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ORIGINAL RESEARCH ARTICLE

TOWARDS SUSTAINABLE ROAD INFRASTRUCTURE DELIVERY IN NIGERIA

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ABSTRACT

Due to current Federal Government infrastructure transformation policy agenda and economic development growth, there is a lot of pressure on Nigeria's infrastructure, especially on roads. The construction of roads is capital intensive requiring long-term financial supports. The aim of this paper is to investigate the theory and practice that adopt sustainability concept at road and general infrastructure delivery in Nigeria. Multi-Criteria Decision Model or Method was used (Weighted Sum Model) for sustainability index. The mathematical model for computing the sustainability index in achieving the required result was formulated. Additionally, a cognitive/reasoning map system was used as decision aid. The result shows that sustainability criteria and indicators are chosen based on the project specific or regional priorities or needs. The study also showed that there is no systematic method of sustainability appraisal in Nigerian construction industry. It proposed both multi-criteria method of analysis and cognitive/reasoning map because of their mathematical foundation and practical applications, and recommends that sustainability drivers should be integrated with their different perceptions and priority needs. It also recommended the introduction of Sustainability Impact Assessment.

1.0 Introduction

Road or general infrastructure development plays a vital role in determining environmental sustainability. It is essentially intermeshed with economic growth, people's lives or livelihood and environmental sustainability. Road infrastructure projects are often large in scope and financial scale. They require high energy input, huge resource consumption, considerable land use and all elements which may cause serious impacts on the environment and society (Yang and Lim, 2008). Therefore, current road infrastructure development in Nigeria will have impact on future sustainability and people's welfare for many years. While their impacts to environmental and social issues are of great concerns, infrastructure development also underpins a nation's economy and prosperity, therefore, it is equally important and necessary to take cognizance of this advantage and balance the constraints and develop sustainable road infrastructure projects in the country. Nigerian stakeholders (both private and public sectors), are under pressure looking for economically feasible, socially viable and environmentally acceptable project management techniques that will lead to the actualization of projects with sustainability elements with respect to the economy, environment, and society. This will require not only the adoption of sustainability principles during project conception, planning, design and innovative technologies and products during construction but also the evaluation of results of doings so and the consideration of accountability during project delivery. However, current efforts to integrate sustainability elements into project conception, planning and execution, are often impeded by different interpretation on sustainability by stakeholders involved in road infrastructure development. As a result, achieving sustainability outcomes for all stakeholders in road projects remains as a formidable task.

The above problem calls for the need to formulate new approaches that are able to integrate and synthesize all the dimensions and different points of view for the logistic consideration by multiple stakeholders in developing sustainable road infrastructure (Oraegbune, 2015).

The successful implementation of sustainability consideration in general infrastructure (road) development may be a viable method to improve the current situation and its shortcomings. Enhancing sustainability of project allows for more environmentally – friendly and socially acceptable operations. The anticipated benefits of sustainability enhancement in road and general infrastructure development are as follows:

i. Improvement of the quality of urban and road life both in the short and long – terms.
ii. Protection of the local environmental and reduction in impact on the worldwide environment from a long – term point of view.
iii. Preserving environmental, social and cultural assets for future generations.
iv. Improving the economic efficiency and life cycle of the road infrastructure and some other utilities/services.

Implementation of sustainability can be achieved in two ways: firstly by gaining institutional support of implementation and secondly by developing and utilizing new technologies that change current practice and provide more sustainable approaches (Koo and Ariaratnam, 2009).

Despite the attention focused on sustainability, neither standard road map or measurement nor a systematic approach of assessment have been officially adopted or developed for use or implementation in Nigeria infrastructure system, although some advanced countries have adopted or developed their own assessment systems in infrastructure or road projects.

The aim of this paper is to investigate the theory and practice that adopt sustainability concept in road infrastructure delivery in Nigeria. The study covers current conceptual applications of sustainability development to the theoretical and practical model for sustainable infrastructure delivery (road projects) in Nigeria. The topics discussed are the following: current sustainability analysis method, sustainability criteria and indicator identification and sustainability assessment tools which uses weighed sum model.

2. Key Performance Indicators as a tool for road infrastructure

In recent studies which identified key performance indicators for infrastructure in the South African/Hong Kong Construction indicators, Ugwu and Haupt (2005) developed a comprehensive list of key sustainability items and their indicators (Table 1). These constructs incorporate internationally accepted matrices such as economy, environment and society. Furthermore, as suggested by the industry operators, they incorporate other performance – based indicators such as health and safety, resource utilization and aspects related to project management (Oraegbune, 2015).

Table 1: Key Sustainability Items and Indicators in Infrastructure Sustainability

S/N	Key Sustainability Items	Indicators	Sub-Indicators
1.	Economy	Direct Cost	Initial cost, life cycle cost
		Indirect Cost	Resettling cost of people /rehabilitating cost of eco-system, adverse impact in tourism values and employment of labour.
2.	Environment	Land Use	Extent of land acquisition, extent of tree falling, extent of loss of habitat or feeding grounds, connectivity with hinter land.

		Water	Impact as to assessment under environment impact assessment regulation (EIAR) and water reuse.
		Air	Impact as to assessment under EIAR, air outlet design, ventilation design during construction and service stage.
		Noise	Impacts as to assessment under EIAR design flexibility for noise reduction measures.
		Visual Impact	Impact as to assessment under EIAR, view from assessor, harmony with surrounding.
		Ecology	Impact as to assessment under EIAR, reprovision of habitat.
		Waste Management	Solid construction materials, liquid waste –toxic and non-toxic, extent of encroachment upon concerned areas.
3.	Society	Cultural Heritage	Footprint of project in archaeological site, complaints from local parties/villages and extent of diversion.
		Public Access	Extent of Blockage, extent of congestion and view from local authorities.
		Public Perception	
4.	Resource Utilization	Site Access	Routes for construction traffic and availability of construction material.
		Material Availability	Use of local materials and those complementary with chosen materials.
		Type	Prefabricated materials and innovative materials.
		Constructability	Early contractors' involvement and early suppliers' involvement.
		Reusability	Reusability of moulds, formwork etc and scrap value after decommissioning.
		Quality Assurance	Ease of quality control
5.	Health and Safety	Occupational Hazard	Short term health (e.g. spread of diseases, cleanliness of site etc), long term health (e.g. respiratory duct disease, permanent deafness etc). Accident, injuries, fatalities etc.
		Public	General, health and safety
6.	Project Management/ Administration	Contract	Type of contract, inclusion of sustainability related clauses in project specification, project duration project complexity and amount of paper.
		Procurement Method	Approach to/criteria for procuring contractors and supplier's choice of delivery system (e.g. design-build).

Source: Lim (2009) and Ugwu and Haupt (2005)

Several reasons for holes or gap in the implementation of sustainability principles by construction stakeholders in infrastructure projects have been advanced by researchers (Oraegbune, 2015, and Ugwu and Haupt, 2005) as follows: (1) Lack of education and mind sets of stakeholders (especially of the construction decision –making), has significant impacts on infrastructure sustainability throughout the projects life cycle; (2) Short-term focus rather than a long-term view during decision making, and (3) Lack of flexible user friendly tools to facilitate quantitative analysis and decision support.

2.3 Current Methods for Sustainability Assessment

Current methods of sustainability assessment being employed in the infrastructure industry and that can be usable in road construction projects for excellent results are presented in Table 2.

Table 2: Assessment Model for Sustainable Infrastructure

Sustainability Assessment Tools	Summary
Civil Engineering Quality Assessment and Awards Scheme.	* Aimed at improving sustainability in civil Engineering and public realm projects by providing an incentive to clients, designers and contractors to adopt best environmental and social practices and therefore deliver more sustainable constructions.
Project sustainability management (PSM) guidelines developed by the international federation of consulting Engineers.	* These constructs/concepts incorporate internationally and accepted sustainability matrices such as economy, environment and society. It also incorporates other performance-based indicators such as health and safety, resource utilization and project management.
Australia Green Infrastructure Council Australia.	* AGIC infrastructure sustainability rating scheme and associated tool is still in the early stage of development of sustainability categories and 27 sub-categories have been identified, covering the areas of project management, and governance, economic performance.
Defence Estate Sustainability Appraisal Tool (DESAT) developed by Australia Ministry of Defence.	* This sustainability appraisal tool has been produced to help MOD project managers, decision-making and construction to fulfil their environmental objectives.
Sustainable project appraisal Routine (SPeAR) developed by Australia consulting company (ARUP).	* A design tool enabling companies and organizations to assess their sustainability performance over time. The tool is applicable to wide range of sections and to all levels of projects from strategic policy development to individual project assessment.
VIC Roads sustainable roads assessment (SRA), developed by Victoria Government in Australia.	* The tool aims to guide the road, construction industry towards more sustainable practices.
Green Highway Partnership developed by U.S.A (EPA & FHWA).	* For transportation infrastructure projects. This is mainly sustainability performance metric for measurement systems that provided guidance specific to building more sustainable transport projects.
Green Highway Construction in Taiwan.	* Another infrastructure designing and construction rating system available for sustainable infrastructure projects. A collection of sustainability best practices which can be applied to any roadway projects.

Source Oraegbune (2015)

From Table 2, the project stakeholder can select the method that best suit the project at hand.

2.4.1 Multi-Criteria Decision Method (MCDM)

In the multi-criteria method, the Weighted Sum Model (WSM) is used formulate the mathematical model for computing the sustainability index (SI). The appraisal matrix from which the model can be formulated is presented in Table 3.

Table 3: Sustainability Appraisal Decision Matrix

Design Alternatives or Options	Sustainability Criteria				
	Sc_1 W_1	Sc_2 W_2	Sc_3 W_3	Sc_4 W_3	Sc_{CN} W_N
A_1	$a_{1,1}$	$a_{1,2}$	$a_{1,3}$	$a_{1,4}$	$a_{1,N}$
A_2	$a_{2,1}$	$a_{2,2}$	$a_{2,3}$	$a_{2,4}$	$a_{2,N}$
A_3	$a_{3,1}$	$a_{3,2}$	$a_{3,3}$	$a_{3,4}$	$a_{3,N}$
A_M	$a_{M,1}$	$a_{M,2}$	$a_{M,3}$	$a_{M,4}$	$a_{M,N}$

Source: (Oraegbune, 2015 and Ugwu et al., 2006)

Key =Sc_i = Sustainability criteria
= Di or Ai = Design Alternative
A_{ij} or D_{ij} = User assigned utility (Scalar value) that measures the performance of Ai or Di on Sc_i

The sustainability index (SI) is defined as a crisp value that is an aggregated measure of performance of an alternative (such as a design alternative or option) along various sustainability dimensions (economy, environment, society, project management, resources utilization, health and safety). The underlying assumption here is the additive/cumulative utility of a given design proposal (as measured by the sustainability index) depend on its individual utilities in the various decomposed elementals sustainability indicators. The assumption holds for most extent theories of utility and is particularly true of the concept of "generalized additivity (Ugwu et al., 2006). Also the use of weighted sum model assumes that the decision criteria can be expressed in the same unit of measures. This is achieved by using dimensionless numerical scores (scalar quantity) in the sustainability appraisal process.

Let Sl_i, (For i = 1, 2, 3…M) represent the final sustainability index (a crisp value) of design alternative (Di or Ai) (Table 3) when all decision criteria a_{ij} are considered. The next problem is how to compute Sl_i .There are different Multi-criteria Decision Method (MCDM) such as Weighted Sum Model (WSM), Weighted Product Model (WPM), Analytical Network Process (ANP) and Analytical Hierarchical Process (AHP) (Saaty, 1980, 2008, Chan et al., 1992 and Triantaphyllou et al., 1994, Fishburn ,1967 and Triantaphyllou, 2000). Any of these methods is considered sufficient for formulating an underpinning or solid base for mathematical model for quantitative sustainability appraisal (Ugwu et al., 2006).

The decision is further buttressed by the fact that a review of some completed case study of major projects and application of MCDM techniques in practice indicates that the weighted sum model is widely used for practical decision making in real life situations (Ugwu et al., 2006). It is therefore considered valid enough to develop a mathematical foundation for sustainability appraisal in using the WSM method; the SI of design alternative Di or Ai is calculated using the following formula adopted from works of Fishburn (1967) and Ugwu et al. (2006) as expressed in the following Equations.

$$Sl_i = \sum_{i=1}^{n} a_{ij} w_j \; (for\ i = 1, 2, 3, \ldots M) \quad (1)$$

$$Sl = \sum Sl_i \quad (2)$$

$A_i\ or\ D_i\ (WSM^{score})$ is defined as follows $A_i\, WSM^{-score} = \sum_{j=1}^{n} aijWj\ (j = 1,2,3, \ldots M)$ (3)

where: W_j is relative weight of importance of the criterion, Cj and aij are the performance value of alternative Ai when it is evaluated in terms of alternative Ai. For the maximization case, the best alternative is the one that yields the maximum total performance value.

Another underlying assumption in all MCDM methods is that the decision maker can quantify performance for a given design evaluation (Ugwu et al., 2006). Therefore, the decision maker is considered to have sufficient knowledge and expertise (including experimental knowledge) in scoring the performance of design Alternatives Computational analysis performed using these assigned dimensionless scores (scalar quantities). Hence they are considered to be valid for the mathematical model formulation that explains the decision-making criteria aij in Equation (1).

3. Survey Instruments and Methodology

Some of the information used in this discuss were obtained from a combination of structured questionnaires, interviews with professionals working with both public and private sectors or establishments, case study project data, sustainable construction projects, environments and transportation/infrastructure projects, literatures on sustainability research and questionnaires-based survey for indicators.

The survey was conducted for a period of 8 months which started from March and ended in September, 2012. A total of 150 questionnaires were sent out or distributed to various professionals, consultants, clients and contractors in some selected geopolitical regions or zones in Nigeria (South East, South-South, Lagos, Abuja, North-East).

In order to achieve the objectives, the questionnaires were divided into 3 parts. Part I elicited respondents background information (demographic data), while parts II and III focused on eliciting stakeholders' perceptions and prioritization on the sustainability of various proposed indicators for use in assessing transport and general infrastructure projects. The questionnaires were distributed using a combination of internal circulation through contact persons working in the identified ministries, corporations or government organization through personal contacts, by email and face-to-face interviews.

In part I, personal background questions and information on such programs as Global Reporting Initiatives (GRI) and United Nations Commissions on Sustainable Development (UNC-CSD) and levels of use or involvement in such programs in practice. It was noticed that sustainability awareness has not been widely addressed in Nigeria. However, government is making effort for the implementations of sustainability concept in our infrastructure projects. It was also observed that there is no systematic appraisal tools and methods use in practice level. The personal background information elicited included the respondents experience and participation in sustainability driven infrastructure projects. Parts II and III of the questionnaires asked respondents to give a score from 1 – 5 against each of the selected indicators to determine the suitability of methods to assess the sustainability of typical transport and general infrastructure projects. This translate as follows on the Likert Scale 1 = not suitable, 5 = very suitable, with 3 being average suitable or value for acceptance of any indicator sustainability.

A total of 98 valid questionnaires were returned giving a response rate of 65.33%, while consultants and contractors gave lowest response rate. The percentage (%) of unreturned questionnaires was 34.67%. North East being the base of the author had the highest response rate, Abuja and South East were second and third respectively, while Lagos and South-South came fourth and fifth respectively.

3.1 Survey Analysis of Indicators (Ranking)

Descriptive statistics (Table 4) was used to present the results of All-Region and various questionnaire based indicators validation. Table 4 indicates that the stakeholders' perceptions of key performance indictors in general infrastructure (road) sustainability had the main scores and ranks (out of maximum score of 5) for the proposed indicators. The cumulative ranking shown is a reflection of stakeholders' views or perceptions.

Table 4: Maximum and Minimum Ranks

Region	Economy (Mean). (Rank)		Environment (Mean), (Rank)		Society (Mean), (Rank)		Project Management (Mean), (Rank)		Resource Utilization (Mean), (Rank)		Health and Safety	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min
ALL Region	Employment of labour (4.16), (1)	Adverse impact on tourism (2.76), (67)	Solid construction material (3.73), (12)	Liquid waste non-toxic (2.78), (66)	View of local authorities (3.62), (20)	Footprint of project in archeological sites or areas (2.85), (65)	Project size/ complexity (3.93), (4)	User rating (3.29), (43)	Construction material (4.13), (2)	Scrap value after the commissioning (3.04), (56)	Safety (3.74), (10)	Long-term health e.g. respiratory disease (2.92), (60).
Abuja	Employment of labour (4.33), (1)	Adverse impact on tourism (2.78), (57)	Solid construction material (4.00), (5)	Liquid waste non-toxic (2.33), (66)	View of local authorities (3.75), (23)	Footprint of project in archeological sites or areas (2.42), (65)	Project duration (4.09), (3)	Approach towards suppliers (3.29), (56)	Construction material (4.30), (2)	Innovative material (2.58), (62)	Safety (3.75), (15)	Long-term health e.g. respiratory disease (2.33), (67).
Lagos	Employment of Labour (4.64), (2)	Adverse impact on tourism (2.50), (61)	Connectivity with inter land (4.56), (3)	Re-provision of habitat (2.50), (63)	Extent of congestion (4.01), (13)	Footprint of project in archeological sites or areas (2.18), (67)	Amount of paper works (4.30), (8)	Inclusion of sustainability clauses in project (2.70), (56)	Construction material (4.30), (8)	Early contractor involvement (3.00), (49)	Management System e.g. policy, programme, etc. (4.00), (15).	Short-term health e.g. respiratory disease (2.27), (66).
North – EasT	Employment of Labour (4.03), (2)	Adverse impact on tourism (2.57), (67)	Solid construction materials (3.61), (18)	Air outlet (2.71), (66)	Extent of congestion (3.63), (17)	Footprint of project in archeological sites or areas (3.00), (61)	Project duration (3.81), (6)	User rating (3.06), (58)	Construction material (4.06), (1)	Scrap value after the commissioning (3.16), (53).	Safety e.g Accident, injuries fertility (3.91), (8)	Long-term health e.g. respiratory duct disease (3.31), (44).
South - South	Employment of Labour (3.43), (14)	Resettling cost of people (2.75), (5)	Extent of loss of habitat or feeding grounds (3.60), (4)	Design flexibility towards noise reduction measures (2.30), (57)	Extent of encroachment upon concern areas (3.45), (11)	Ubuntu (Public perception) (2.67), (58)	Approach towards suppliers (3.80), (1)	Amount of paper work (2.90), (50)	Innovative Material (3.64), (3)	Use of local materials (2.50), (60)	Safety (3.36), (19)	Management system e.g. policy, programme, (2.70), (56).

4. Basic Inferences from the Survey

The maximum and minimum ranked indicators for each of the six sustainability criteria or domains in All-region representing Abuja, Lagos, North-East and South-South are discussed as follows. In the discussion, the highest and lowest ranked priority indicators were based on their ranking indicators.

i. **Economy:** Employment of labour is ranked on the top (1) by all stakeholders in All-region (Nigeria). Its ranking under general infrastructure (road) is an indication of positive relationship between employment level and economic growth in construction industry in Nigeria. Also in alignment with Federal Government transformation agenda which include construction of road and other infrastructure and will generate employment of labour in All-region (Nigeria). This also reflects on economic preference that are bonded in encouraging micro-economic growth and capacity building through employment creation or generation and other policy statement which then will improve sustainable economy of All-region (Nigeria).

ii. **Environment:** Priority ranking is given to solid construction materials indicators by the stakeholders in All-Region (Nigeria). Solid materials are waste management related sustainability criteria and product of construction and infrastructure development activities. As discussed previously, transformation agenda of the present government in general infrastructure especially in road, railway, power, agriculture, airport, oil and gas, there is need to guard against long-term clean-up costs with its associated implications or effects in Nigeria. Nigeria is now witnessing a vast or huge infrastructure development which is generating more wastes and if not properly handled shall increase cost of construction activities, collaborating with Ugwu et al. (2006), most of the indicators under sustainable environment are performance based and could be built into total quality management (TQM) systems for monitoring site level construction operations.

iii. **Society:** Views of local authorities is ranked on top (20) amongst the key performance indicators in Nigeria or All-region. Views of local authorities are public perceptions –related sub-sustainability which is community base indicator(s). They are stakeholders in the community level and are direct users of these infrastructures. Because of their position in the community set-up, their views are taken into consideration under social sustainability and in decision-making. Therefore, it is not mistake that it is ranked 20th position amongst key performance indicators in general infrastructure in Nigeria.

iv. **Project Management:** Project size/complexity indicator is project management related sustainability and one of the key performance indicators which occupy 4th position. Similarly, indicators under project management/administration account for the need to adopt strategies that facilitate collaborative working among project teams. It is a condition to achieving sustainability objectives in both transport and general infrastructure (road) development in Nigeria. One of the most vital requirements in this indicator is the need for Nigeria to consider detail project planning and realistic programming before the commencement of transport and general infrastructure projects. This will improve the quality of construction products and well enhancing sustainable transportation and general infrastructure (road) delivery in Nigeria. While referring to (Ugwu et al., 2006) contribution, the author agreed that in developing country like Nigeria, indicators under project management highlighted the need for industrial strengthening and power development. This is essential in addressing the several perennial problems that militate against efficient project management in developing countries of which Nigeria is one of them. Procurement routed such as public private partnership (PPP) and partnering are enablers that encourage human relations and enhance collective social capital in a project environment.

v. **Resources Utilization:** Construction material is material availability-related sustainability which is under resources utilization criteria is ranked (2) amongst other indicators in All-region (Nigeria). Collaborating with (Ugwu et al., 2006), indicators under resources utilization relate to construction methods and strategies that need to minimize depletion of the limited resources. That construction is an intensive transformation process that often involves assembling and transforming resource into physical artifacts. Construction material needs to be conserved through innovative designs and specific methods for instance, contractors are most of the time involved at the construction level of the projects and they are in the best situation to maintain optimized resources utilization during construction process e.g. material re-use, recycle, good quality control systems or method to avoid material wastage or reworks. Again in (Ugwu et al., 2006), adopting performance based specifications would facilitate resources utilization as it gives contractors flexibility in choosing complementing alternative material.

vi. **Health and Society:** Safety indicators are ranked on top (10) among key performance indicators. The high-ranking positions of safety indicator, is as a result of general awareness on health and safety related matters in construction and the wider society. This could be explained by the serious campaign on safety related issues in construction and in our roads by the Federal Road Safety Corps and Federal Road Maintenance Agency (Creed for safety driving and for safety construction environment). While collaborating with (Ugwu et al., 2006), the author also substantiated with the Sustainable Development Unit (SDU), slated some sustainability elements like health and safety are vulnerable to shifts in society's definition of sustainability and prioritization of core elements. However, this raised some issues related to intergenerational priorities in sustainability, and enhance the associated risks in construction environment (Ugwu et al., 2006).

5. Cognitive/Reasoning Map System as Decision Aid for Infrastructure Sustainability Appraisal.

For the purpose of using sustainability key performance indicators in practical applications or situations, it is importance to understand the relationships and interactions between the various indicators at sub-dimensional levels. A Cognitive/reasoning map plays vital roles in problem structuring. This is the same as quantitative methods in assessing sustainability decisions. Because of the problems, this section develops reasoning and mapping models that shows the cause- and- effect relationship between the various indicators. It uses the reasoning map to illustrate the complexities of the interaction between the various indicators. Knowing of the interactions, would facilitate the sustainability appraisal process. This appraisal is based on previous usage among researchers to perform multi-criteria dimensional assessment of decision alternatives (Ugwu et al., 2006, (Bana et al., 1999, Kosko, 1986 and Chan and Hwang, 1992) (Figure 1).

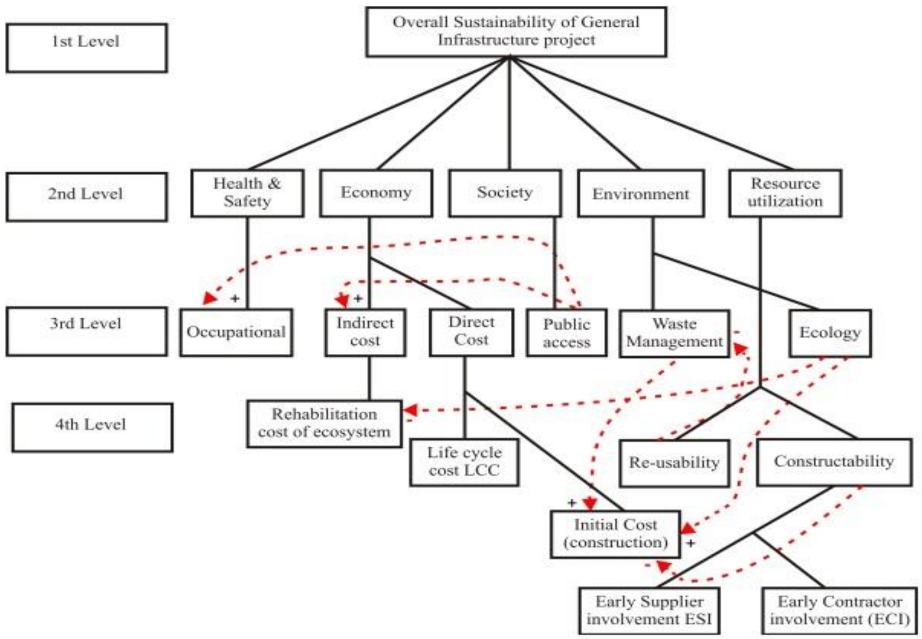

Figure 1: A hierarchy of key performance indicators and cognitive/reasoning map for infrastructure sustainability appraisal;
Source: My field work

Key: ----- (dashed line) = shows destination interaction between the indicators;

= **+** = indicates increasing causal effect from source to destination.

Key: = - = Indicates decreasing causal effect from source to destination.

i. Economy: Ecological design concept could increase initial cost or effect (+), but such concept design will have long-term positive effect on both the environment and tourism.

ii. Constructability: Ugwu et al., (2006) stated that poor constructability increases initial construction cost both in terms of lateness and associated claims, material wastages as well as rework (+). Therefore, good constructability has a reverse or reduced impact. Early contractor and supplier involvement (ECI/ESI) also adds or increase the opportunity/chance meeting constructability goals or aims. Procurement methods such as design and build, build, operate and transfer or other partnering methods also facilitate (ECI/ESI). Recently, second Niger bridge contract was awarded using procurement method design, build, finance/fund, operate and transfer. This will result in earlier completion as well as good results in value engineering practice. This will also check constructability design problem.

iii. Waste Management: Waste Management Method increases or adds to direct cost (construction) of an infrastructure project (+). But efficient material re-use or recycling and the use of already made material helps or improves the waste process and reduces the associated cost (-) and added impact on initial cost.

iv. Public Access and Occupational Safety: Insufficient provision of public access (for instance, temporal diversion routes for construction of infrastructure projects) could lead to accident or other problems which may stairs contractor- subcontractor relationship (Materials suppliers or subcontractors or other public access users). In some cases, this could cause to unhealthy and unsustainable human relations that can result in physical blows or fights and injuries can be sustained during construction.

Although, provision of good site access may increase initial cost or cost of construction (+) or increase causal effect of construction (+). It is generally believed that this will improve occupational safety and health and therefore adds to a sustainable construction and infrastructure development.

6. Conclusions

This paper presented the background information and recent literature reviews of sustainability in road infrastructure, multiple stakeholders' perceptions or views on sustainability and key performance indicators for sustainability appraisal in infrastructure.

The mathematical foundation models, Weighted Sum Model in Multi-Criteria Decision Method were used- based on Delph Method.

The study further discussed on key performance indicators for transport infrastructures sustainability and observed that some of the sustainability indicators are regional or project site –specific while others are generics.

The cognitive map illustrated hierarchy of key performance indicators in road infrastructure sustainability appraisal.

The maximum and minimum priority indicators with their sustainability criteria were discussed base on stakeholders' perceptions and their ranking priorities to determine indicators with highest and lowest ranking positions.

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