Fuzzy Multi-Criteria Decision-Making Model for Prioritisation of Road Project Investments: Validity Evidence from Lagos State

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Abstract

Decision making process for prioritizing investment on road projects can be very challenging within the public sector as it is influenced by several factors such as political, social and economic factors. The importance of designing a reliable scientific model to address the associated challenges is key for making optimal decisions about investment in road projects. This study focused on prioritizing investment on road projects in Lagos State. In a bid to achieve this, a fuzzy multi-criteria decision-making model was developed. The model comprised of the Delphi Technique, Analytic Hierarchy Process, and Technique for Order of Preference by Similarity to the Ideal Solution. The Delphi technique was utilized to determine and rank criteria that should be considered. Agreement among raters was measured using Kendall's coefficient of concordance (W). A simplified model for decision-making on prioritization of investment on road projects was developed with the Analytic Hierarchy Process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). AHP was employed for obtaining the weight of each criterion considered, while TOPSIS was used to analyze three existing projects based on the criteria already identified in this study. The result showed that Agege - Pen Cinema Flyover ranked as the most important alternative for consideration, while Agric - Isawo Road and, Lekki-Epe Expressway ranked second and third respectively.

Keywords: *Prioritization, Road project investment, Delphi technique, Analytic hierarchy process, Technique for order of preference*

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Introduction

The task of prioritizing projects in the public sector can be excruciating, as it is subjected to different economic, social, and political factors. Those factors could also serve as constraints, which can also lead to a decision-making problem. Alemayehu (2004) indicated that economic, social, and political factors could be complex and therefore needed to be decomposed for decision-making. Road construction can be capital intensive, and in a highly congested city like Lagos; special consideration must be applied to ensure that prioritization of road projects is done properly thus maximizing the investment potential and meeting the most crucial needs of the people. Considering the size and population of Lagos, approaching road construction investment decisions with proven systematic solutions no doubt aids better decision-making on road projects. Lagos state is the most densely populated state in Nigeria, due to the high development in the state, while sub-hubs and neighboring towns are also rapidly developing (Salami, Falebita, Fatoba, & Ajala, 2012). Atubi (2010) claimed that road transportation is the major mode of transportation in Lagos State. Atubi (2010) maintained that Lagos state is considered the commercial capital of Nigeria, which is responsible for a high volume of activities on Lagos roads. Data released by Lagos State Government (2013) projected that there are over 20 million people in Lagos state. The data revealed that in 2013, Lagos State had 148 cars per 1,000 people, with a high car density of 620 per square kilometer. Furthermore, the document indicated that the state has a total road network of 9,900 km, thus transportation is predominantly road-based and carries up to 93% (percentage) of total passengers and goods traffic. Lagos state declared that the available road infrastructure is greatly overstretched, as total traffic per day is put at seven million passenger trips (Lagos State Government, 2013). BudgIT (2018) reported that in 2006 there were 833,957 vehicles and 25,958 motorcycles in Lagos Metropolis. Ikioda (2016) argued that Lagos state has overstretched the capacity of the available infrastructure due to rapid population growth on; therefore, justifying the importance of this scientifically driven decision-making process for investments related to road construction in densely populated Lagos state metropolis.

The factors to be considered in making an investment decision regarding road construction are enormous, so there is a need for a scientifically driven method to determine the prioritization of investments in road projects. Prioritizing investments related to road projects should require a rational decision-making technique for optimal results, this view was affirmed by Babatunde and Dandago (2014), who maintained that properly initiated internal control over project decisions and management gives a positive result.

Decision-making processes involve a series of steps: identifying the problems, constructing the preferences, evaluating the alternatives, and determining the best alternatives (Tzeng & Huang, 2011). Alemayehu (2004) maintained that several factors are involved in investment decisions across the public sector, the decision relating to investments in road projects thus involve multiple criteria. These criteria or factors are best analyzed and prioritized based on results obtained from well-researched and proven methods. Prioritizing investments in road projects should involve vital investment decision-making steps by key players handling the limited state resources. The optimality of such a decision is what this research will be seeking to achieve. The criteria involved in the decision-making process for prioritization of road projects are numerous, and the need for a technique to deal with the multiple criteria involved became inexcusable. Multi-criteria decision-making involves selecting the most suitable choice from the identified decision alternatives described by their attributes

(Mardani, Jusoh, Nor, Khalifah, Zakwan & Valipour, 2015). Ho (2008) describes multiple-criteria decision-making (MCDM) as a generic term for all multi-criteria methods of aiding people with decision-making according to their preferences. There are various multiple criteria decision-making (MCDM) solutions that have proven credible, among which are: Analytic Hierarchy Process (AHP) proposed by Saaty (1977), Technique for Order Preferences by Similarity to an Ideal Solution (TOPSIS) proposed by Hwang and Yoon (1981), Elimination Et Choice Translating Reality (ELECTRE) by Roy (1968), Preference Ranking Organization Methods for Enrichment Evaluations (PROMETHEE) by Mareschal, Brans, and Vincke (1984). Many studies have explored the use of MCDM in public sector investments and construction, however, there are not too many works done on prioritizing investment decisions on road projects using a fuzzy MCDM that comprises three components in a model. This study will employ TOPSIS to prioritize objectives indicated as crucial for investment decisions on road projects, while AHP will be used to determine relative weights according to the appropriate hierarchical structure. Delphi technique will be employed for obtaining various criteria that must be considered for making investment decisions on roads projects, after which the AHP and TOPSIS are used for further analysis to obtain the best possible solution.

Research Problem

Decision-making within the public sector is challenging and more importantly in developing countries like Nigeria can be more challenging. Curristine, Lonti, and Joumard (2007) identified decision-making bottlenecks within the public sector; which include budgetary restrictions, interference, and noncompliance by the politician. Okeke, Onuorah, and Okonkwo (2016) maintain that investment decisions of government agencies were constrained by government planning criteria and procedures; they rarely considered the needs of communities. Decision-making by the government can be highly subjective; thus, their criteria for investments in road projects could further make investment decisions on projects such as roads difficult or ineffectual. There seems to be no effectual decision-making process for road investment decisions in Lagos State, this was revealed by Ikioda (2016); while arguing that due to the unorganized nature of urban expansion, very high population, and very limited space in Lagos, several government agencies established to address challenges related to road infrastructure and traffic management have not been able to do much to address the issues. This suggests that there are challenges to making an optimal investment decision on road projects in Lagos State. Adama (2017) claimed that political consideration is a major decision-making factor within the public sector. He opined that the current investment decision-making on road construction projects is not optimal. Ikioda (2016) claimed that infrastructure in Lagos state is overwhelmed due to the rapid increase in population since Lagos state is the most populous state in Nigeria, with over 20 million people, and about 7 million passenger trips daily (Lagos state Government, 2013). Atubi (2010) argued that the traffic situation in Lagos is that bad because of the absence of effective transport planning, which the road network is crucial to. Road investment decisions, road transport development, traffic situation, and economic growth in Lagos state are almost inseparable; Atubi (2013) stated that transport development is crucial in the developmental process of an economy and the healthy growth of a society. The analysis of revenue and budgetary allocation by BudgIT (2020) revealed decline in revenue. This is largely due to declining oil revenue, which is the major source of income for most states in Nigeria, and the recent covid19 pandemic which aided economic meltdown, thus the budget size for capital expenditure has become very thin.

Declining revenue and tight budgetary allocation mean investment decisions by the government must be smarter and based on rational judgment especially when it comes to investment that requires intense funding such as road construction. It is challenging that over the years there is no popularly known documented method on how prioritization of investments on road projects has been consistently revealed. This is the problem this research hopes to solve by deploying analytical methods for deciding how the investment decision on road projects should be prioritized.

Objectives of the Study

The objectives of this study are to:

(i) investigate the methods utilized by Lagos State for prioritizing investment in road projects.

(ii) investigate the established criteria or attributes that should be considered for the prioritization of investment in road projects.

(iii) determine the most important criteria that should be considered for prioritization of investment in road projects.

(iv) provide a simplified multi-criteria decision-making model for the optimal decision on prioritization of investment on road projects in Lagos State.

Research Questions

(i) What are the decision-making methods being used for the prioritization of investment in road projects by Lagos State?

(ii) What are the established criteria or attributes that should be considered for prioritization of investment in road projects by Lagos State?

(iii) What are the most important criteria that must be considered for prioritization of investment in road projects by Lagos State?

(iv) Which simplified multi-criteria decision-making model can be implemented for the optimal decision on prioritization of investment in road projects in Lagos State?

Significance of the Study

Optimal use of resources available through taxpayer's money is important, as this will ensure resources are deployed for significant purposes. Lagos State was considered for this study due to its large population, high traffic congestion, and an increasing number of issues related to the poor road network. It is obvious that government cannot invest all the limited resources in road projects; thus, investment decisions must be optimal. This study will provide a model that can be utilized by decision-makers in determining the priority of road projects when decisions are being made; doing so will ensure improvement in the socio-economic well-being of Lagos State and its habitants. This study will serve as a scaffold for other related research, as we will scientifically; through experts obtain the major criteria that must be considered and ranked accordingly. Finally, this research will provide software engineering firms, entrepreneurs, and the government with an efficient model for investment decision-making on road projects across the public sectors. It will also serve as an addition to the existing literature on investment decisions.

Literature Review

Theoretical Framework

Overview of Multi-Criteria Decision-Making Methods (MCDM)

Several methods for solving MCDM exist. These include TOPSIS, AHP, MULTIMOORA, VIKOR, DEMATEL, ELECTRE, and so on. This literature focuses on DELPHI, AHP, and TOPSIS. DELPHI methods were utilized to determine the consensus among experts on road construction and public sector investment on what criteria should be considered most important for investment in road projects. The result will further be analyzed with

AHP for calculation of weights and later with TOPSIS for prioritization. A combination of the three methods has been widely studied and empirically implemented across various industries. Joshi, Banwet, and Shankar (2011) applied the methods to improve the framework for prioritization of cold chains, and Zhang and Lam (2019) utilized a variant of the three methods to identify the barriers to the adoption of big data analytics. Tzeng and Huang (2011) applied the methods to determine alternative buses for fuel management. Pangsri (2015) applied the methods to prioritize the construction of road projects in a group decision-making process, Yavuz (2020) used the Delphi, APH and Fuzy Topsis to eliminate subjective preference of expert judgment. Wu, Chang, and Liao (2020) applied Delphi, ANP, and TOPSIS methods to determine the optimal host for a variety of shows in the social media era. Sekhar, Patwardhan, and Vyas (2015) developed a framework for prioritization of intellectual capital indicators using Dephi AHP and TOPSIS, Chen, and Hwang (1992) observed that MCDM may be of various methods, however, they have certain aspects in common. Munier, Hontoria, and Jiménez (2019) classified the common aspects of MCDM as components of MCDM. The components of MDCD as described by Munier, Hontoria, and Jiménez (2019) as well as Chen and Hwang (1992) are:

- **Alternatives:** This represents the feasible choices and opportunities available to a decision-maker in order to attain the objectives or goals for which the decision is being made.
- **Criteria:** These use measures used to evaluate alternatives and determined according to the characteristics of the alternatives involved. Criteria could vary from one project to another.
- **Multiple Attributes:** MCDM problems are associated with multiple attributes. Attributes can also be referred to as decision criteria or goals.
- **Conflict among Criteria:** Different criteria indicate different scopes of the alternatives; there are possibilities of conflict between them (cost may conflict with profit etc.)
- **Incommensurable Units:** Different criteria may be associated with different units of measure. This challenge of having different units makes MCDM problems inherently hard to solve.
- **Decision Weights:** Many MCDM methods require that weight should be assigned for each criterion to determine its importance. These weights are then usually normalized to add up to one.
- **Decision Matrix:** MCDM problems are easily expressed in a matrix format. Decision matrix A is an (m x n) matrix in which element A_{ij} indicates the performance of alternative A_i when evaluated in terms of decision criterion C_j (for i =1,2,3, ..., m, and j = 1,2,3, ..., n)

Strategy for Solving MCDM Problems

There are specific patterns for resolving MCDM problems. These patterns can be described as a sequence of steps that must be considered in other to provide an encompassing solution when attempting to proffer solutions to MCDM problems. Howard (1991) also provided similar but more polished steps to resolving MCDM problems:

(i) Defining the objectives
(ii) Choosing the attributes
(iii) Specifying the alternatives
(iv) Transforming the attribute scales into commensurable units
(v) Assigning weights to the attributes which reflect their relative value to the decision maker
(vi) Selecting and applying an algorithm for ranking the alternatives and choosing an alternative.

Rolander, Ceci, and Berdugo (2003) summarized the processes into three phases; structure, analysis, and synthesis. The structure involves the composition of decision components. The analysis involves accessing possible impacts of alternatives and also determining decision-makers preferences for consequences. Syntheses involve the evaluation and compare alternatives.

Delphi Method

Delphi technique is an organized communication a consensus-building approach between a group of experts on a complex problem (Chan, Yung, Lam, Tam & Cheung, 2001). Though a problem might not necessary be difficult, but complex in the sense that there are many schools of thought towards which solution should be best, more importantly all solutions could even produce a right answer. The primary goal of Delphi technique is to get professional feedback from experts on how best a problem can be approach. Delphi method remains a particularly useful alternative for the situation when unbiased data are unattainable, there is a lack of empirical evidence, or experimental research is unrealistic or unethical (Hallowell & Gambatese, 2010). Delphi techniques is the common techniques used in Construction Engineering and Management (CEM). Ameyaw, Hu, Shan, Chan and Le (2016) provided a quantitative perspective into the use of Dephi techniques for CEM. To avoid subjective option when dealing with multi-criteria decision-making issues, researchers tend to rely on expert's opinion, which can be accessed using Delphi techniques. Chen and Hwang (1992); Tzeng and Huang (2011); Pangsri (2015); Wu, Chang and Laio (2020); Yavuz (2020) all combined Dephi technique with various MDCM methods to obtain criteria for their various topics. Gupta and Clarke (1996) stated that when Delphi technique is designed inappropriately and badly executed, it may raise controversies about the result of such a study. Pangsri (2015) specifically used Delphi techniques to determine the factors that are affecting project selection. Delphi techniques will be applied in this study to determine the most important criteria to consider when prioritizing investment on road projects.

Analytic Hierarchy Process (AHP)

The analytic Hierarchy Process was developed by Saaty between 1971 and 1975 while at Wharton School (Saaty, 1987). Since the development of AHP, it has been widely used in various fields to either solve MCDM problems weighting or for ranking. Kasperczyk and Knickel (1996) cited in Lamaakchaoui, Azmani, Jarroudi, and Laghmari (2016) indicated that AHP is one of the best-known and most widely used MCA approaches. Pangsri (2015) described AHP as the structured technique for solving complex decisions; Pangsri maintained that AHP has three basic functions that feature complexity, measuring on a ratio scale, and synthesizing. Papathanasiou and Ploskas (2018) stated that APH's core interest is the determination of the relative difference of one alternative over another. Tzeng and Huang (2011) discussed eigenvalue method, the geometric mean method, the linear programming method, and the lambda-max method as methods to derive weights using the AHP. Eigenvalue method is the only method that was used to deal with number with certainty, while other methods were used to deal with fuzzy numbers. AHP utilizes pairwise comparisons for classifying numerical evaluations of qualitative phenomena from decision makers. Triantaphyllou (2010) observed that AHP model decomposes a difficult MCDM problem into a system of hierarchies of m x n matrix where, m is the number of alternatives and n is the number of criteria. Papathanasiou and Ploskas (2018) described seven steps involved in AHP. These steps are briefly discussed below:

Step 1: Formulate Pairwise Comparison Matrix of the Criteria.

Decision maker expresses how two criteria or alternatives compare to one another. A comparison scale developed by Saaty (1977) is mostly used. The scale is described in Table 01.

Step 2: Perform consistency check on the pairwise comparison matrix of the Criteria. The maximum eigenvalue (λmax) must be equal to n if the pairwise comparison matrix is consistent. Consistency Index (CI) is calculated with;

$$CI(x) = \frac{\lambda \max - n}{n - 1} \qquad (1)$$

Table 01: Saaty Rating Scale

Intensity of Importance	Definition
1	Equal Importance
2	Weak
3	Moderate Importance
4	Moderate Plus
5	Strong Importance
6	Strong Plus
7	Very Strong Importance
8	Very, Very Strong
9	Extreme Importance

Source: Papathanasiou and Ploskas (2018)

Step 3: Compute Priority Vector of Criteria

The most popular method utilized is eigenvector method. Here the principal eigenvector (X) is determined from matrix (X) whose elements are obtained as ratio between weights.

Step 4: Formulate the Pairwise Comparison Matrices of the alternatives for each criterion.

Decision maker decides methods with which alternatives compare to each other for each criterion, thus generating a pairwise comparison matrix of the alternatives for each criterion. These evaluations are collected in ***n*** pairwise comparison matrices of size ***m*** × ***m.***

Step 5: Perform a consistency check on the pairwise comparison matrices of the alternatives. A process similar to step two is repeated, the only difference is that n (number of criteria) is replaced by m (number of alternatives).

Step 6: Compute the local priority vectors of the alternatives.

This is similar to step three where intrinsic alternative priorities are computed for each pairwise comparison matrix of the alternatives.

Step 7: Aggregate the local priorities and rank the alternatives.

The priority criteria and intrinsic alternative priorities are combined to calculate the global alternative priorities.

AHP was extensively applied to prioritization issue of road transportation problems by Shelton and Medina (2010) and Pangsri (2015) to determine weights of criteria. This study will utilize AHP to determine weight of the evaluated criteria for prioritizing road construction obtained from Delphi techniques.

Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)

Hwang and Yoon (1981) developed the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method for solving MCDM. It has gained popularity and used by many researchers; it has also seen tremendous improvements over the years. TOPSIS is based on finding the distance among alternative, where the shortest distance between alternatives considered as ideal positive solution and the farthest distance is referred to as ideal negative (anti-ideal) solution (Triantaphyllou, 2010; Papathanasiou & Ploskas, 2018). Antuchevičiene, Zavadskas and Zakarevičius (2010) evaluated ideal solutions by using Mahalanobis distances, the method was called TOPSIS-M. Euclidian distance approach is the most popular method of evaluating the relative closeness among alternatives for the ideal solution. Triantaphyllou (2010) maintained that preference order of the alternatives can be derived by a series of comparisons of these relative distances. The steps involved in utilizing the Hwang and Yoon (1981) algorithm is briefly discussed below:

Step 1: Convert the various criteria dimensions into non-dimensional criteria. Element $\mathbf{r_{ij}}$ of the normalized decision matrix ***R*** can be calculated using equation (2).

$$r_{ij} = \frac{x_{ij}}{\sum_{k=1}^{m} x_{kj}^2} \qquad (2)$$

Step 2: Construct the Weighted Normalized Decision Matrix

Set of weights ***W*** defined by the decision maker is combined with the decision matrix to generate the weighted normalized matrix ***V***

Step 3: Determine the Ideal and the Negative-Ideal Solutions

The ideal solution is donated as A*, and ideal negative is denoted as A^-alternatives (solutions)

Step 4: Calculate the Separation Measure

The n-dimensional Euclidean distance method is applied to measure the separation distances of each alternative from the ideal and ideal negative solution.

Step 5: Calculate the Relative Closeness to the Ideal Solution

The relative closeness of alternative A_i with respect to the ideal solution A* is measured.

Step 6: Rank the Preference Order

The optimal alternative is decided according to the preference rank order

Prioritization Techniques for Road Construction

Prioritization has been a difficult task on road construction and maintenance, since it can be highly subjective or influenced politically.

Putro and Utami (2017) maintained that prioritization can be implicitly seen when it comes to making choices. Botta and Bahill (2007) explained prioritization as a negotiation process in achieving compromise between diverse stakeholders with different interests. In relations to road constructions, Trigueros (2008) stated that objective of prioritization is to appraise the targeted projects and to rank them in order of importance. Alemayehu (2004) proposed a method called Alternate Methodology (AM) which was specifically developed for developing countries, focuses on attributes of new road project by allocation of weights to prioritize and streamline the projects. Ewadh, Almuhanna and Alasadi (2018) described the methods used for prioritization, such as Simple ranking by PCI measure, ranking by multiple measures and incremental benefit-cost analysis ranking. Ionescu, Burduja and Burlacu (2016) described model for optimal project selection which focuses on disbursement, impact, legitimacy, and feasibility. They further defined another six criteria (efficiency, effectiveness, clarity, fairness, transparency, and capacity) which were referred to as corresponding requirements. Janic (2003) and Walker (2010) agreed that MCDA is a more appropriate decision-making technique for road construction and maintained projects.

Conceptual Framework

The conceptual framework for this study pivots on prioritization of prioritization of investments on road projects. The literature review emphasized the relationship between identified elements of the conceptual framework.

Prioritization

There have been several studies on prioritization; this study focuses on road projects; thus, it discusses prioritization of road projects and infrastructure related issues in the public sector. Defining prioritization in relations to projects, Vanier, Tesfamariam, Sadiq, and Lounis (2006) described prioritization as ranking of projects. This suggests that prioritizing is making optimal decision about project by arranging projects in order of importance. Ionescu, Burduja and Burlacu (2016) identified some core objectives for optimal project selection, which are disbursement, impact, legitimacy, and feasibility. They further described efficiency, effectiveness, clarity, fairness, transparency, and capacity as corresponding requirements for prioritization. Prioritization of project can be very difficult. Meyer and Miller (2001) discussed how subjective method was previously used for determining the cost effectiveness of project, but was found to be highly ineffective. Trigueros (2008) stressed how subjective prioritization can lead to selection process prone to human biases and lack of consistency. He further stated that subjective prioritization will create political bias, thus other methods to improve prioritization must be adopted. The findings above suggest that prioritization is a key to optimal decision making.

Investment on Road Projects

This study describes road project as activities related to construction of new roads or reconstruction of existing road. Investment requires making resources available for execution of road projects. Alemayehu (2004) revealed that many road projects in developing countries are financed by bank loans, grants and some sort of consortium between parties. Investment on road projects is vital to development; Ali and Rieker (2008) stated that efficient infrastructure, such as road projects are not only crucial to the growth of local economy but closely linked to modernization of such environment. Adama (2018) maintained that investment in infrastructure is a popular strategy for attracting private capital. A city like Lagos which is the case considered for this study constantly explore private public partnership investment pattern (PPP). Morley (2002) described PPP as collaboration between the public and private sectors to facilitate a capital-intensive infrastructure project using private finance funding, which is then realized over an agreed period of time from revenue generated through utilization of the completed projects. Road infrastructure is extremely important to development of a nation; Otegbulu (2011) argued that relationship between investment in transportation and economic development has vast implications, as benefits goes beyond movement of goods and people. The provision of efficient infrastructure services should therefore not be seen as only crucial to local economic growth but is intimately linked to the dream that the modern city promises it inhabitants. Agbigbe (2016) argued that road transport infrastructure remains capital intensive; which simply suggest that road project requires huge investment. This established that huge investment on road projects will need to be properly prioritized so that various benefits around such investment can be fully realized.

Prioritization of Investments on Road Projects

Securing the funds required for road projects could be very tedious and time consuming. Alemayehu (2004) maintained that securing funds from lenders involves exhaustive analysis of project prioritization as well as detailed evaluation. Ionescu, Burduja and Burlacu (2016) explained that investment in road projects involves deliberate trade-offs between various purpose of road projects. There are various economic, social and political factors that must be properly considered before an investment decision is made. Prioritization is an act of decision-marking by ranking possible options in the order of priority. Pradeep and Nair (2013) described some popular methods involved in prioritization of projects, which include: (i) Cost Benefit Analysis (CBA) (ii) Producer Surplus Approach (iii) Multi-criteria Analysis. Ionescu, Burduja and Burlacu (2016) argued that there is a need to make optimal decision regarding investments on road projects, which should maximize the value for money. The importance of assessing several criteria involved in prioritization of road projects cannot be overemphasized. Putro and Utami (2017) described multi criteria prioritization technique as methods of evaluating several criteria which must be considered for investment on road projects. Vanier et al. (2006) maintained that the need to critically examine several factors associated to prioritization of road project is vital. Flintsch and Bryant (2006) claimed that the prioritization techniques are usually used in selecting projects in order to evaluate the attributes of different projects under consideration and to justify the purpose of funding. This study focuses on leveraging on multi-criteria decision-making techniques for prioritization of investment in road projects.

Empirical Framework

Filani (2012) claimed that Lagos State is one of the fastest growing cities in the world with a population of 15 million. The most common and crucial means of transportation in Lagos State is road transport, which is widely available and congested throughout the costal state of Lagos (Aigbe, Ogundele & Aliu, 2012); Atubi, 2013(a) & (b)). Several researches affirm the influence of road projects in urbanization; however, the associated difficulties were also identified. Atubi (2010) describe issues like traffic congestion, population and environment as a major problem facing road projects in Lagos State. Due to the huge investment capital required for road projects and the associated impacts on the socioeconomic realities, the need for prioritization of investment of road projects has become vital. Botta and Bahill (2007) described prioritization as process aimed at achieving tradeoff among different players with diverse interest in a project. The earlier explanation of prioritization focuses on the availability of alternatives and their ratio of importance of each of the alternatives. Thus, optimality of prioritization became non mask able through decision making. There have been various researches on decision-making, since there is need to evaluate many criteria between alternatives, a multi-criteria decision-making method is considered the most appropriate for this study.

Alemayehu (2004) worked on prioritization methodology for planning new road projects in developing countries, which established the importance of evaluating key criteria categorized under three broad class: economic, social and political factors. Alemayehu studied the impact of each factor mentioned above to determine the priority on road construction across developing country in research that compared three methods of the evaluation.

Pal, Maitra and Sarkar (2016) relied on AHP, TOPIS and another statistical method for rating in their empirical application of the aforementioned methods to prioritize state highways. Their research emphasized certain attributes they referred to as techno-economic factors to assess the most crucial attribute for prioritization of state highways in India. They also highlighted strategic factors which were believed to be key to their environment considered. They are strategic connectivity to national highway, international borders, availability of road carriageway width, surface condition, connectivity to tourist destinations, industrial hubs and remote locations. Relative weights among various alternatives calculated via AHP, scaled priority index was determined with RIDIT, ranking was then done with TOPSIS and optimal choice was determined. Their solution was empirically applied to determine certain road section and a database was developed for their research. The obtained results from their research have been established to provide good aid to decision makers.

Perhaps the most closely related method describe in this study was by Pangsri (2015) which combined Delphi, Analytic hierarchy process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) for multi-criteria decision-making for project selection within the construction industry. His research was broad regarding project selection but was not sufficient enough to provide a base for combing Delphi, AHP and TOPSIS for prioritizing road projects. Delphi was extensively used to obtain the most important criteria which must be considered for road projects. The criteria obtained from Delphi was referred to as critical success factors, as they are obtained with experts in the field been considered for project selection. It was earlier noted that the choice of MCDM approach was due to social, economic and political factors identified by Alemayehu (2004). In other to prioritize, AHP was utilized to obtain the weight of each criterion. AHP generally involved constructing a hierarchy in relations to the decision, and pairwise comparison matrices to obtain priorities required for determination of weight of each criterion (Alemayehu, 2004). Pangsri (2015) used TOPSIS to rank and determine priorities among alternatives construction projects that he evaluated. The method provides efficient approach to group decision making like road project prioritization. The literature examined above provides a path to understanding the existing research that are most relevant to the prioritization of road projects, they serve as fulcrum for direction and validation of various methods combined for prioritization of road projects. Nevertheless, there are several literatures on prioritization using MCDM to evaluate road project, however this study explores the most relevant and empirical literature on using MCDM for road prioritization.

The Case Study: Lagos State Road Projects

Lagos state is located in the south-west Nigeria, with a dense population, which has been said to have about twenty-four million inhabitants (Atubi, 2010). Lagos State Ministry of Economic Planning and Budget (2013) revealed that in 2009, Lagos state reported that there were about 9,100 roads and expressways in Lagos, actively plied by over 1 million cars, and more than 6 million trips were made daily. Traffic congestion is a notable problem in Lagos State, which has led to many social economic problems in the state. Several agencies were established by various governments to handle road project and monitor traffic situation; introduction of those agencies brought some changes, however, there has not been very significant improvement in road and traffic management. The study considered validating this research by analyzing three roads and ranking them according to order of priority. The combination of Delphi, AHP and TOPSIS was used to enhance and analyze decision making about investment on road projects in Lagos state.

Gap in Literature

There have been many scientific researches on prioritization and utilizing MCDM for prioritization, which proved that MCDM can be a reliable asset to decision makers on prioritization of road projects. However, the existence of research that combined the three methods (Delphi, AHP, TOPSIS) to proffer solution to prioritization of road project is unknown, also no previous work on MDCM for road prioritization in Nigeria was available. The few studies available on prioritization of road projects using MCDM were foreign authored and none of such works focused on peculiarity of Africa.

Methods

Research Design

The research design describes the entire structure describing the processes, tool and techniques utilized to investigate and achieve the objectives of a scientific study. Akhtar (2016) described research design as glue that holds the elements in research together; which covers blue print for collection, measurement and analysis of data. The research focused on prioritization of investment on road project, with Lagos State, Nigeria as a case study. It relies on both quantitative and qualitative data obtained through questionnaires; a specially crafted questionnaire was employed for each round of Delphi technique, till experts involved reached a consensus. A nine point (9 point) Likert scale was used to evaluate the weightage of the criteria obtained through Delphi. Likert scale is a commonly used psychometric scale, the survey questionnaire with Likert scale was deployed to a number of respondents whose role is related to road management, traffic management or road investment. The obtained result was further processed with Analytic Hierarchy Process (AHP), which is aimed at obtaining weight for each of the criteria being considered. Secondary data for three (3) roads was obtained from the Lagos State Ministry of works. Quantitative data was obtained from the secondary data about each criterion previously decided through Delphi method. To determine investments priority among the three (3) identified roads, the quantitative data was processed with Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) which will lead to determination of priority rating (ranking) for each of the alternative roads. In order to calculate AHP and TOPSIS, python programing language was carefully designed to analyze the data and provide value for the needed metrics with little computation resources. The research design was crafted to obtain the most important criteria that must be considered for investment decisions by decision makers within the public sectors on road projects.

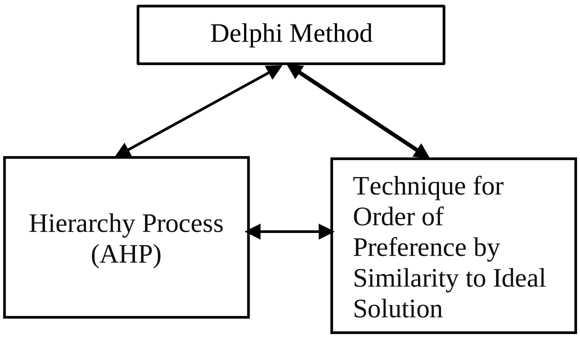

Figure 01: Research Design Overview

Population of the Study

Decision making on infrastructure within the public sector is a known problem, and capital-intensive projects like roads are more in the light. The wildling resources from oil revenue which is the major income shared by the Nigeria states calls for smarter and more effective decision-making concerning road investment decision. The population of the study is the public sector entities responsible for investment decision on road projects.

Data Collection Method

This study relied major on primary data, based on the criteria obtained from the Delphi technique; the Lagos State Ministry Works provided secondary data where specific value for those criteria is extracted for the three alternative roads that were considered in this study. This study focused on investment decisions made from 2003 till 2021. The data consist of data for consensus factors agreed upon by experts using Delphi method. Nine experts involved in managing investment on road project were used as respondents for the Delphi method. Questionnaire was utilized to obtain expert opinion at each round of Delphi technique. The number of rounds of Delphi method was dependent on when consensus is reached amongst the experts involved. A 5-point Likert scale was used to evaluate the weightage of the criteria obtained through Delphi in AHP. Qualitative data was obtained from Lagos State Ministry Physical Planning and Urban Development, Lagos State Ministry of Works and Infrastructure, Lagos State Traffic Management Authority (LASTMA), Lagos Metropolitan Area Transport Authority (LAMATA) and Lagos State Ministry of Finance. The data obtained comprised of:
(i) criteria that must be considered for investment in road projects, (ii) relative importance of each criterion mentioned in (i), (iii) road alternatives to be considered for analysis and ranking based on the methods proposed in this study and (iv) value related to each criterion in (i) for each road alternative specified in (iii)

Data Analysis Method

Several data analysis methods will be utilized at each stage of the analysis. An interview was conducted to obtain response about the current decision-making processes on road investment projects by Lagos States. The obtained qualitative data was coded for interpretation, and analyzed in Microsoft Excel. Delphi technique was used to obtain the criteria need for prioritization; Kendall's coefficient of concordance was used to determine the degree of consensus among the experts involved in Delphi method. AHP was further used to determine the weight of each criterion obtained from Delphi. The secondary data for the three (3) chosen roads was then analyzed with TOPSIS, utilizing the weight of each criterion obtained through AHP.

Delphi Technique

Utilizing the Delphi technique, a questionnaire was distributed to six experts involved in investment and management decisions on road projects in Lagos. The questionnaire employed a five (5) point Likert scale. Another question was drafted based on the first questionnaire issues to expert respondents. The final round of Delphi technique was determined when consensus was reached. Kendall's coefficient of concordance was used to determine the reliability of the consensus reached.

Kendall's W

$$W = \frac{12R}{m^2(k^3 - k)} \qquad (3)$$

m is the total number of experts (raters), ***k*** is the total number of criteria (subject), while ***R*** is the square deviation, $\bar{R}$ is the mean of *R*, r_{ij} is the rating expert (rater) ***j*** gives to criteria (subject) ***i.***

$$R = \sum_{i=1}^{k} (R_i - \bar{R})^2 \quad (4)$$

$$R_i = \sum_{j=1}^{m} r_{ij} \quad (5)$$

Analytic Hierarchy Process (AHP)

AHP was used to determine weight of each criterion identified through Delphi technique. The qualitative measurements was converted into quantitative values to obtain the respective commensurate units. Road project prioritization criteria was assessed using the following five (5) rating: very low, low, average, high, and very high. The response obtained was then transposed into a pairwise comparison: 9,7,5,3, 1 and 2,4,6,8 respectively. The procedure for AHP analysis was then used.

Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

The three (3) alternative roads obtained from secondary data obtained from Lagos State were analyzed with TOPSIS. Based on the value of obtained from the secondary data about the alternative roads. TOPSIS ranks the alternatives based on their closeness with ideal solution.

i.

$$r_{ij} = \frac{x_{ij}}{\sqrt[1]{\Sigma_{i=1}^{m} \ \Sigma_{j=1}^{n} \ x_{ij}^2}} \quad (6)$$

r_{ij} = relation matrix
x_{ij} = input for matrix i=1……m as alternatives,
j= 1….,n as criteria

ii. Build the weighted normalized matrix
$v_{ij} = w_i r_{ij}, \ i = 1, \dots \dots . m \qquad j = 1, \dots \dots n$
v_{ij} = weighted normalized matrix

iii. Calculate the positive and negative idea solutions

$$A^+ = \{ v_1^+, . \dots \dots v_n^+ \}, where \ v_j^+ = \{\max(v_{ij}) \in J; \ \min(v_{ij}) \ if \ j \in j'\} \quad (7)$$

$$A^- = \{ v_1^-, . \dots \dots v_n^- \}, where \ v_j^* = \{\min(v_{ij}) \in J; \ \max(v_{ij}) \ if \ j \in j'\} \quad (8)$$

A^+ *is positive ideal solution and* A^- negative ideal solution

iv. Measure separation (positive and negative) measures for each alternative.

$$S_i^+ = \sqrt{\sum_{j=1}^{n} \left(V_J^+ - V_{i_j}\right)^2}, i = 1, \dots \dots, m \quad (9)$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} \left(V_J^- - V_{i_j}\right)^2}, \quad i = 1, \dots . . , m \quad (10)$$

S_i^+ $is\ seperation\ from\ ideal\ solution,$
S_i^- $Separation\ from\ Negative\ ideal\ solution$

v. Calculate relative closeness to the ideal solution

$$C_i^+ = \frac{S_i^-}{(S_i^- + S_i^+)}, \qquad 0 < C_i^+ < 1, i = 1, \dots . m \quad (11)$$

C_i^+ $is\ clos$eness to ideal solution
In (v) alternates are evaluated for ranking the ideal best solution.

Findings and Discussion

Analysis According to Research Objectives

Investigate the methodologies utilized by Lagos State for prioritizing investment on road projects.

An interview became necessary to investigate the existing methodologies used by Lagos Sate. Senior government officials that are knowledgeable about decision making relating to prioritization process in Lagos State were interviewed independently. To ensure consistency, the guideline below was developed:

i. Describe your knowledge about road constructions and investment decision making on Lagos roads?
ii. How does Lagos state decide which roads to construct?
iii. Do you know if there is a scientific model of doing this, such as some software for determining which road should be considered first for investment.
iv. Describe the methods used in (iii) or any other methods used to determine the priority of road constructions?

The responses from the interviews were analyzed with Microsoft excel, thus revealing the symmetrical patterns about the research objective.

Investigate established criteria considered for the prioritization of investment on road projects

The research investigated the position of experts on the list of criteria that should be considered for prioritizing of investments on road projects in Lagos state. To achieve this, forty open-ended questionnaires were distributed to professionals involved in road management, construction and investment in Lagos. A qualitative data was returned and analyzed with Microsoft excel. The result was grouped based on similarity and a total of twelve criteria was discovered. The criteria include: interconnectivity; traffic relieve; political considerations; proximity to strategic locations; capacity to serve as bypass; socio-economic benefits; environmental safety; overall project cost; construction complexity; popular demand by citizens; population density of the areas, and associated cultural heritage.

Thus, from the result obtained through our open-ended questionnaires, twelve criteria that would be considered by professionals to prioritize investment in road project in Lagos state were determined.

Determine the most important criteria that should be considered for prioritization of investment on road projects

In a bid to determine the most important criteria, we engaged nine (9) professionals drafted from Lagos State Ministry of Physical Planning and Urban Development, Lagos State Ministry of Works and Infrastructure, Lagos State Traffic Management Authority (LASTMA), Lagos Metropolitan Area Transport Authority (LAMATA) and Lagos State Ministry of

Finance. A table listing the twelve criteria was sent to each of the professionals engaged. In other to prevent group think effect, we employed the use of Delphi technique to filter out topmost criteria that should be considered. After three rounds, the most occurring criteria were visible. To measure the agreement among the raters, we utilized Kendall's coefficient of concordance (W) to determine the reliability of the consensus reached.

$$W = \frac{12R}{m^2(k^3 - k)} \qquad (12)$$

W is Kendall's coefficient of concordance, m is the total number of experts (raters), k is the total number of criteria (subject), while R is the square deviation, $\bar{R}$ is the mean of R, r_{ij} is the rating expert (rater) j gives to criteria (subject) ***i.*** The following result was obtained as agreement between raters.

Table 02: Kendall's coefficient of concordance

	Mean Rank
Interconnectivity	10.00
Traffic Relieve	8.89
Political Considerations	7.72
Proximity to Strategic Locations	5.78
Capacity to serve as Bypass	9.78
Socio-economic Benefits	10.22
Environmental Safety	3.67
Overall Project Cost	4.67
Construction Complexity	5.06
Popular Demand by Citizens	6.00
Population Density of affect areas	4.00
Associated Cultural Heritage	2.22

$$\boldsymbol{W} = 0.580 \;, \qquad m = 9$$

Kendall's coefficient shows that 58% of the 9 professionals engaged using the Delphi technique agreed that certain criterion are more important than other. Thus, each criterion is ranked according to order of priority. The five topmost criteria considered as being of most important are: Socio-economic benefits; Interconnectivity; Capacity to serve as bypass; Traffic relieve; and Political considerations. Thus, from the result obtained through stepwise analysis of the data obtained from Delphi techniques, five topmost criterions that should be considered for road investment prioritization was established.

Provide simplified multi-criteria decision-making model for optimal decision on prioritization of investment on road projects in Lagos State

The model to simplify prioritization of investment on road projects in Lagos state was built on Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and Analytic Hierarchy Process (AHP). In order to test the effectiveness (ascertain the effectiveness of the model) secondary data obtained from Lagos State Ministry of Works and Infrastructure was utilized to investigate alternative road projects that should be considered for prioritization using the TOPSIS model provided in chapter three of this study. The first approach was to prepare the criteria obtained from earlier process by adding weight to them in other to decide the implication of each criterion on each of the alternative road projects. To achieve this, Analytic Hierarchy Process (AHP) is a proving tool for determine the weight of each criterion in relations with the alternatives been considered. However, since the research requires the input of professionals directly involved in investment, construction and management of road projects across Lagos State, it became vital to ensure there is an agreement on how established criteria are impressed for consideration as it applies to each of the alternatives. Kendall's coefficient of concordance (W) was used to determine the agreement among the professionals as to how each criterion was considered for investment in the selected alternatives.

The three alternative choices of road considered from the secondary data are: Agric - Isawo Road, Agege - Pen Cinema Flyover, and Lekki-Epe Expressway. Each of the criteria was ratted in comparison to how they apply to the alternative roads. To achieve this, the five selected professionals were given 5 point Likert scale to rate each of the criteria as it applies to each of the alternative road projects.

Table 03: Five (5) Point Like RT Scale

Scale	
Strongly Agree	1
Agree	2
Undecided	3
Disagree	4
Strongly Disagree	5

Each road alternatives are then rated according to the criteria provided. The agreement among raters was further measured using Kendall's coefficient of concordance (W).

Table 04: Rating of Agric-Isawo Road

RATER	Socio-Economic Benefit	Interconnectivity	Capacity to Serve as Bypass	Traffic Relieve	Political Consideration
1	1	1	1	2	3
2	2	1	1	4	1
3	1	1	2	1	2
4	1	2	1	5	2
5	2	1	2	1	1

The result of Kendall's coefficient of concordance (W) is **0.133** (13.3% of the raters) which obviously shows raters varying opinion about how each criterion applies to Agric – Ishawo road which is been considered as first alternative.

Table: 05: Agege - Pen Cinema Flyover

RATER	Socio-economic Benefits	Interconnectivity	Capacity to Serve as Bypass	Traffic Relieve	Political Considerations
1	1	4	3	1	1
2	4	4	2	1	1
3	4	3	4	1	4
4	5	5	5	1	4
5	3	2	4	2	2

Result of Kendall's coefficient of concordance (W) is **0.546** (54.6%, among five raters) which shows that more than half of the raters agreed with how each criterion applies to Agege-Pen cinema flyover road which is been considered as second alternative.

Table 06: Lekki-Epe Expressway

RATER#	Socio-economic Benefits	Interconnectivity	Capacity to Serve as Bypass	Traffic Relieve	Political Considerations
1	1	4	1	1	4
2	1	4	2	1	5
3	1	5	2	1	5
4	1	5	2	2	3
5	1	3	1	2	4

Kendall's coefficient of concordance (W) is **0.882**, which shows that 88.2% of the raters agreed with how each criterion applies to Lekki-Epe expressway road that is been considered as the third alternative.

The following step was taken to organize and analyze the data.

i. The hierarchical system by decomposing the problem into a hierarchy of interrelated elements was setup

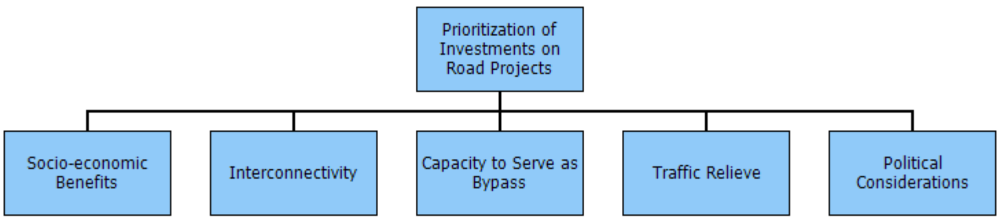

Figure 02: Hierarchical System

ii. A pairwise comparison matrix of the criteria is then formed using the Saaty's nine (9) point scale described in earlier chapter, the comparisons are collected in an n × n pairwise comparison matrix.

Table 07: AHP Pairwise comparison of criteria

	Socio-economic Benefits	**Interconnectivity**	**Capacity to Serve as Bypass**	**Traffic Relieve**	**Political Considerations**
Socio-economic Benefits	1	3	4	6	8
Interconnectivity	1/3	1	4	6	9
Capacity to Serve as Bypass	¼	¼	1	3	7
Traffic Relieve	1/6	1/6	1/3	1	2
Political Considerations	1/8	1/9	1/7	1/8	1
Column Total	45/24	163/36	199/21	129/8	27

iii. The preferences obtained from the comparisons was used to weigh the priorities in the level immediately below in the matrix. This was done for every element. For each element in the level below, add its weighed values and obtain its global priority.

Table 08: Normalized matrix for ranking and weighting of criteria

	Socio-econ	**Interconnectivity**	**Capacity to serve as bypass**	**Traffic Relieve**	**Political Consideration**	**Priority Weight**
Socio-econ	0.5333333	0.662577	0.422111	0.372093	0.296296	0.457282
Interconnectivity	0.177778	0.220859	0.422111	0.372093	0.333333	0.305235
Capacity to serve as bypass	0.133333	0.055215	0.105528	0.186047	0.259259	0.1478764
Traffic Relieve	0.088889	0.036810	0.035176	0.062016	0.074074	0.059393
Political Consideration	0.066667	0.024540	0.015075	0.007752	0.-37037	0.030214

λ_{max} =5.391 CI =0.0978 CR =0.087 < 0.1

Continuing the evaluation aimed at ranking the three alternatives in the order of priority, TOPSIS model was employed. The following steps were adopted to obtain result using TOPSIS.

STEP 1: A decision matrix was drawn by adopting the difference between the mean for each criterion obtain during the calculation of Kendall's coefficient of concordance (W).

Table 09: TOPSIS Decision Matrix

	Socio-economic Benefits	**Interconnectivity**	**Capacity to Serve as Bypass**	**Traffic Relieve**	**Political Considerations**
Agric - Isawo Road	2.8	2.3	2.9	3.6	3.4

Agege - Pen Cinema Flyover	3.7	3.5	4	1.5	2.3
Lekki-Epe Expressway	1.5	4.4	2.4	2.1	4.6

STEP 2: Normalize the decision-matrix

The following expression was used to normalize the matrix.

$$r_{ij}(\mathrm{x}) = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \qquad i = 1, \dots, m \quad ; j = 1, \dots \ , n \quad (13)$$

$r_{ij} = relation\ matrix$
$x_{ij} \ = input\ for\ matrix\ i = 1 \dots \dots m\ \ as\ alternatives\ ,$
$j = \ \ 1 \dots . , n\ \ as\ criteria$

Table 10: Normalized Matrix

Agric - Isawo Road	0.574	0.379	0.528	0.813	0.551
Agege - Pen Cinema Flyover	0.759	0.576	0.728	0.339	0.373
Lekki-Epe Expressway	0.308	0.724	0.437	0.474	0.746

STEP 3: Calculate the weighted normalized decision matrix

The normalized matrix is multiplied by the weight of the criteria, obtained from AHP in Table 08.

$$v_{ij}(\mathrm{x}) = w_j r_{ij}(x) \qquad i = 1, \dots, m \quad ; j = 1, \dots \ , n \qquad (14)$$

where, v_{ij} = weighted normalized matrix.

Table11 shows the weighted normalized decision matrix.

Table 11: Weighted normalized matrix

	Socio-economic Benefits	**Interconnectivity**	**Capacity to Serve as Bypass**	**Traffic Relieve**	**Political Considerations**
Agric - Isawo Road	0.271	0.115	0.071	0.045	0.018
Agege - Pen Cinema Flyover	0.358	0.176	0.098	0.019	0.012
Lekki-Epe Expressway	0.145	0.221	0.059	0.026	0.024

STEP 4: Determine the positive ideal and negative ideal solutions

TOPSIS is used to calculate the degree of distance of each alternative from positive and negative ideals.

$A^+ = (v_1^+, v_2^+, \dots, v_n^+)$

$A^- = (v_1^-, v_2^-, \dots, v_n^{-+})$

A^+ *is positive ideal solution and* A^- negative ideal solution

So that,

$v_j^+ = \{(max\, v_{ij}(x) \mid j\epsilon j_1), (min\, v_{ij}(x) \mid j\epsilon j_2)\}\ i = 1, \dots, m$

$v_j^- = \{(min\, v_{ij}(x) \mid j\epsilon j_1), (max\, v_{ij}(x) \mid j\epsilon j_2)\}\ i = 1, \dots, m$

v_j^+ *positive ideal solution and* v_j^- negative ideal solution

where j_1 and j_2 denote the negative and positive criteria, respectively.

Table 12: shows both positive and negative ideal values

	Positive ideal	Negative ideal
Socio-economic Benefits	0.358	0.145
Interconnectivity	0.221	0.115
Capacity to Serve as Bypass	0.098	0.059
Traffic Relieve	0.045	0.019
Political Considerations	0.024	0.012

STEP 5: Determine distance from the positive and negative ideal solutions

In TOPSIS method, alternatives are ranked based on the relative closeness degree to the positive ideal and distance from the negative ideal.

$$S_i^+ = \sqrt{\sum_{j=1}^{n} [v_{ij}(x) - v_j^+(x)]^2} \quad , \quad i = 1, \dots, m$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} [v_{ij}(x) - v_j^-(x)]^2} \quad , \quad i = 1, \dots, \mathrm{m}$$

where,

S_i^+ *is seperation from ideal solution and* S_i^- *separation from Negative ideal solution*

Table 13 shows the distance to the positive and negative ideal solutions.

Table 13: Distance to positive and negative ideal points

	Distance to positive ideal	Distance to negative ideal
Agric - Isawo Road	0.14	0.129
Agege - Pen Cinema Flyover	0.054	0.225

Lekki-Epe Expressway	0.217	0.106

STEP 6: Calculate the relative closeness degree of alternatives to the ideal solution.

The relative closeness degree of each alternative to the ideal solution is obtained by the following formula. If the relative closeness degree has value near to 1, it means that the alternative has shorter distance from the positive ideal solution and longer distance from the negative ideal solution.

$$C_i = \frac{d_i^-}{(d_i^+ + d_i^-)} \quad , \quad i = 1, \ldots, m$$

C_i^+ *is clos*eness to ideal solution

Table 14: Relative closeness degree of each alternative to the ideal solution and its ranking

C_i value and ranking		
	C_i	**Rank**
Agric - Isawo Road	0.481	2
Agege - Pen Cinema Flyover	0.808	1
Lekki-Epe Expressway	0.329	3

The result shows that Agege - Pen Cinema Flyover ranks 0.808, which makes it the most important and it's investment should be prioritized ahead of other road investment alternatives. This is followed by Agric - Isawo Road, while Lekki-Epe Expressway ranks the least of the three roads. Thus a simplifed approach using TOPSIS model provides simplified multi-criteria decision-making model for optimal decision on prioritization of investment on road projects in Lagos State.

Discussion

Through the interview conducted with three top officials responsible for road investment related decision making in Lagos State, the study was able to establish that Lagos State does not have a scientific model dedicated for making decision on investment on road projects. The current methodologies are manual combination of decision made according to geographical information tools, financial data and subjective political influence usually dictated by the direction of the ruling government.

Twelve criteria were discovered as the most impressing factors that are considered for prioritization of investment on road projects in Lagos State. They are interconnectivity; traffic relieve; political considerations; proximity to strategic locations; capacity to serve as bypass; socio-economic benefits; environmental safety, overall project cost; construction complexity, popular demand by citizens; population density of the affect areas and associated cultural heritage.

The need to narrow down the criteria earlier discovered became very eminent. Using Delphi techniques, the five topmost important criteria that must be considered were obtained and ranked accordingly. The criteria are listed according to rank of importance as socio-economic benefits, interconnectivity, capacity to serve as bypass, traffic relieves, and political considerations.

The model created used AHP to assign weigh to each criterion which was passed to TOPSIS for further computation in other to obtain a result of how road prioritization for investment on the selected roads should be ranked using secondary data obtained from the Lagos State Ministry of Works and Infrastructure. Since the criteria described earlier does not relate directly to the obtained secondary data, Delphi technique was used to get experts to agree on how the value of each criterion should apply to each of the alternative road been considered for TOPSIS computation. Agege - Pen Cinema Flyover ranked first with relative closeness to idea solution of 0.808, while Agric - Isawo Road ranked second with relative closeness to ideal solution of 0.481, and Lekki-Epe Expressway ranked lowest with relative closeness to ideal solution of 0.329. This suggest that had this model being used to make decision on investment on road project by Lagos State Government base on the five important criteria stated earlier, Agege - Pen Cinema Flyover should be the most important project in comparison with the two other alternatives road projects. These findings are novel and possibly the first of its kind in west Africa, since related studies that measures prioritization of investments on road projects using multi-criteria decision-making model such as TOPSIS to achieve the objective was not discovered prior to this research study.

Conclusion

The study clearly answers the research questions which it was designed to answer. The current pattern of prioritization of investment on road project by government needs to be improved by adopting scientifically proving method. Key criteria to be considered for prioritization was established, the most important criteria were also identified and validated by ranking three alternative road projects through a multi-criteria decision-making technique called Technique for Order of Preference by Similarity to Ideal Solution. Engaging the developed simplified decision-making model on road investment decision in Lagos State could be a game changer, capable of enhancing and standardizing decision-making on investment in road projects in Lagos State.

Recommendations

Based on the findings and conclusion, the following have been recommended for decision making about prioritization investment on road projects in Lagos State:

There is need for Lagos State to adopt a stable model for decision making about prioritizating investment on road projects. Adopting this simplified approach for empirical use will make decision around road projects more transparent, efficient and less dependent on the emotions of the government in power and associated political will.

There is also a need to invest in scientific methods to measure criteria identified as most crucial for prioritization investment on road projects in Lagos state. Thus, available secondary data about road projects in Lagos State can be shared with relevant stakeholders (the academics) with a view to validate the data on how those criteria apply to projects under consideration.

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