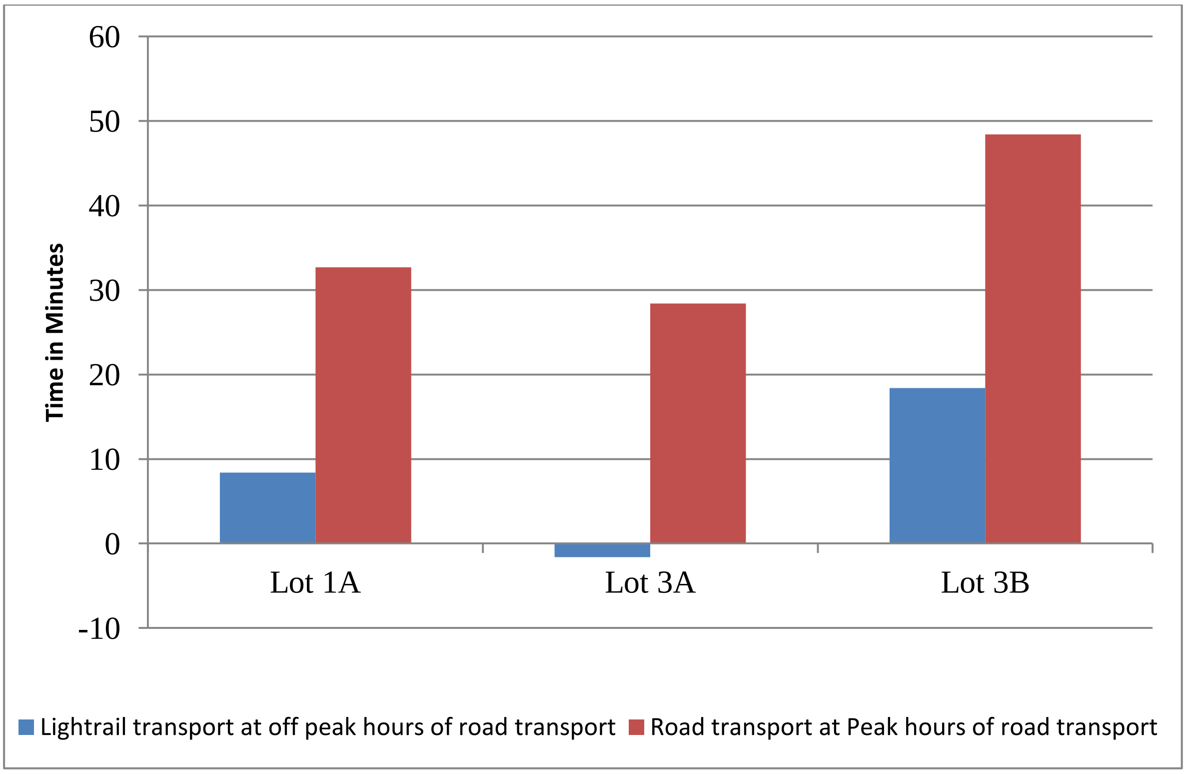


Chart three above shows the summary of timesaving by Lots 1A, 3A and 3B as compared to their respective road routes to achieve its specific contribution to sustainability development of the light rail infrastructural project. Lot 3B gained most at both the off peak and peak hour of road transport by 18.4 minutes and 48.4 minutes respectively. Followed by Lot 1A, which gained as a time benefit, 8.38 and 38.38 minutes at off peak and peak hours of road transport respectively. While Lot 3A, lost (-1.56) minutes at off peak hours and gained 28.4 minutes at peak hours of road transport. It is important to note that lot 3A by rail during off-peak hours lost (-1.56).

This developed logical and spatial reasoning provides more insights to the level of trade-offs some routes can provide in the form of better travel demand and traffic modelling for optimum benefit as income to be generated from the commuters. Furthermore, considering that there are still three more rail lots to be built, loosing time during the peak and off peak periods as compared to the road routes, can be avoided through alternative route designs. This is capable of delivering cost effective large capital expenditures on the rail, minimum time of movement between locations and better travel demand for higher income to the government. Promoting better timesaving benefit as useful information for the commuters, will go a long way in facilitating a high modal shift from the roads to the rail usage, thus fulfilling the provision of a common good, as a mass transport system in a fast growing population and city like Abuja.

4.6 Spatial Relationship between the Respondents' Location and their Selected Indictor

In the image map 7 below, it shows the spatial relationship between the respondents' location and their selected indictor. Nine respondents settlement location was randomly selected based on locations along the rail routes and also 3 out of these nine selected because they reside outside of the federal capital city but still in the federal capital city, while one out of these resides completely outside the city in another state close to the city. Nine was chosen at random because depicting the total 62 respondent will produce a noisy (congested) map.

Therefore, it was also deduced that the location of some respondents has influence on the selected indicator, as observed that 2 out of 9, one within the city and the other in another state close to the city chose timesaving as their number one ranked indicator. While the rest 7 out of 9 chose other indicators as their most priority.

This further explains that respondents' place of work may be close to the rail station stops but very far from the city, therefore means the place of work is also important to their selected indicator. As observed, two out of the nine respondents who lives at kuje, which is located in the FCT but outside the FCC, chose proximity of settlement to the rail stop, most likely because the respondent lives outside the FCC. In addition, the respondent from Suleja, located completely outside the FCT in another state entirely called Niger state, gave the same higher rank to five indicators, namely travel-time, employment generation, affordability, modal shift and urban regeneration as rank one to the five indicators. It can be deduced that these five selected indicators selected by the respondent from Suleja, outside FCT, are more important especially when the rail routes are closely linked to each other, making transport easier from outside the city, no longer driving for many kilometres before having access to the rail.

Image Map 7: Image map Showing Spatial Relationship between Respondents Location and Selected Indicator

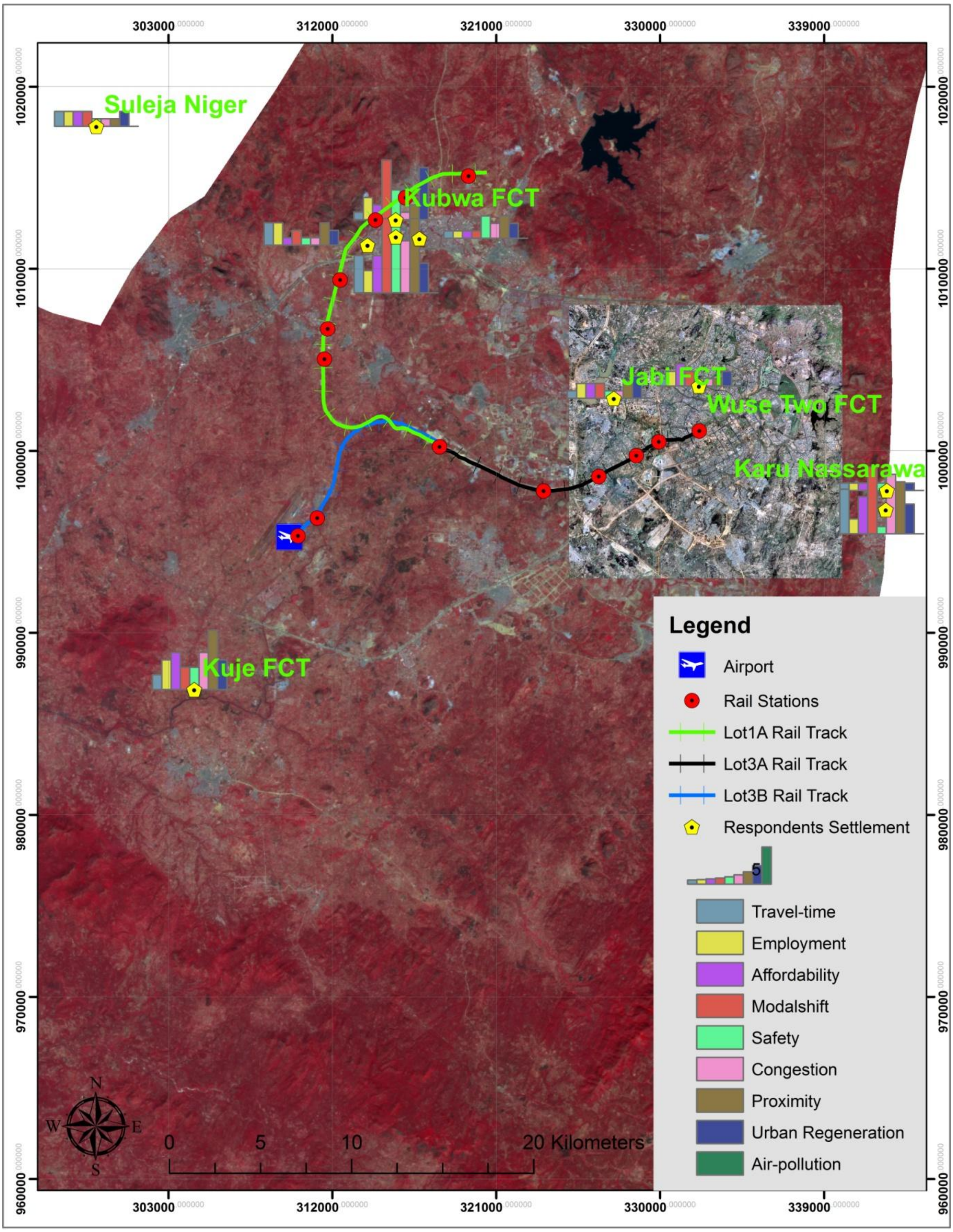


Image Source: NASRDA, 2011

4.7 List of other social, economic and environmental benefits, as stated by respondents

The respondents stated some other vital social, economic and environmental benefits of the urban light rail. These are: Reduction in budget for road construction and maintenance, reduction in possibility of committing high way crime, reduce petrol purchase budget, reduce cost of house rent due to increase in accessibility and estate developments, improve life of rural dwellers, increase land value along rail corridor, transfer of technology during construction and operation, reduce pressure on car ownership, promote even distribution of population due to accessibility, improve tourism and aesthetic beauty to the city and environment.

4.8 Assessing the Sustainability benefit of the total road congestion reduced by the light rail as compared to road vehicle transport scenarios

The viability of assessing the reduction in congestion on the busy roads of the Federal Capital Territory Abuja, especially along the axis in the Federal Capital City and at the axis close to the territory boundaries in itself has other secondary benefits attached to it. These benefits such as less pollution promoting clean air due to less hold-up on roads, better timesaving and better safety of less accidents.

Furthermore, there is no single, broadly accepted definition of traffic congestion (OECD/ECMT, 2004). One of major reasons for this lack of consensus is because congestion is both a physical phenomenon relating to the manner in which vehicles impede each other's progressive movement as demand for limited road space approaches its elastic limit and also the fact that a relative concept relating to user expectations relative to system performance.

Assessing reduction in road congestion due to the use of the light rail is an important step that guides in delivering better congestion outcomes. However, congestion should not be described using a single metric for assessment purposes. The use of a single metric to do this, results to obscure the quantitative aspects of congestion or its relative and qualitative aspects of congestion. It is vital to note that these two aspects cannot be disassociated from a more conceptualized assessment of congestion, which should be based on sets of indicators that capture both of these aspects (OECD/ECMT, 2004). Selecting a set of good indicators is based on a wide network of road sensors, such as selecting important metrics that are relevant to both road managers, users and rail infrastructural assessment before construction, such as speed and flow, queue length and duration, predictability of travel times, system reliability, e.t.c.

Acquiring these important data as indicators for assessment is a great challenge, as the data of this nature over time is not available, due to inadequate data gathering ethics in the transport sector on major routes overtime. However, data of this nature is now becoming important due to a re-engineered Federal Road Safety Corps (FRSC) initiative. This gap in data for assessing the reduction in congestion is an avenue for future research, over the years, as data can be developed to generate adequate data for assessment with time.

This chapter has shown the development and application of a new methodology complementary to the sustainability diamond and multicriteria assessment in the conceptual framework. This new methodology is the application of spatial analysis using Geographic Information System to ascertain in a very valid and provable manner, the use of timesaving as a measurable indicator to assess its sustainability benefit to the light rail in a clear, reliable and empirical manner.

Chapter 5: Conclusions and recommendations

5.1 Conclusion

The conceptual framework, using the sustainability diamond and multicriteria assessment in this research in addition to the newly developed methodology of spatial analysis using Geographical Information System (GIS), are used to compare transport routes alternatives of the rail and their corresponding road routes, measuring the timesaving as an economic sustainability benefit. Thus, revealing how the economic measurement indicator, i.e. timesaving, which was selected as the most ranked indicator that results into different empirical rate or level of contribution to sustainability benefit, thus answering the question how are the sustainability benefits of the urban light rail system assessed.

This further explains the necessity to measure the specific rate of contribution of different indicators to measure and monitor the level of benefit in either an increase or a decrease in a specific indicator. In the case of this thesis, the timesaving indicator was able to show the extent at which each lot rail track was able to contribute to sustainability benefit. During this process it was pertinent to note that lot 3A does not save time as compared to the respective road route, by losing 1.6 minutes (-1.6 minutes) during off peak, but gained 28.4 minutes during peak period due to the 30 minutes added as peak period hold-ups. However the remaining lots 1A and 3B saved time during the peak and off-peak periods as seen in chart 4.

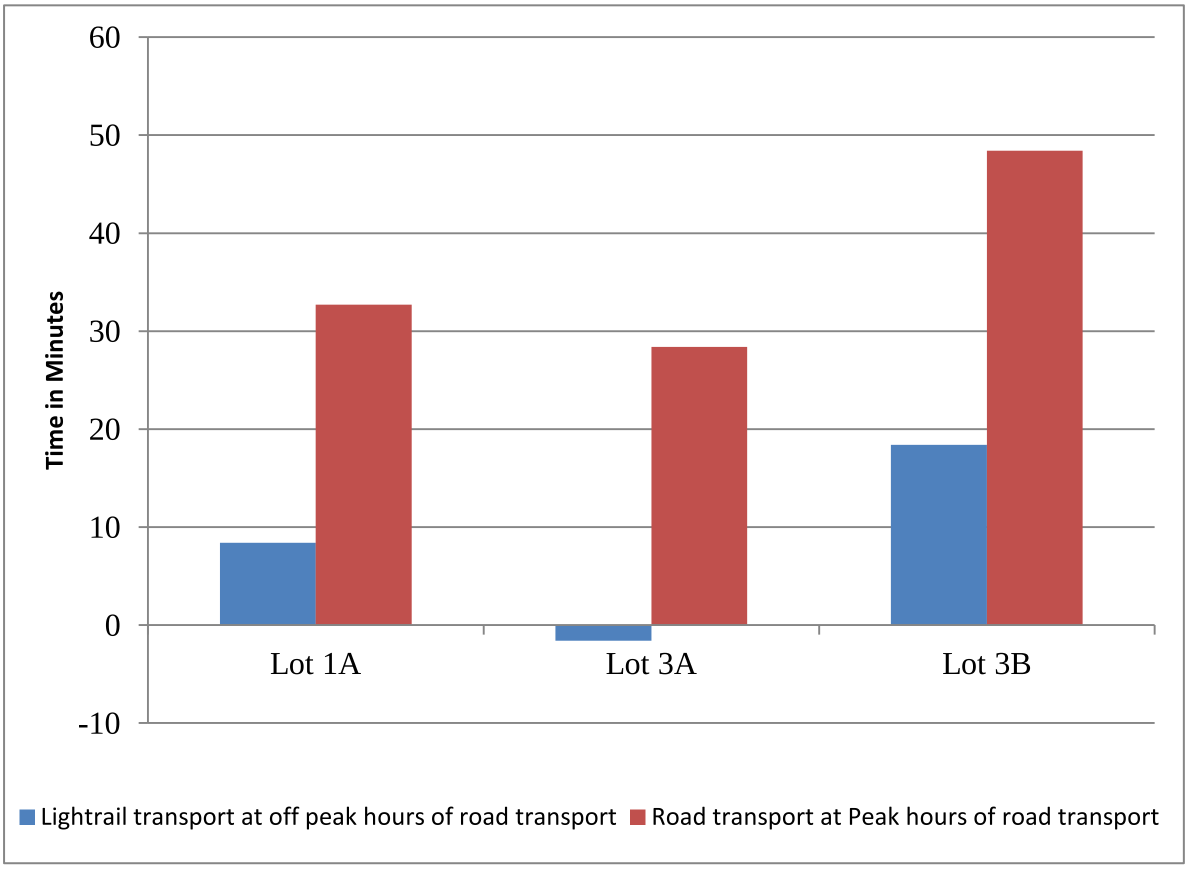
The sustainability diamond and multicriteria assessment concept further illustrates the relative impacts of alternative plans on system performance, i.e. the economic, environmental and social quality of life that helps decision-makers categorize the main choice. In the case of this research, the relative impact of the travel timesaving indicator can be used to determine different parameters that could be used by decision makers to reduce or increase certain planned inputs, such as head way time, stoppage time, number of rail stations and amount of diesel fuel to be used by each route movement, in order to improve the economic, social and environment benefits. This is such that the headway time can be increased or reduced, for example in the case of lot 3A, to improve its travel time-savings benefit. This can also help to determine the addition of more or less rail station stops that will guarantee more revenue income at a national scale to the government as an economic benefit. The amount of pollutant emissions released from diesel fuel along these routes can be discouraged before the purchase of trains are made, when the amount of negative health affecting gases are modeled and calculated along each routes to determine its increase over baseline and future aspirations.

This study aimed at assessing the sustainability benefits of the Abuja urban light rail transport using nine relevant indicators from related literatures. The travel-time and reduction in congestion were the most raked amongst the nine indicators presented to be ranked with the questionnaire by sixty-two experts.

Using the sustainability diamond analysis and multicriteria assessment as a conceptual framework, it provided an opportunity to synergize the most reckoned indicators with indicators that have more relationship with a developing country like Nigeria, considering its socio-economic situation.

The use of Geo-Information System (GIS) to quantitatively evaluate the empirical level of benefit (Barrella, 2012) and simple calculus to quantify also in empirical terms that is practically provable, which provides quality in terms of reliability and validity of result over time. The timesaving indicator as a sustainability benefit will consequently lay a very good foundation in assessing the sustainability benefits of an infrastructure especially before it is implemented, in order to achieve a more time and economic efficient transport system that will provide valid base information in delivering quality service to the people. This gives better meaning and usefulness to this research because it is an ex-ante research, which deals with modelling different scenarios of a project before it is been implemented. This provides adequate chance to observe different scenarios that will be of optimum benefit, limiting cost and encouraging in-depth understanding of assessing sustainability benefits before its operation.

Chart 4: Summary of Timesaving by Lots 1A, 3A and 3B compared to their Road Route



Is summary as calculated and observed from the summary of timesaving in chart 2 for lots 1A, 3A and 3B as compared to their road routes, the following conclusions, approximately was reached:

1. Lot 1A along Kubwa to Idu rail route stations (7 stations along route) is faster as compared to the road route between the same locations by 8.4minutes at off-peak hours and 38.4 minutes at peak hours.

2. Lot 3A along Idu to Abuja metro route stations (6 stations along route) is slower as compared to the road route between the same two locations by 1.6 minutes during the off-peak hours i.e. (-1.6) but faster by 28.4 minutes at peak hours.

3. Lot 3B along Idu to Airport route stations (3 stations along route) is faster as compared to the road route between the same locations by 18.4 minutes during the off-peak period and 48.4 minutes during peak period.

4. Another interesting finding is that lot 3A gave a negative number of (-1.6 minutes) during the off-peak hours. This can be taken into cognisance for further perceptions and re-planning, as a rail at 100km/hr compared to 75km/hr is ordinarily meant to get a commuter to its destination faster at peak or off-peak hours of the same route. This is because ordinarily it will be argued that the rail will be faster than the related road route, but it shows a different value as losing time rather gaining time as a benefit.

Therefore, the information above describing in empirical terms the number of minutes gained or lost during the peak and off-peak periods provides precise answers to the research question on how the sustainability benefits of the urban light rail system can be assessed. This is required to know in specific terms how a particular Sustainability indicator will benefit an urban city when a rail transport infrastructure is provided.

Finally, in generating empirical and valid levels of benefit to sustainability development in the indicator based assessment of sustainability benefit to the light rail, the use of the new and complementary methodology of spatial analysis using the geo-information system approach for the timesaving indicator, has shown to be capable of reliable assessment. This assessment is reliable because it can be proved in a scientific, provable and non-subjective manner, delivering accurate empirical values that are used to measure the rate or level of a sustainability benefit or negative impact, promoting a more informed and reliable implementation of large infrastructural projects, such as the Abuja light rail project.

5.2 Addition to the Existing Body of Knowledge and Projections for Further Research

This study has added to the existing body of knowledge with the use of geo-information system as a decision support tool for the assessment of some indicators based sustainability benefits of the light rail transport. This implies that the spatially related indicators, such as timesaving is a highly provable method to assess chosen indicators, which at times are also complimentary to the multicriteria assessment that is mostly based on monetary values. Empirical spatial values of timesaving is a valid and reliable approach in assessing the timesaving indicator as it shows in specific terms the level of benefit it has added to the light rail transport.

However, in order to assess other indicators, such as reduced congestion, employment, modal shift, safety, proximity, urban regeneration and air pollution, adequate availability of data over different scenarios is strongly required. As these data is been gathered over the years, providing adequate data, the future and further work will need to be done to assess these remaining indicators, especially in a developing country like Nigeria, which lacks comprehensive data capable of experimenting and building reliable scenario assessment over many years.

Two new research questions for this further research are: How are indicators based assessment data generated in developing countries to assess the sustainability benefits of the light rail transport? How can scenario building or forecasts for indicator based assessment be validated? These research questions can be solved by critically reviewing the relevant literatures and most importantly identifying peculiar developmental applications capable, reliable and valid assessment to developing countries as a niche to be developed by the researcher.

This assessment will have a strong and positive impact on how experts, consultants, policy makers and other stakeholders alike view and assess the extent that an indicator will be beneficial to the urban light rail system, which will consequently assist in complimenting and validating other forms of assessment. In essence, understanding the positive or negative implication of the variable in any measuring indicator will determine other decisions to be taken during implementation processes for economic, social and environmental sustainability benefits.

5.3 Recommendations

1. The implementation of the National Geo-spatial Data Infrastructure (NGDI) and further empowerment of the already existing Federal Bureau of Statistics should be put in place to revolutionize the data generation, archiving, availability and distribution. All sectors especially in the transports and urban management sectors should be empowered to acquire adequate data for easier and researchable models to be analysed. This will promote easy modelling of scenarios over time that will assist indicator-based assessments. One of the major functions of the NGDI is to make available to every demand where what is being demanded is available, in what quantity and scale, which makes it easier to know how and where what is demanded resides. It generally serves as a data clearing house to all organisations in the country.

2. The study of how indicators affect our decisions for assessment and use of indicator assessment tools should be encouraged. This will promote the development of required data and the use of it. This can be done through funding of research years ahead, before the implementation of any form of assessment. This will promote informed and reliable planning.

3. The use of ex-ante research should be promoted because it is presently inadequate in Nigeria. This ex-ante type of research, will facilitate modelling of outcomes for a large-infrastructural investment by the government, such as the Abuja light rail project. This will over time, avoid unforeseen challenges that can be detrimental to lives and loss of huge capital investments, thus promoting more efficient use of infrastructural capital, good quality of common good provided and better health and safety.

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Annex1: Questionnaire

This questionnaire entails ranking already prepared set of indicators in order to assess the Sustainability benefits of the Abuja light rail system, it is vital that a wide range of experts and stakeholders should be involved.

The three thematic areas for Sustainability transport indicators, which reflect a standard definition of Sustainability transport that has been adopted for this study, are the three 'Sustainability Development Pillars', which is equally applied to the light rail transport. These are as follows:

A. ECONOMIC - Creating Sustainability economic growth and prosperity

B. ENVIRONMENTAL - Protecting and enhancing the environment

C. SOCIAL - Ensuring social equity (fairness) or well being

Your participation and cooperation is highly appreciated.

SECTION A: Personal Information

1. Profession of respondent

2. Job description

3. Job Income category. Please tick below your corresponding answer

30,000-50,000	60,000-90,000	100,000-150,000	160,000-200,000	300,000 and Above

4. Mode(s) of transport used presently by you. Please tick below your corresponding answer.

Public transport	Private transport	Both public and private transport

5. Number of times in a week you use the mode of transport in question 4 above?

SECTION B: Knowledge/Awareness of the Abuja Light Rail Transport

6. Are you aware of the Abuja Light rail project?

Yes	No

7. What is the length of the rail track?

8. When will the light rail be commissioned for use?

9. Will you use the light rail transport?

Yes	No

10. If yes, how many days a week will you use the light rail?

11. How many minutes will it take you to get to your place of work, using the light rail from the nearest rail stop?

12. How many minutes will it take you to get to your home, using the light rail from the nearest rail stop?

SECTION C: Personal Opinion on benefits of the light rail to the respondent (you) and others

S/N	Type of Benefit	Benefit to you(Indicate Yes or No)	Benefit to other(Indicate Yes or No)
1	Reduction of travel time using the light rail as compared to the mode of transport used before, example as compared to personal car or other public transports such as bus or taxi.		
2	Employment generation (Additional employment to be generated by the new light rail transport)		

3	Transport Affordability by people as compared to public road transportation (i.e. as compared to mass transit buses and taxis within the same route)		
4	Increase in the use of the light rail public mass transport (Increase in public transport trips per day, based on better timing and periods of availability).		
5	Safety Improvements (reduction of accidents and death rate from road accidents per year)		
6	Reduction in road congestions for better time management during transit due to reduction in vehicle use on roads		
7	Proximity of Settlements to Rail stations (Accessibility to the rail station without extra cost of using a public or private road vehicle to get to the rail station or rail stop, i.e., are the rail stops within 5-20 minutes walking distance to the settlements?		
8	Reduction in Air Pollution (Reduction of pollutant emissions of Carbon-monoxide (CO), Sulphur Oxide (SO), Nitrogen Oxide (NO_x), lead, particulate matter (PM) in tons/year of road vehicles to be reduced from roads, such as trailers, buses, cars and as compared to pollution emitted by the light rail		
9	Urban Regeneration (Urban regeneration in the vicinity of light rail transport, i.e. urban development for improved environment along the areas of the light rail corridor)		

Are there other economic, social and environmental benefits of the light rail to you or others, please list below and choose yes or no for each.

SN	Type of Benefit	Benefit to you (Indicate Yes or No)	Benefit to others (Indicate Yes or No)
1			
2			

D. Ranking of Indicators in order of importance

In your own opinion, how would you rank or quantify the following indicators in order of importance in measuring the benefits of the light rail transport economically, socially and environmentally as a reason for investing and constructing the rail transport?

The ranking is from 1 – 9, where 1 = Highest importance and 9 = Lowest importance, INSTRUCTION: Please write the ranked number (1 - 9) by the side of your corresponding indicator

SN	Indicator	Ranking
	ECONOMIC SUSTAINABILITY	
1	Reduction of travel time as compared to the use of vehicles on the roads (Total travel time saved by the use of the light rail as compared to both the public and private road transport, such as private car and public bus mass transit.	
2	Employment generation (Additional employment to be generated by the new light rail transport).	
3	Transport Affordability by people as compared to public road transportation (i.e. as compared to mass transit buses and taxis within the same route)	
	SOCIAL SUSTAINABILITY	
4	Increase in the use of the light rail public mass transport, i.e. Increase in public transport trips per day, based on better timing and periods of availability (modal shift)	
5	Safety Improvements (reduction of accidents and death rate from road accidents per year)	
6	Reduction in road congestions for better time management during transit due to reduction in vehicle use on roads	
7	Proximity of Settlements to Rail stations (Accessibility to the rail station without extra cost of using a public or private road vehicle to get to the rail station or rail stop, i.e., are the rail stops within 5-20 minutes walking distance to the settlements?	
	ENVIRONMENTAL SUSTAINABILITY	
8	Urban Regeneration (Urban regeneration in the vicinity of light rail transport, i.e. urban development for improved environment along the areas of the light rail corridor)	
9	Reduction in Air Pollution (Reduction of pollutant emissions of carbon-monoxide (CO), Sulphur Oxide (SO_2), Nitrogen Oxide (NO_x), lead, particulate matter (PM) in tons/year of road vehicles to be reduced from roads, such as trailers, buses, cars and as compared to pollution emitted by the light rail.	

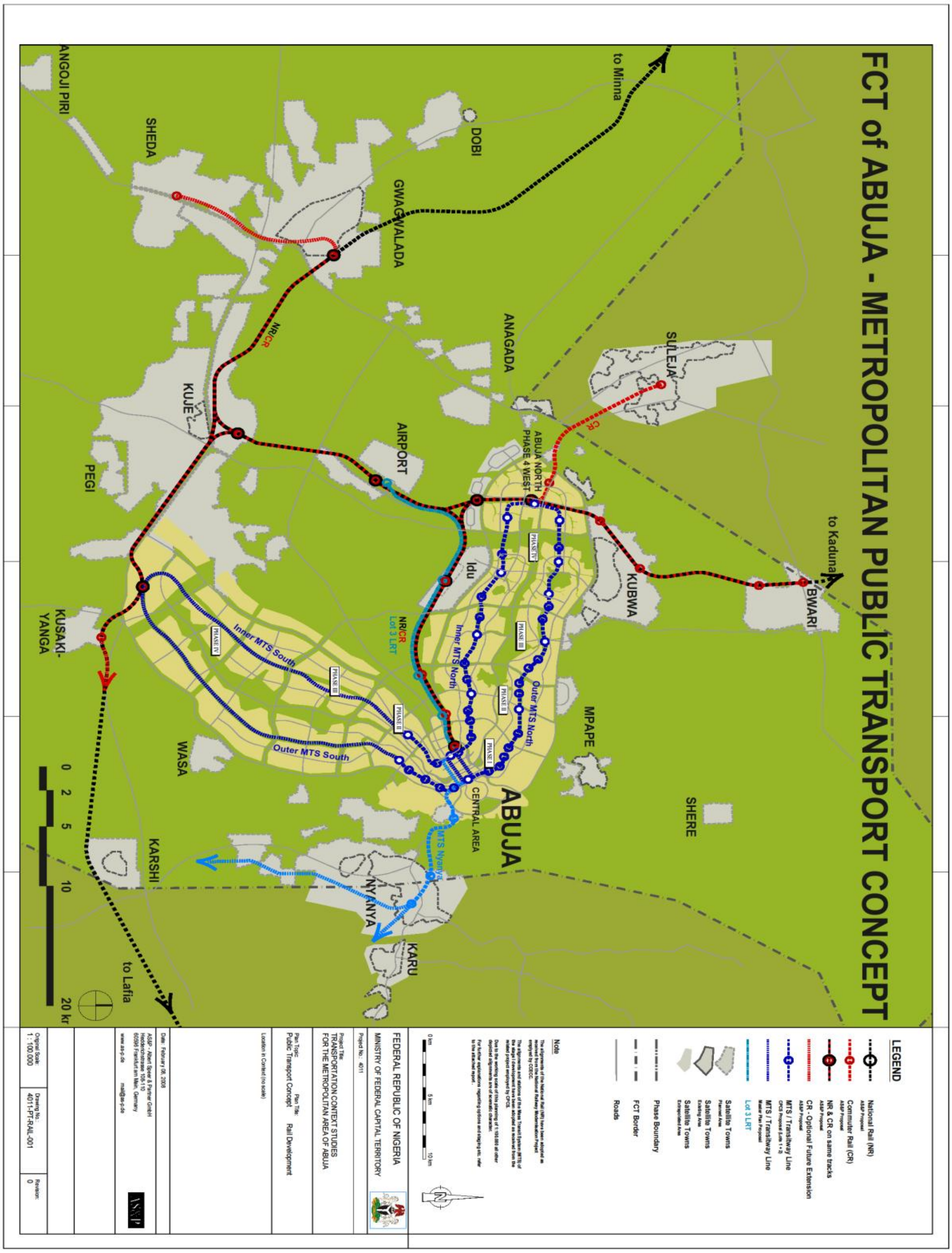
Are there other indicators you think can also be useful in assessing the benefits of the light rail? Please feel free to use extra sheets if needed. If yes, please list and weigh them on a scale of (1-2, 1-3, 1-4) depending on how many indicators you have listed, just as the nine indicators where listed and ranked above).

S/N	Indicator	Ranking
1		
2		
3		
4		

13. Do you wish to be contacted for further discussions to help improve the sustenance of the light rail in the nearest future? If yes, please prove the following contact information.
    Skype I.D:
    E-mail:
    Phone number:
14. Please feel free to contact me or send information you may want to share with me based on the Abuja Light Rail project.
    Email: taslimalade777@gmail.com
    Phone: 08036305390

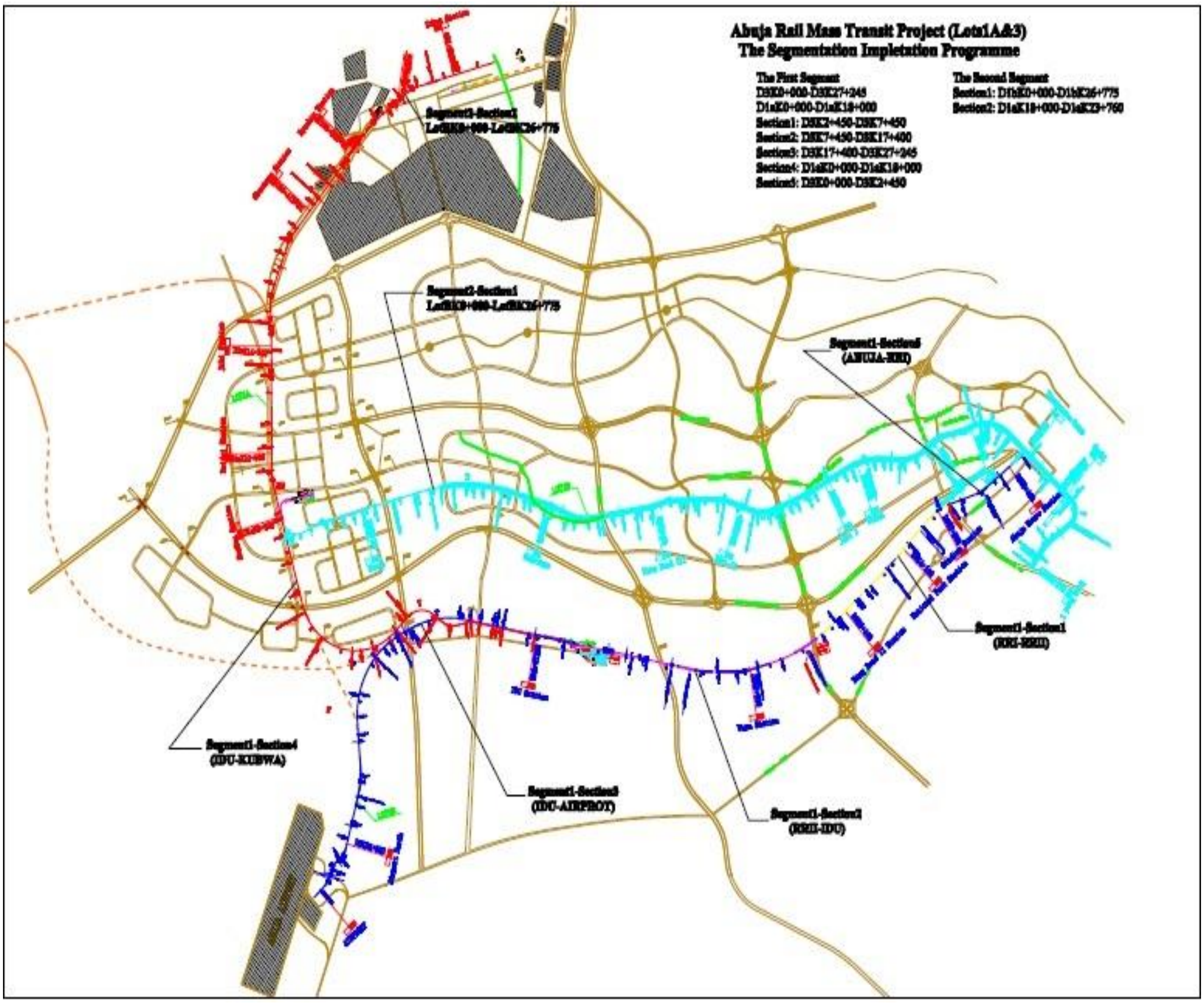
Thank you very much for your participation and cooperation

Annex 2: Federal Capital City of Abuja- Metropolitan Public Transport Concept



Source: Federal Capital Development Authority (FCDA), Abuja, 2013

Annex 3: Revised master plan for Lot 1A, 3A and 3B phase to be commissioned by 2015



Source: FCDA, Abuja 2013

The annex three above shows the light rail tracks Lots 1A in red colour from Kubwa to Idu, and Lots 3A and 3B in blue colour consisting of Idu to Airport and Idu to Abujametro. These three lots are the tracks to be commissioned for operation in the year 2015. While the green line represents lot 1B which is not part of the rail tracks to be commissioned in 2015, that is why the research focused only on this tracks to be in operation in 2015.

Annex 4: Photograph of the Rail testing train at the rail site used for testing the already laid tracks to confirm standards

Annex 5: Photograph showing Rail track at Ring Road Two

Annex 6: Photograph showing Engineers at work at the rail site

Annex 7: Photograph showing National Park Rail Station, getting ready for commissioning in 2015