TIME RISK ASSESSMENT FRAMEWORK FOR HIGHWAY PROJECTS IN NIGERIA

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DEDICATION

To The Almighty ALLAH who has made it possible for me to attain this academic level in my chosen profession

To my parents, who Almighty ALLAH have used to provide the necessary support and motivation towards the attainment of this academic level

To my wife Risikat Ayobami and son, Abdullahi Adeolu who have been great sources of inspiration and shown their understanding throughout the duration of the study

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ABSTRACT

Time overrun on construction projects continue to linger and is substantial in both developed and developing countries. Numerous risk management standards and risk assessment models have been developed to identify and minimise risks in improving time performance of construction projects. However, such attempts do not seem parallel with the improvements required. Hence, this study aims to develop a two dimensional risk assessment framework for highway rehabilitation projects by integrating probability and severity measures of significant risk factors with organisational risk management capability measures to derive risk magnitude index for highway rehabilitation projects. To accomplish this aim, quantitative survey research design was employed. Two sets of questionnaires were developed and administered to construction professionals and organisations that are directly involved in the execution of the sampled design, bid and build highway rehabilitation projects in Nigeria. List and classification of risk factors were validated by Delphi survey and data collected from the questionnaire survey were analysed by the application of Fuzzy set theory, analysis of variance and spearman rank correlation. Results of the data analysis reveal that the overall risk indices on rehabilitation projects executed by different construction organisations are significantly different but have strong inverse relationship with the risk management maturity indices of the construction organisations. Based on this relationship, a decision matrix was developed as a tool to combine overall risk indices with risk management maturity indices to derive risk magnitude indices for all risk factors and project level risk. The inputs, concepts, techniques and tools leading to this result formed the basis for the development of the proposed risk assessment framework. The framework was validated through structured interview with a team of experts. The validation team strongly agreed with the logical soundness and completeness of the proposed two dimensional risk assessment framework, affirming the framework to be practicable and acceptable for assessing time risks on highway rehabilitation projects in Nigeria. The framework can thus be adopted to ensure a complete and comprehensive assessment of risk on highway rehabilitation projects.

ABSTRAK

Masalah penyiapan projek-projek pembinaan diluar masa yang telah ditetapkan masih berterusan dan wujud di kedua-dua negara maju serta negara membangun. Pelbagai standard pengurusan risiko dan model penilaian risiko telah dibangunkan untuk mengenal pasti dan mengurangkan risiko bagi meningkatkan prestasi masa projek-projek pembinaan. Namun begitu, usaha-usaha tersebut seolah-olah tidak selari dengan penambahbaikan yang diperlukan. Oleh itu, kajian ini bertujuan untuk membangunkan satu kerangka kerja penilaian risiko dua dimensi dengan mengintegrasikan ukuran kebarangkalian dan ketenatan faktor risiko yang signifikan dengan ukuran keupayaan pengurusan risiko organisasi untuk mendapatkan indeks magnitud risiko bagi projek pemulihan lebuh raya. Reka bentuk penyelidikan kajian kuantitatif telah digunakan dalam kajian ini. Dua set soal selidik telah dibangunkan dan ditadbir untuk para profesional pembinaan dan organisasi yang terlibat secara langsung dalam pelaksanaan projek pemulihan lebuh raya persekutuan di Nigeria yang dibangunkan secara reka, bida dan bina yang telah digunakan sebagai sampel dalam kajian ini. Senarai dan klasifikasi faktor-faktor risko telah disahkan dengan kajian Delphi manakala data yang dikumpul daripada borang soal selidik kajian dianalisis menggunakan teori set Fuzzy, analisis varians dan korelasi perangkat Spearman. Hasil analisis data menunjukkan bahawa indeks risiko keseluruhan projek pemulihan lebuh raya yang dilaksanakan oleh organisasi pembinaan yang berbeza adalah secara signifikan berbeza tetapi mempunyai hubungan songsang yang kukuh dengan indeks kematangan pengurusan risiko organisasi pembinaan. Berdasarkan hubungan tersebut matriks keputusan telah dibangunkan sebagai alat untuk menggabungkan indeks risiko keseluruhan dengan indeks kematangan pengurusan risiko untuk mendapatkan indeks magnitud risiko untuk semua faktor risiko dan risiko peringkat projek. Input, konsep, teknik dan peralatan daripada keputusan ini membentuk asas bagi pembangunan kerangka kerja penilaian risiko yang dicadangkan. Kerangka kerja ini telah disahkan melalui temu bual berstruktur dengan kumpulan pakar. Pasukan pengesahan sangat bersetuju dengan kemantapan logik dan kesempurnaan kerangka kerja penilaian risiko dua dimensi yang dicadangkan dan mengesahkan kerangka kerja tersebut adalah praktikal dan boleh diterima untuk menilai risiko masa bagi projek-projek pemulihan lebuh raya di Nigeria. Kerangka kerja tersebut boleh diterima pakai bagi memastikan penilaian risiko yang lengkap dan komprehensif untuk projek-projek pemulihan lebuh raya.

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LIST OF ABBREVIATIONS

ORI   -   Overall risk index

RGI   -   Risk group index

RFI   -   Risk factor index

RP   -   Risk probability

RS   -   Risk severity

PSI   -   Probability-severity index

SRF   -   Significant risk factor

FAM   -   Fuzzy associative memory

TMF   -   Trapezoidal membership function

TFN   -   Triangular fuzzy number

ATFN   -   Aggregated triangular fuzzy number

TOPSIS   -   Technique for order preference by similarity to ideal solution

COPRAS   -   Complex proportional assessment

AHP   -   Analytical hierarchical process

RM3   -   Risk management maturity models

RMMI   -   Risk management maturity index

RMC   -   Risk management capability

PMBOK   -   Project Management Body of Knowledge

RAMP   -   Risk analysis and management of projects

AZ/NZS   -   Australia/New Zealand

PRAM   -   Project risk analysis and management

RMP   Risk management plan

DBB   Design, bid and build

BMPIU   Budget Monitoring and Price Intelligent Unit

SSA   Sub-Sahara Africa

WBS   Work Breakdown Structure

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CHAPTER 1

INTRODUCTION

1.1   Background to the Research

Effective and adequate basic infrastructure enhances speedy growth of nation's gross national income (Ibrahim, 2011). This is because effective basic infrastructures improves productivity, changes economic output, creates direct employment, changes population pattern and increase suburbanisation. Basic infrastructural facilities desirable for sustaining economic development of a nation include good transportation network, water supply, power (electricity and alternative energy), fuel and housing provision (Ogunsemi, 2005). On the other hand, poor state of the basic infrastructure has been identified as the major challenges to the economic growth and development in developed and developing countries (Shatz, et.al. 2011). This assertion is particularly relevant to Nigeria that has a total road ways of 196,200km serving over 175 million people of Nigeria and the entire territory covering 910,768 square kilometres of land.

The poor state of the infrastructural facilities has consequential adverse effect on the economic growth and development in Nigeria. Hence, a long term development plan termed ``The Nigeria Vision 20:2020``become operational in 2007. The economic plan has the goal of propelling the country into the league of the top 20 economies in the world by the year 2020, with a minimum GDP of 900 billion US dollar and a per capita income of no less than 4000 US Dollar per annum (Usman,

2010). Among the strategies for achieving this goal is the plan to rehabilitate, upgrade, modernise and expand 7,000km of the existing highways before 2013. Many highway rehabilitation projects were embarked upon to improve the pavement condition of the highway network in Nigeria.

Consequent upon the extent of distress, damage to the highway pavement, obsolete geometrics, needs for capacity improvement and re-alignment of the existing highways in Nigeria, highway rehabilitation projects were embacked upon to increase structural capacity, functionality and serviceability of the existing highway. Thus the highway rehabilitation projects in Nigeria involves the removal and replacement of subbase and base layers of a very large portion of the existing highway pavement as well as asphalt and concrete layers. It is often done in combination with subgrade and drainage remediations, and possible geometric changes. All the highway rehabilitation projects were contracted by Design, Bid and Build procurement (DBB) approach.

To achieve the full benefits of design, bid and build procurement (DBB) approach on highway rehabilitation and construction contracts in Nigeria, the procurement act 2007 was enacted. The act provided the necessary regulations and standards required to arrive at best procurement decision. It also establishes the bureau for public procurement that is presently known as Budget Monitoring and Price Intelligent Unit (BMPIU) to enforce the provisions of the act. The BMPIU also developed due process rules of contracting games to ensure effective delivery of design, bid and build highway rehabilitation and construction projects. Despite all the provisions in the procurement act 2007 and the due process rules of contracting games, new highway constructions and highway rehabilitation projects in Nigeria are experiencing challenges of time and cost overrun (Okonjo-Iwealla, 2010). However, the challenges of time and cost overrun on highway construction projects are global phenomena but their magnitude is more in developing countries (Fybjerg, *et al.,* 2003).

Studies on performance of highway projects in Bangladesh, India, Thailand and China revealed an average time overrun of 33.37% and the time overrun ranges between 13.63% and 55.69% (Ahsan and Gunawan, 2010). In the United Kingdom,

time overrun on highway projects ranges from 1.5% to 38.2% (Olawale and Sun, 2010). Assaf and Al-Hejji (2006) also observed that time overrun on highway projects in Saudi Arabia ranges from 0 to 30% and in Nigeria, Ameh, *et al* (2010) observed that delay on infrastructure projects is on the average of 188%. These studies reflect that the magnitude of time overrun vary from one country to another and are substantial both in the developed and developing countries. Hence, causes of the time overrun experienced on highway projects both in the developed and developing countries have also been examined.

Studies on international highway construction projects in Bangladesh, India, Thailand, China and Indiana revealed that financial process, scope changes, adverse weather condition, contract bid amount, project types and riot and commotions constitute the major causes of delay on the projects (Ahsan and Gunawan, 2010; Anastasopoulos *et al*, 2012). Causes of delay on highway construction projects in Malaysia include improper planning and poor site management, inadequate contractor's experience, problem with sub-contractor, inadequate client finance and delayed payment for completed work (Sambasivan and Soon, 2007; Alaghbari, *et al.,* 2007). In Saudi Arabia and United Arab Emirate, studies on highway construction projects affirmed that major causes of time overrun include change order, low bid, inefficient planning, delay in approval, delay in expropriation, delays in payment, design change, lack of project funds, lack of specialized technical staff, poor performance of labor and subcontractor, contractor's lack of experience on the job, contractor's cash flow problems and delay in mobilisation, poor productivity, and unexpected ground utility (Assaf and Al-Hejji, 2006; Al- Kharashi and Skitmore, 2009; Sameh *et al*., 2015; El- Sayegh, 2008; Perera,*et al*, 2014).

In Egypt, partial and delay payment, financial difficulties arising from client and contractors, low productivity level, ineffective planning and schedule, change of work scope, adverse effect of lowest bid, and non-utilisation of professionals and unexpected ground conditions are the major causes of delay on civil engineering projects (Abd El- Razek, *et al*,2008; Mohamed, et al, 2012). In Nigeria very little studies are reported on causes of delay on highway projects but significant causes of

delay on construction projects in general are reported to include financial issues, poor contract management and contractors site management problems (Aibinu and Odeyinka, 2006) improper planning and ineffective communication (Kasimu and Usman, 2013).

The Project Management Institute (2004) described uncertain events or conditions as risk, if their occurrence has positive or negative effect on any of the project performance objectives such as cost, time and quality. Thus, all the causes of delay on highway projects that are extensively described are infact uncertainties that lead to delay, cost overrun and underrun and poor quality on highway projects and so they are risk factors. It is therefore very important to properly and effectively manage the potential risk factors on highway projects if improvement on the project performance is to be achieved. In facilitating effective management of potential risk factors on highway projects, numerous systematic and formal risk assessment models have been developed. Within the context of this research, these models are broadly classified into one dimensional and two dimensional risk assessment models.

1.2   Problem Statement

Highway rehabilitation projects constituted about 90% of all highway construction projects in Nigeria. The highway rehabilitation projects are complex, unique in nature and they were executed under uncertain project environment. Hence, highway rehabilitation projects in Nigeria are subjected to numerous and variety of uncertain events and conditions. Uncertain events and conditions on highway construction projects are greater than other types of construction projects (Sameh *et al*, 2015). These uncertainties relate to risks leading to time and cost overrun (PMI, 2004). Occurrence of time and cost overrun often lead to additional cost of construction, loss of profits, arbitration, litigation and total abandonment (Kikwasi, 2012; Enshassi *et al.* 2009; Sambasivan and Soon, 2007), numerous contractual claims and increased project cost (Lo, *et al.* 2006), financial waste and poor quality work

(Ramanathan *et al*., 2012). Iyer and Jha (2006) asserted that major part of cost overrun on construction projects could be contained if risk factors causing time overrun are consciously and properly managed. This means that if risk factors causing time overrun are properly managed; additional cost, loss of profits to construction organisations and total project abandonment would be drastically minimized on highway rehabilitation projects in Nigeria.

Research efforts towards effective managemeent of time related risk factors on highway construction projects led to the development of numerous risk assessment techniques and models which are in the context of this research broadly classified into one dimensional risk assessment models and two dimensional risk assessment models. Despite the number of the existing risk assessment techniques and models, time overrun on highway construction projects could not be curtailed, it continue to linger and its extent is substantial in both developed and developing countries. Hence, the existing risk assessment models are unsuitable for effective management of risks on highway construction projects. This constitutes a cause for concern in this research.

To achieve an effective management of time related risks on highway rehabilitation and construction projects, the time related risk factors have to be effectively identified and assessed. In lieu of the complex and unique nature of highway rehabilitation and construction projects, seven essential requirements are identified for effective assessment of risks on highway projects. These essential requirements are to estimate the probability of occurrence of risks and severity of the risks, and then combine the estimates to derive consequences of the risks on highway projects' performance objectives (Thomas *et al*. 2006; Jannadi and Almishari, 2003), application of quantitative techniques that is capable of handling the vagueness and ambiguity in subjective risk data on highway projects (Hwang *et al*, 2014; Guyonnet *et al*, 2003; Dikmen and Birgonul, 2006), appropriate structuring of risks on the highway projects and adopting quantitative technique that is capable of estimating the magnitude of individual risk factors and overall project level risk (Taroun *et al.,* 2011), integration of organization dimension of risk management practice with probability-severity parameters to derive the risk magnitude (Zhang, 2007; Mafakheri *et al*.,

2012),complete and comprehensive assessment of organisational risk management capability, and adopting systematic technique to assess the organisations risk management maturity level.

The existing one dimensional and two dimensional risk assessment models are deficient in meeting up with all the essential requirements for effective assessment of risks on highway rehabilitation and construction projects. One dimensional risk assessment models assessed risks by considering the probability and severity parameters of risks on highway projects. They adopted different quantitative techniques that are within the context of this research grouped into classical, modified classical and multi-criteria risk assessment models. The classical risk assessment models were developed with quantitative techniques such as Monte Carlo methodology (Molenaar, 2005; Oztas and Okmen, 2004); multiple regression analysis (MRA) and relative important index (Creedy *et al.,* 2010; Mahamid and Bruland, 2012); Decision Tree Analysis (Dey, 2010). These models provide range of estimated time and cost of highway projects but could not provide the magnitude of risk factors on projects and are incapable of handling subjective risk data which are inevitable on highway projects. The models also did not structure the potential risk factors on highway projects and this could affect the accuracy of the estimated time and cost of projects. Hence modified classical models were developed to handle the inevitable subjective risk data on highway projects.

Modified classical risk assessment models were developed by applying Monte Carlo simulation under fuzzy logic principles. Guyonnet, *et al,* (2003) developed Monte Carlo simulation model with possibility and probability transformation, and Baudrit *et al.*, (2005) developed hybrid Monte Carlo simulations model. These models also provide range of estimated time and cost of highway projects but could not provide the magnitude of risk factors on projects. The models also did not structure the potential risk factors on highway projects and this could affect the accuracy of the estimated time and cost of projects. Hence, multi-criteria one dimensional risk assessment models were developed with quantitative techniques that are based on the application of Analytic Hierarchy Process (Zhang, *et al.,* 2007; Zayed, *et al* 2008;

Subramanian, *et al.,* 2012); Technique for Order Performance by Similarity to Idea Solution (TOPSIS), Fuzzy synthetic evaluation process (Xu *et al.,* 2010) and Fuzzy inference technique (Carr and Tah ,2001). The multi-criteria one dimensional risk assessment models provide ratings of alternative highway projects based on the developed structure of the potential risk factors on highway projects. However the models could not provide the magnitude of risk factors on projects and the ratings are provided without considering the effect of organisational risk management capability on the consequences of the potential risk factors on highway projects.

The three groups of one dimensional risk assessment models described above are unable to meet up with four of the essential requirements for effective assessment of risks on highway rehabilitation and construction projects. The common limitations of these models are their inability to estimate the magnitude of individual risk factors and overall project level risk, this will make it difficult to plan and respond to the potential risk factors on highway projects and also defeated the purpose of formal risk management practice. The models also failed to integrate organization dimension of risk management practice or any supporting factors with probability-severity parameters to derive the magnitude of risks on projects. Hence, none of the attributes of organisational risk management capability was considered and no systematic technique was adopted to assess risk management maturity level of organisations.

Research efforts toward overcoming the common limitations of one dimensional risk assessment models led to the development of two dimensional risk assessment models. The current two dimensional risk assessment models integrated probability-severity parameters with different supporting factors, applied fuzzy inference and fuzzy synthetic evaluation techniques. Jannadi and Almishari (2003) proposed risk assessment model that integrated personnel/ property 'exposure' to all hazards of a work activity with probability-severity parameters. Zeng *et al.,* (2007) introduce factor index in its fuzzy AHP risk assessment model and Ebrahimnejad *et al.,* (2010) integrated quickness of reaction, event measure quantity and event capability criterion in the proposed Fuzzy TOPSIS risk analysis procedure. In addition, Dikmen *et al* (2007) proposed a two dimensional risk assessment models that

integrated company experience and favourability of contract clauses with probability-severity parameters of risk factors. Organisational risk management capability parameter was introduced in Mafakheri, *et al.,* (2012) to develop a Fuzzy AHP based two –dimensional risk assessment approach.

The two dimensional risk assessment models make very little improvement on the risk assessment modelling approaches but also fall short of meeting up with all the essential requirements for effective assessment of risks on highway construction projects. The supporting factors introduced in these models are not comprehensive for accurate and effective assessment of organisational risk management capability and the techniques adopted for assessing the supporting factors are unstructured and unsystematic. Attributes of organisational risk management capability such as risk management process, culture/awareness, resources and risk management practice/application (Ren and Yeo, 2004; Zou, *et al*., 2010; Mu, *et al.,* (2014) are neither estimated nor integrated with the probability-severity parameters of risks on highway construction projects in the existing two dimensional risk assessment models.

In addition to the limitations of the existing risk assessment techniques and models, "due process rules of contracting games" that governs the procurement of design, bid and build (DBB) highway contracts in Nigeria do not provide formal risk management guidelines and procedures for highway rehabilitation and construction projects. This implies that initial contract period for federal highway rehabilitation and new highway construction projects in Nigeria are estimated by the application of informal risk management approach**.** Hence, the poor time performance experienced on highway rehabilitation and construction projects in Nigeria (Okonjo-Iwealla, 2013) could be associated with the absence of formal risk management guidelines and procedures in the Nigeria "due process rules of contracting games".

Based on the essential requirements for effective assessment of risks on highway construction projects and the limitations of the one and two dimensional risk assessment models, the existing risk assessment models are incomplete and not suitable for effective assessment of risks on highway construction projects. Hence, the

existing risk assessment models could not curtail the occurrence of time overrun on highway construction projects. Further research effort is very essential to improve upon the existing risk assessment modelling approaches. Consequently, this research focus on developing a two dimensional risk assessment framework for design, bid and build highway rehabilitation projects in Nigeria. The proposed framework integrates all the essential requirements for effective assessment of risks on highway projects in order to overcome the limitations of the existing risk assessment models.

The proposed framework integrated three input parameters namely probability, severity and risk management capability to derive risk magnitude indices of the significant risk factors. Probability was considered as the frequency of occurrence of risk factors on highway rehabilitation projects and severity is the impact of the risk factors on the projects' time performance. Probability and severity estimates of the significant risk factors are combined to obtain the probability-severity indices. However, to overcome the limitations of the existing risk assessment models, risk management capability of the contractors were examined in terms of their risk management culture, risk management process, available resources and risk management practice. The impact of the contractors' risk management capability on the probability-severity indices of risk factors were examined in terms of risk magnitude indices. The risk magnitude indices were derived by combining the probability-severity indices with the risk management capability indices. It is hoped that the proposed framework will serve as good basis for developing formal risk management guidelines and procedures to be included in the Nigeria "due process rules of contracting games". The essential requirements for effective assessment of risk factors leading to time overrun on highway construction projects, the scope and limitation of the existing one and two dimensional risk assessment models for highway construction projects are summarised and shown Figure 1.1.
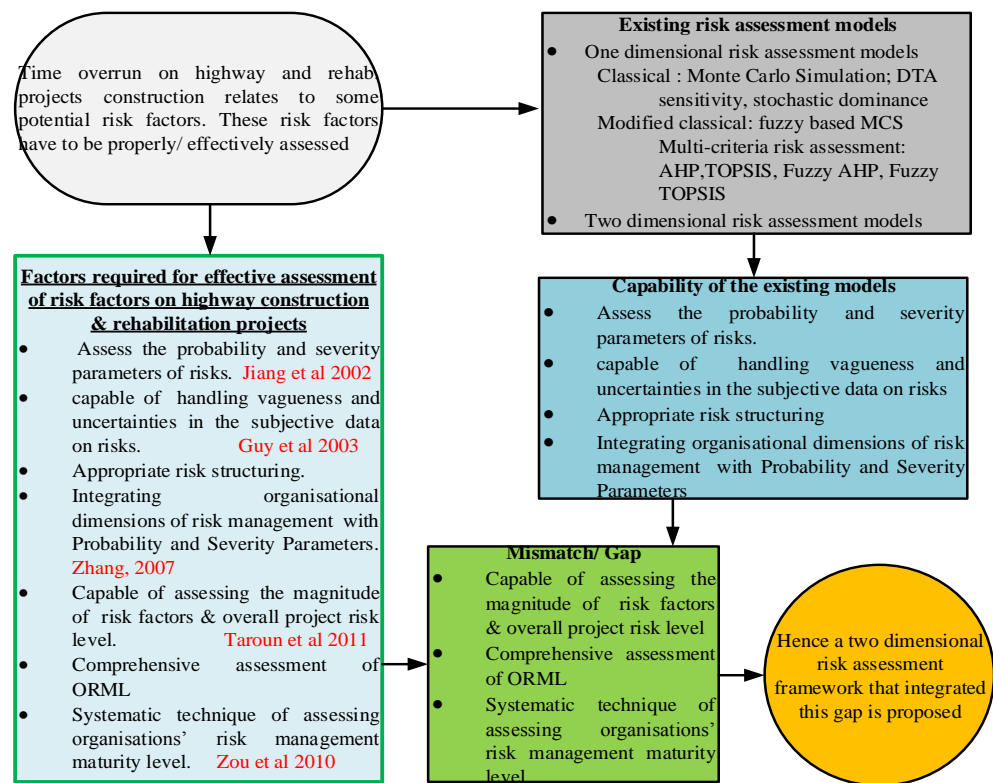
Figure 1.1   **Scope and Limitations of the existing one and two dimensional risk assessment models.**

1.3   Research Questions

This research attempts to answer the following questions:

1. What is the extent of time overrun on design, bid and build (DBB) Federal highway rehabilitation projects in Nigeria?

2. Which of the potential risk factors on highway projects are significantly preventing the achievement of time performance on the Federal highway rehabilitation projects in Nigeria?

3. What are the probability-severity indices of the significant risk factors, risk groups and project risk level on Federal highway rehabilitation projects in Nigeria?

4. Are there any significant difference in the probability-severity indices of significant risk factors on Federal highway rehabilitation projects executed by different construction organisations?

5. What is the impact of the different locations of the highway rehabilitation projects on probability severity indices of significant risk factors?

6. What is the risk management maturity level of the construction organisations executing the Federal highway rehabilitation projects in Nigeria?

7. What is the nature of relationship between probability-severity indices of the significant risk factors on highway rehabilitation projects executed by different construction organisations and their current risk management capability?

8. What is the magnitude of significant risk factors on highway rehabilitation projects?

9. What process should be adopted to develop an effective and acceptable risk assessment framework for highway rehabilitation projects?

1.4   Aim and Objectives of the Research

The aim of this research is to develop a two dimensional risk assessment framework for design, bid and build (DBB) procured highway rehabilitation projects in Nigeria. Accordingly, the objectives of the research are as follows:

i. To determine time performance of and the significant risk factors on DBB procured highway rehabilitation projects in Nigeria;

ii. To assess probability severity indices of the significant risk factors on highway rehabilitation projects in Nigeria;

iii. To assess risk management capability of construction organisations undertaking highway rehabilitation projects in Nigeria;

iv. To determine the risk magnitude indices on highway rehabilitation projects in Nigeria

v.   To formulate and validate a two dimensional time risk assessment framework for highway rehabilitation projects.

Answers to the research questions stated in section 1.3 are obtained in the corresponding research objectives as described in Table 1.1

Table 1.1   The corresponding research questions in the objectives of this research

Research Questions	Research Objectives
1 and 2	Objective 1:To determine time performance of and the significant risk factors on DBB procured highway rehabilitation projects in Nigeria
3, 4 and 5	Objective 2:To assess probability severity indices of the significant risk factors on highway rehabilitation projects in Nigeria
6	Objective 3:To assess risk management capability of construction organisations undertaking highway rehabilitation projects in Nigeria;
7 and 8	Objective 4:To determine the risk magnitude indices on highway rehabilitation projects in Nigeria
9	Objective 5:To formulate and validate a two dimensional risk assessment framework for highway rehabilitation projects

1.5   Scope of the Research

This research focused on Federal highway rehabilitation projects that are procured by design, bid and built (DBB). The focus on the Federal highway rehabilitation projects is limited to the projects located in Lagos, Ogun, Oyo, Ondo and Osun states in the South West zone of Nigeria. The focus on the DBB highway rehabilitation projects are also limited to the projects awarded and executed between 2001 and 2013. The research also focused on highway rehabilitation projects with completion stage ranging from 60% -100% as at December 2013. This is to ensure that sufficient risk data are obtained on every highway rehabilitation projects understudy in this research. However, highway rehabilitation projects that are 100% completed and their period of practical completion has expired as at 2013 were excluded from this research because risk data on them were not readily available. In addition, this

research is project specific and so it focuses on only the client, construction organisations and consulting firms that are undertaking the studied highway rehabilitation projects

1.6   Justification and Significance of this Research

Risks on highway projects are greater than other types of construction projects (Sameh *et al.,* 2015) and so effective management of the risks on them is critical to their successful performance. The existing risk assessment studies and models placed emphasis on highway construction, buildings and other civil engineering projects (Kaliba *et al*.,2009; Ahsan and Gunawan ,2010; Kikwasi (2012), Mahamid, *et al.* ,2012; Marzouk and El-Rasas ,2014;and Sameh *et al*.,2015). Very little of the studies and models are done to assess risks on highway rehabilitation projects. In Nigeria, majority of the risk assessment researches on construction projects were on building projects and on construction projects in general (Aibinu and Odeyinka, 2006; Kasimu and Usman, 2013). Most of them are not project specific and very little emphasis was placed on the assessment of risks on highway rehabilitation projects. However, most of the highway projects embarked upon in Nigeria between 2001 and 2014 are rehabilitation projects and these projects are facing issue of time overrun. Hence, this research focused on the effective assessment of risk factors to enhance time performance on highway rehabilitation projects. The outcome of the research established the extent of time overrun on highway rehabilitation projects and provided a checklist of probability and severity estimates of significant risk factors.

The attributes and techniques for assessing organisational risk management capability in the existing two dimensional risk assessment models are incomprehensive and unsystematic for effective assessment of risk management practice of organisations (Ren and Yeo, 2004; Zou, *et al.,* 2010; Mu, *et al.,* 2014). Hence, this research explored the risk management maturity models (RM3) and derived a systematic technique for a comprehensive estimation of the risk management

maturity of construction organisations. The systematic technique was applied on the contractors that are undertaking the studied highway rehabilitation projects and the outcome of the application established the risk management maturity levels of Federal highway rehabilitation contractors in Nigeria. The maturity levels described strength and weakness of highway contractors in risk management practice.

In addition, the existing risk assessment models estimates range of time and costs of projects and provided relative ratings of risk factors but they are not capable of estimating the magnitude of risk factors on projects (Taroun *et al.,* 2011). This means that the existing risk assessment models are inadequate for the project managers to make decision on risk response planning. Thus the purpose of formal risk management process is defeated. Hence, this research proposed a risk assessment framework that combined probability and severity measures of risks on highway rehabilitation projects with risk management maturity estimates of construction organisations to derive magnitude of risk factors and project risk level on highway rehabilitation projects. The risk assessment framework is comprehensive and systematic. In addition, quantitative technique adopted for assessing the probability-severity indices of risks on highway rehabilitation projects and the risk management maturity levels of the construction organisations in the framework was found suitable for handling subjective and objective risk data and for comprehensive assessment of organisational risk management capability.

Therefore, the outcomes of this research highlights the need to integrate risk management capability measures of construction organisations with the probability and severity measures of risks in highway rehabilitation projects. The research also highlighted the need to have good understanding of the risk management capability of construction of construction organisations prior to the award of rehabilitation contract. The outcome of this research also provided the indigenous construction organisations in Nigeria the database of probability and severity estimates of significant risk factors in Federal highway rehabilitation projects. This could serve as a checklist for the identification of potential risk factors in the future highway rehabilitation projects. Similarly, with the growing prospect of infrastructure development business in

Nigeria, the database of probability and severity measures of significant risk factors are useful information for SWOT analysis of Federal highway rehabilitation projects by foreign construction firms that are anticipating to explore highway construction business in Nigeria. The proposed framework would serve as a guide to the client and construction organisations towards effective assessment of risk factors on highway rehabilitation projects and boost the efficiency of the risk response plan.

1.7   Research methodology

This research commenced with the review of literatures to identify research problem, scope and limitations of the existing risk assessment models and approaches. The review was also used to determine the possible means of improving upon the risk assessment modelling and to determine the appropriate research approach and design for the identified aim and objectives of the research.

In lieu of the quantitative nature of the research objectives, survey research design was adopted. Consequently, two sets of questionnaire was developed, the first set was used to collect risk data for assessing probability and severity parameters of risk factors on highway rehabilitation projects and the second set was used to collect data for assessing the risk management capability of construction organisations. The developed questionnaire was validated in two round Delphi survey of experts and the validated questionnaire was administered to professionals who are directly involved in the execution of the sampled highway rehabilitation projects. The collected data were initially analysed by normalisation analysis process to identify the significant risk factors on highway rehabilitation projects. Collected data on significant risk factors were further analysed with Fuzzy inference technique to compute probability-severity indices of the significant risk factors, risk groups and project risk level on Federal highway rehabilitation projects. Similarly, collected data from the second set of the questionnaire were analysed with Fuzzy synthetic evaluation method to compute risk management maturity indices of the construction organisations.

Probability-severity indices of the significant risk factors and risk management maturity indices of the construction organisations were correlated by computing spearman rank correlation coefficient to establish the extent of relationship between them. Result of the computed correlation coefficient form the basis for the development of decision matrix. In addition, the developed decision matrix was used to combine probability-severity indices (PSI) and risk management maturity indices (RMMI) of construction organisations to derive risk magnitude indices. Therefore the concepts, process, tools and techniques adopted in this survey research and the developed decision matrix were used to develop an improved two dimensional risk assessment framework which was validated by structured interview. The flowchart of this methodology is shown in Figure1.2 and terms used in this research are defined in Table 1.2.
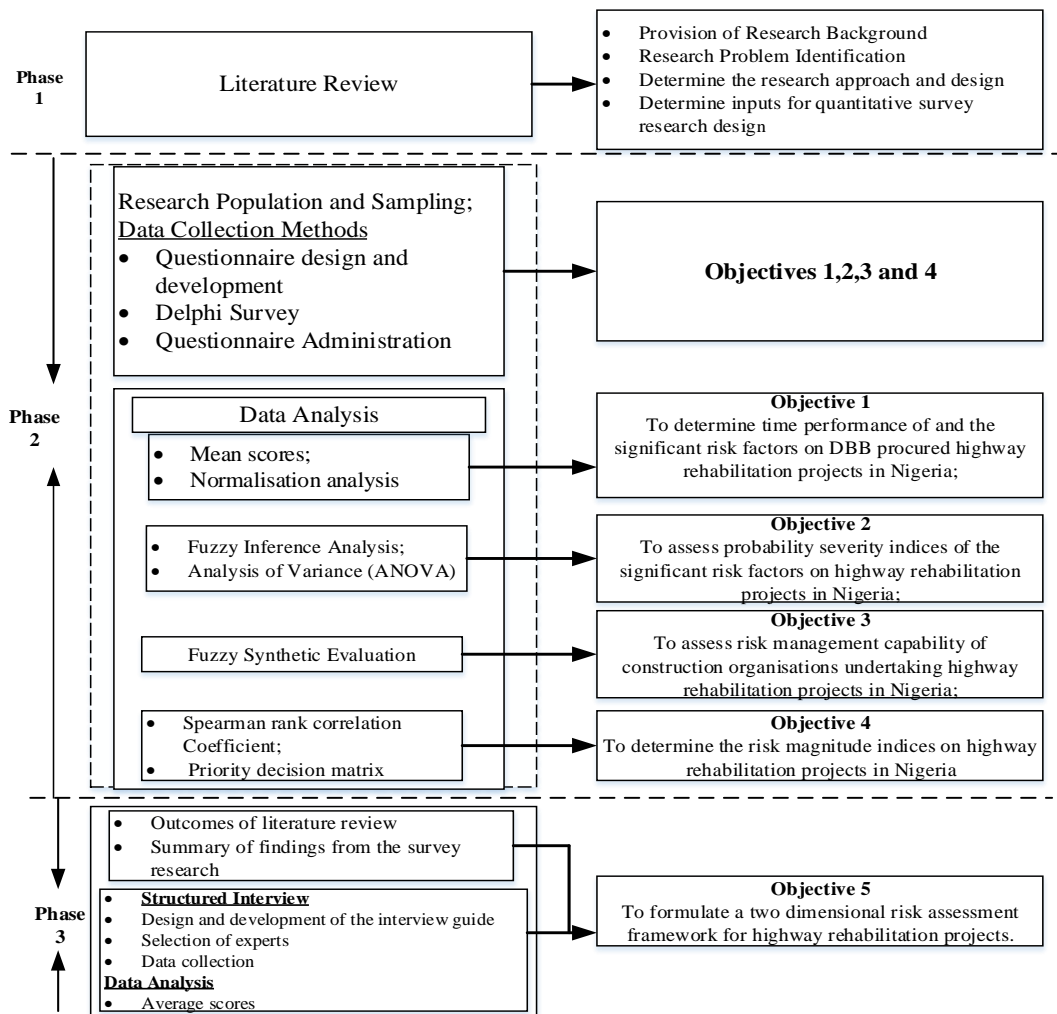
Figure 1.2   Research Methodology

Table 1.2   Definitions of Terms as Related to this Research

Terms	Definition
Risk	The uncertain events or conditions that their occurrence led to time overrun on highway rehabilitation projects
Risk management practice	This is the culture, practice, processes, resources put in place towards effective management of potential opportunities and threats to project
Risk management process	The systematic application of management policies, procedures and practice for the purpose of identifying, assessing, treating, monitoring, documenting and communicating project risk
Risk identification	The process of determining what are likely to occur at all stages of construction process, how and why
Risk analysis	The first part of risk assessment activities that systematically employ available information to determine the significant risk factors on highway rehabilitation projects.
Risk evaluation	The process of determining the tolerability of risk events and priorities of significant risk factors
Risk assessment	A phase in risk management process that involves risk analysis and evaluation
Risk probability	The frequency of occurrence of risk potential risk factors on highway rehabilitation projects. It is measured on the scale 1 to10
Risk severity	This is the degree of the consequences of potential risk factors on the time performance in highway rehabilitation projects
Probability-severity index	The measure of the product of probability and severity parameters of a significant risk factor
Risk group index	The measure of the product of probability and severity parameters on a group of significant risk factors
Risk management maturity index	The measure of the overall risk management capability of construction organisations
Attribute index	Measure of the individual attributes of the risk management capability in an organisation
Risk magnitude index	Measure of the combination of probability-severity index and risk management maturity indices of construction organisations.
Highway rehabilitation	Highway rehabilitation is the structural or functional enhancement of a pavement which produces a substantial extension in service life by substantially improving pavement condition and ride quality. It involves the removal and replacement of subbase and base layers of highway pavement as well as asphalt and concrete layers. It is often done in combination with subgrade, drainage remediations, and possible geometric improvement.

1.8   Organisation of Chapters

This thesis is made up of seven chapters. Chapter one is the Introduction to the research and consists of the background of the study, statement of the problem, research questions, aim and objectives, scope of the study, justification and significance of this research, brief research methodology, definition of terms, and outline of the thesis

Chapter two is the first part of the review of related literatures undertaken in this research. The chapter is organised in the following order: definition of transport infrastructure; transport infrastructure investments and economic development; conditions of highways in developed and developing countries; issues on the development of highway projects: time overrun on highway projects, sources of time overrun on highway projects in developed and developing countries; perception and nature of risks nature of risks; background information of Nigeria and highway rehabilitaion projects' delivery: geographical and socio-economic characteristics of Nigeria, National development plans and highway development in Nigeria, road classifications and extent of distress on Federal highways in Nigeria, investment on Federal highway projects in Nigeria, procurement approach and regulations governing delivery of highway rehabilitation projects, project management models for highwy rehabilitation projects in Nigeria.

The chapter also contain uncertain events and condition on highway rehabilitation projects in Nigeria: client related uncertainties on highway rehabilitation projects in Nigeria, contractor related uncertainties on highway rehabilitation projects in Nigeria, consultant related uncertainties on highway rehabilitation projects in Nigeria, uncontrollable uncertain events; risk factors on highway rehabilitation projects in Nigeria and then chapter summary.

Chapter three is the second part of the review of literature; the chapter contains the review of the techniques and theories for managing risks and uncertainties on

highway projects: multi-attributes decision making technique; basic structure of fuzzy systems, basic principles and operations of fuzzy logic for risks assessment. The chapter also covers the review of the existing risk management standards for highway construction projects and formal risk management process: risk planning, risk identifications, risk analysis and evaluations on highway projects, the essential requirements of effective risk assessment technique, risk analysis process and risk assessment models such as: one dimensional risk assessment models and two dimensional risk assessment models. The chapter is concluded with the review of the organisational risk management capability; risk management maturity models for projects; techniques for assessing overall risk management maturity of organisations; essential requirements of holistic risk management practice; risk management practices on construction projects and summary of this chapter.

Chapter Four briefly describes the various research designs and perspectives. It focuses on the adopted research procedure and design, describe the justification for the choice of the research design, study population, sampling frame and sample and the different phases of the research. The adopted hierarchical structures for risk factors and risk management capability were also presented. The chapter describes the design and contents of the developed questionnaire, method of validating and administration of the developed questionnaire. The chapter also describe methods of data analysis adopted in this research: fuzzy inference, fuzzy expert system algorithm and fuzzy synthetic evaluation methods. The chapter concludes with the description of the development and validation process of the proposed two dimensional risk assessment framework.

Chapter five presents the background information of the respondents engaged for this research namely: the academic and professional qualifications, the working experience, profile of the contractors and results of the reliability test. The chapter also included the results of data analysis techniques namely: fuzzy inference, fuzzy synthetic evaluation, analysis of variance, spearman rank correlation that were applied in this study were also presented. The results of the data analysis and findings were

organised and presented in the order of the research objectives of this study. The chapter ended with the summary of findings and discussions.

Chapter six contains the development and validation process adopted in this research to formulate a two dimensional risk assessment framework for highway rehabilitation projects. It provides the definition of framework and the three phase of the development process adopted for the proposed risk assessment framework: framework conceptualisation, drafting the proposed risk assessment framework and validation of the proposed framework. The chapter concludes with the summary of the chapter.

Chapter seven highlights the achievement of the research objectives, recommendations, and limitations of this research and suggestions for further research.

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