

## Fuzzy Synthetic Assessment of Overall Risk Level of Build-Operate-Transfer Highway Projects in Nigeria

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<https://doi.org/10.5281/zenodo.20491771>

### Abstract

Build-Operate-Transfer (BOT) is one of the most popular Private Finance Initiatives (PFI) models for the provision of highways in Nigeria. Private investors are however reluctant to invest in the BOT highway industry. This paper assesses how risky the BOT highway industry in Nigeria is to the stakeholders. This study's population includes important players such as public sector entities (government agencies), quantity surveyors, highway engineers, registered contractors, concessionaires, and selected financial institutions who are active participants in the BOT highway projects sector in Nigeria. The study was conducted in Lagos and Abuja. Respondents were administered one hundred and ten (110) questionnaires using stratified random sampling. The study adopted this sampling method due to the number of different participants involved and the number of cities the participants were located. The questionnaires were administered personally by the researchers. The analysis was carried out using 72 valid questionnaires as returned from the survey. The study used Fuzzy Synthetic Evaluation (FSE) with the aid of MATLAB 2023a for data analysis. The experts in the study classified twenty-one (21) risks as significant. The analysis found that the overall risk level for BOT highway projects is high (3.850 out of 5.000). However, this study dispelled the myth that the BOT highway sector is a no-go area. The study suggested that stakeholders must collaborate to enhance the BOT highway sector, which has underperformed expectations.

**Keywords:** Build-Operate-Transfer, construction, highway, risk

### 1. Introduction

A highway is a broad phrase that refers to a public road for the purpose of motor vehicle traffic, which

includes the whole right-of-way (FDOT, 2016). Every nation's lifeline is its highway infrastructure. It is crucial that it is safe, effective, and healthy (Deng, 2010). According to Obozuwa (2010), developed economies all over the world expanded and increased their infrastructure in order to strengthen their economies. The majority of nations worldwide have seen sluggish economic growth and development due to the appalling state of their fundamental infrastructure (Shatz *et al.*, 2011). The current state of affairs in Nigeria, which has more than 200 million inhabitants, 196,200 kilometers of highways, and a total land area of 910,768 square kilometers, but less than 40% of the highways paved, makes this claim pertinent (CIA, 2014).

This is utterly insufficient. Although there was little improvement, a number of procurement techniques were employed to lessen the insufficiency of roadway infrastructures. Nigeria's federal and state governments have resorted to engaging the private sector for the provision of infrastructures and utilities by implementing various Public Private Partnership (PPP) models in order to close the infrastructure gap. This change reflects the advantages of collaborative and BOT initiatives. These partnerships with the private sector can increase the availability of infrastructure, which will lessen the financial strain on governments and promote the growth of local capital markets (Awodele, 2012, Kukah *et al.*, 2022). In 2016, Nigerian infrastructure provision is moving toward public-private partnerships, according to former President Muhammadu Buhari:

“The nation has a huge infrastructure deficit for which we require foreign capital and expertise to supplement whatever resources we can marshal at home. In essence, increased engagement with the outside world is called for as we seek public private partnerships in our quest for enhanced capital and expertise. This is the way of the new world for all countries in the 21st century (Buhari, 2016)”.

Concerns have been expressed over the benefits of employing BOT procurement because of the numerous risks associated with the intricate combination of design, building, operation, and finance (Levy, 1996). Due to the larger number of participants and agreements, BOT projects carry far more risks than traditional projects (El-Sayegh and Mansour, 2015). Due to the economic conditions in developing nations, private sector investors have been reluctant to make investments in the BOT highway industry. Ameyaw (2014) proposed that the risky character of the projects is the reason for the inadequate investments in infrastructure provision in many African countries. Therefore, this paper assesses the overall risk level of BOT highway projects in Nigeria in order to inform stakeholders about the degree of riskiness of BOT highway and to dispel the myth that the BOT highway sector is unsuitable for investors.

## 2. Literature Review

### 2.1 Nature of Risks in BOT Highway Projects

Different definitions of risk exist based on the viewpoint of researchers. Risk is "viewed as a potential, unknowable event whose occurrence has a negative impact solely on project performance objectives" (Smith, 2002). Despite this belief, "risk is defined by many organizations and authors as uncertain events or conditions which, if they occur, have a positive or negative effect on any of the project performance objectives" (PMI, 2013; Creedy *et al.*, 2010). According to Creedy *et al.* (2010), "risk is a situation where circumstances planned in a specific chronology are changed by an external factor and this affected the premeditated progression of events, resulting in time and cost impacts." Risk so significantly affects project goals.

Risks are divided into three categories by Odeyinka (2003): known, known unknowns, and unknowns. He also proposed that "a risk is considered known when the likelihood of all potential outcomes and their repercussions occurring is known." A risk is categorized as known unknowns when its potential outcomes

are known, including its likelihood of occurring and its potential implications. The risk is considered unknown risk if neither the likelihood of occurrence nor the effects of the potential outcomes of the risk are known. Additionally, Adams (2008) distinguished between subjective and objective risks. Objective risks are those that, if their effects and likelihood of happening on a project are precisely estimated and documented. Therefore, quantitative analysis of objective risks is feasible. Since subjective risks cannot be objectively observed, qualitative assessments based on experts' knowledge, opinions, and experience of the risks can be conducted. Zayed *et al.* (2008) posited that highway projects are more uncertain and riskier than other kinds of infrastructural projects. Greater geographic coverage and numerous dangerous underground circumstances are responsible for this (Tadayon *et al.*, 2012, El-Sayegh and Mansour, 2015).

When these risks occur they result in time overruns, reductions in quality standards, and failure to keep within the budget (Jin and Zhang, 2011). The involvement of many participants and conflicting interests make BOT highway projects riskier (Carbonara *et al.*, 2015). Therefore, in order to improve performance, important risk factors in these kinds of projects need to be carefully and appropriately controlled (Rasheed *et al.*, 2022). This will guarantee that the clients get value for their money and improve project delivery.

### 2.2 Fuzzy Synthetic Evaluation

One method of decision-making in the domains of fuzzy logic is called Fuzzy Synthetic Evaluation, or FSE. Fuzzy set theory, developed by Zadeh in 1965, was intended to manage complicated, ambiguous, and imprecise data in order to assess options or reach judgments. The distribution of a fuzzy set's membership between 0 and 1 allows for varying membership degrees (Mazher *et al.*, 2019). FSE is applicable in many fields, where there is frequently a lack of reliable data or where expert opinions are valuable, FSE is applicable because it is especially helpful when dealing with subjective, low-certainty qualitative inputs (Ameyaw and Chan, 2015a, Boussabaine, 2013).

Several steps make up the FSE process: factors and criteria are represented as fuzzy sets to allow for gradual membership. These criteria are assessed using fuzzy membership functions and linguistic variables. Then, the evaluations are combined using weighted

average techniques and a defuzzification to convert fuzzy evaluations into precise values for ranking and rule- or preference-based decision-making (Liu *et al.*, 2013, Osei-Kyei *et al.*, 2017).

In order to determine the key elements affecting health and safety procedures in the Malaysian construction sector, Oni *et al.* (2023) used FSE analysis. By using this method, they were able to learn important lessons about improving safety procedures and practices in the building industry. The FSE approach was also used by Gurmu (2021) to determine the overall important index of human resource management practices that affect worker productivity in the construction industry. This study offered a methodological approach to labor management decision-making and clarified the major elements affecting productivity.

The application of FSE in construction management research is not limited to evaluation of multi-criteria decision problems only. Hu *et al.* (2016) adopted this technique to evaluate performance index of a construction organization on the delivery of construction project in China. Their study employed Delphi survey, which was used to gather expert opinions. The data collected was analyzed using FSE.

Recent studies have shown that the FSE technique could be used for risk assessment and allocation in PPP projects. Ameyaw and Chan (2016) used FSE to allocate risks in PPP water projects in developing countries. Similarly, Mazher *et al.* (2018) adopted FSE in their studies on risk assessment of PPP infrastructural projects in Pakistan. The goal of the study was to build on this trend by using FSE to calculate the proportions of risk distribution in Pakistan's PPP projects. FSE is preferred over the conventional weighted approach because it may effectively handle the subjectivity that frequently emerges in human cognitive processes and ensure objectivity in decision-making process (Ameyaw and Chan, 2015b). This study adopted fuzzy logic-based methodology, to deal with uncertainties and imprecisions that characterized inherent risk in construction projects.

### 3. Research Method

#### 3.1 Sampling Techniques and Data Collection Instrument

This study's population includes important players such as public sector entities (government agencies), quantity surveyors, highway engineers, registered con-

tractors, concessionaires, and selected financial institutions who are active participants in the BOT highway projects sector in Nigeria. Using a stratified random sample technique, 110 respondents were administered questionnaires. Fifty-five questionnaires were administered to the respondents in Lagos. Government agencies (8), Consultants (18), Concessionaires (10), Contractors (9), and Bankers (10). This gives a total of fifty-five respondents. Fifty-five questionnaires was equally administered to respondents in Abuja. Government agencies (17), Consultants (22), Concessionaires (5) and Contractors (11), making a total of fifty-five respondents. The distribution was based on the data from Infrastructure Concession and Regulatory Commission (ICRC) on key participants on PPP projects. Seventy-two valid questionnaires were returned and used in the study. There were four sections on the questionnaire. The socio-economic characteristics of the respondents was addressed in Section A. This included the respondents' designation, educational and professional background, years of industry experience, number of projects managed, positions in the project, and expertise with BOT highway projects. This information was obtained from the respondents, which helped establish the appropriateness of the information they provided and how well-informed they were about the topic of risk allocation of BOT highway projects. Section B discussed the issues preventing PPP/BOT projects in Nigeria from being implemented. It included a table listing the obstacles to Nigeria's BOT highway projects' operation. Based on their industry experience, the experts were asked to tick their opinion. Combining objectives 2 and 4, Section C focused on identifying important risk factors in Nigerian BOT highway projects and allocating risk due to the multitude of risk factors.

Its purpose was to evaluate the study's possible risk variables' probability and severity characteristics. The likelihood of occurrence and severity descriptive ratings displayed 70 possible risk variables. The questionnaire categorized these possible hazards according to the risk source, as recommended by (Xenidis and Angelides, 2005; Ameyaw, 2015). Nonetheless, the questionnaire included a 5-point Likert scale for the three main sections: significant risk considerations, obstacles to BOT highway projects, and risk distribution between public and private entities. It used the following variables to identify significant risk

factors: Very likely = 5, likely = 4, Somehow likely = 3, Slightly likely = 2, and Not likely = 1 for the probability of risk occurrence, and Disastrous = 5, Severe = 4, Substantial = 3, Marginal = 2, and Negligible = 1 for the risk impact. The degree of agreement among respondents was sought for factors pertaining to issues impeding the execution of BOT highway projects in Nigeria. Therefore, Strongly Disagree = 1, Disagree = 2, Agree = 4, and Strongly Agree = 5. In construction risk management studies, rating scales are a practical and efficient instrument for recording practitioners' risk perceptions (Odeyinka *et al.*, 2012; Ameyaw *et al.*, 2015).

### 3.1 Evaluation of Overall Risk Level (ORL) of BOT Highway Projects in Nigeria

#### 3.1.1 Categorization of risks in BOT Highway projects

Determining key risk variables is the first critical stage in establishing the level of riskiness of BOT highway projects. Thus, defining the factor structure (main factors) is essential to ensure FSE model development. The 21 SRFs were categorized into four groups. This is owing to the fact that the experts utilised in this study were 72 in number, while the factors to be examined were 21. As a result, the premise of factor analysis, which demands a minimum variable-to-sample ratio of 1:5, was not met (Field, 2013). Several groups have been proposed in the literature. This analysis followed the categorisation proposed by Özdoğan and Birgönül (2000), Salman *et al.* (2007), and Ameyaw (2014).

The rationale for this is that it categorises the factors associated with various parts of common risks in BOT projects. The 21 significant risk factors were classified based on their relationship: eight factors in the macroeconomics and project finance category, five in the state and socio-legal policy category, four in the natural and relationship category and four in the construction and operation category.

There are two benefits to the grouping: the reduction of 21 SRFs into 4 easily manageable PRFs, which lessens the strain of managing 21 SRFs, and the use of PRFs as input variables for evaluating the overall risk level of BOT highway projects. At this point, the decision-makers can focus on the four crucial areas. (i) Which PRF makes the most contribution to BOT highway projects? These are the questions that need to be answered right away. (ii) How risky are BOT highway projects, taking the PRFs into account? FSE provides

answers to these two queries. Table 1 classifies the risk factors.

Table 1 shows the grouping of the PRFs and the significant risk variables (21 in this case). Column 2 of Table 1 displayed the values of the risk's impact, as well as the overall and category ranking for all significant risk variables. Ameyaw (2014) described how to estimate the overall risk level of projects. This involves different PRFs (four in this case), each with a distinct level of criticality, and risk factors (within each PRF) on the next lower level. In this study, each PRF is evaluated on the basis of criticality. The overall level of risk is then measured.

The main advantage of FSE is its capacity to analyse multi-factor and multi-level decision problems related with project risk evaluation. Thus, the membership grades are calculated level by level, beginning with the lowest risk factors and progressing to the top principal factors, where the overall risk level of the projects is determined based on the membership grades. Furthermore, the fuzzy character of the data and the necessity to rely on expert judgement make fuzzy set theory an essential tool for this study (Boussabaine, 2014).

#### 3.1.2 Determining the Membership Functions of SRFs and PRFs

In determining the Membership functions at this stage, the significant risk factors (SRFs) are obtained from the responses of survey conducted on the experts using Equation (1), which presents the membership functions for risk probability and risk severity respectively. The results obtained constitutes the third level membership function (MF) obtained from the output of SPSS

$$M_i = \frac{\sum_{i=1}^w W_i f_i}{\sum_{i=1}^w f_i}, \quad \text{eq 1}$$

#### 3.1.3 Calculating the Weighting Functions of the SRFs and PRFs

Equation (2) was used to calculate the weightings for each SRF and PRF. The weighting functions for SRFs were derived using average values from the expert survey. Thus, risk probability and severity were computed. However, in order to obtain the weightings, all the means were normalised to unity, that is, the total of all weightings equal 1. Table 2 displays the weighting function of SRFs and PRFs.

$$W_i = \frac{M_i}{\sum_{i=1}^n M_i}, \quad \text{eq 2}$$

where  $W_i$  = relative weight of each SFR/PRF

Table 1 Classification of Risk Factor

Significant Risk Factors (SRF) and Categories	Risk Impact	Overall Ranking	Ranking Within Categories
<b>Macro-economics and Project Financing</b>			
<b>PRF1</b>	4.52	1	1
Inflation rate volatility, u <sub>11</sub>	4.19	3	2
Exchange rate fluctuation, u <sub>12</sub>	4.07	4	3
Interest rate volatility, u <sub>13</sub>	4.05	5	4
High finance cost, u <sub>14</sub>	3.73	12	5
Influential economic condition, u <sub>15</sub>	3.62	16	6
Bankruptcy of the concessionaire, u <sub>16</sub>	3.61	17	7
Poor financial market, u <sub>17</sub>	3.60	18	8
Availability in finance, u <sub>18</sub>			
<b>Policy of State and Socio-Legal Factor</b>	4.03	6	1
<b>PRF2</b>	3.91	7	2
Corruption and lack of respect for rule of law, u <sub>21</sub>	3.89	9	3
Lack of standard model for PPP agreement, u <sub>22</sub>	3.79	10	4
	3.64	15	5
Public opposition to Toll payment, u <sub>23</sub>	3.90	8	1
Unsteady legal and regulatory framework, u <sub>24</sub>	3.74	11	2
	3.66	14	3
Unstable government, u <sub>25</sub>	3.59	19	4
<b>Construction and Operation PRF3</b>			
Material/labour availability, u <sub>31</sub>	4.45	2	1
Tariff change, u <sub>32</sub>	3.67	13	2
Operational revenue below expectation, u <sub>33</sub>	3.56	20	3
Insolvency/default of subcontractors or suppliers, u <sub>34</sub>	3.51	21	4
<b>Natural, Relationships and Residual PRF4</b>			
Geotechnical conditions, u <sub>41</sub>			
Delay in projects approval and permits, u <sub>42</sub>			
Force majeure, u <sub>43</sub>			
Inadequate distribution of responsibilities and risks, u <sub>44</sub>			
Source: Authors (2025)			

**Table 2:** Weightings for SRFs and PRFs for BOT highway projects.

Significant Risk Factors	Probability			
	Mean (P)	Weightings SRF	Total Mean PRF	Weightings PRF
<b>Principal Risk Factors (PRF) and Category</b>				
Inflation rate volatility $u_{11}$	4.49	0.146		
Exchange rate fluctuation, $u_{12}$	4.07	0.132		
Interest rate volatility, $u_{13}$	4.01	0.130		
High Finance costs, $u_{14}$	3.89	0.126		
Influential economic conditions, $u_{15}$	3.57	0.116		
Bankruptcy of Concessionaire, $u_{16}$	3.54	0.115		
Poor financial market, $u_{17}$	3.57	0.116		
Availability in Finance, $u_{18}$	3.68	0.119		
<b>Macro-economics and Project Finance PRF1, <math>u_1</math></b>			30.82	0.389
Corruption and lack of respect for rule of law, $u_{21}$	4.01	0.212		
Lack of standard model for PPP agreement, $u_{22}$	3.90	0.207		
Public opposition to toll payment, $u_{23}$	3.72	0.197		
Unsteady legal and regulatory framework, $u_{24}$	3.78	0.200		
Unstable government, $u_{25}$	3.47	0.184		
<b>Policy of State and Socio-legal PRF2, <math>u_2</math></b>			18.88	0.238
Material/labour availability, $u_{31}$	3.79	0.261		
Tariff change, $u_{32}$	3.69	0.254		
Operational revenues below expectation, $u_{33}$	3.60	0.248		
Insolvency/default of sub-contractors or suppliers, $u_{34}$	3.43	0.237		
<b>Construction and Operation PRF3, <math>u_3</math></b>			14.51	0.183
Geo-technical condition, $u_{41}$	4.40	0.292		
Delay in project approvals and permits, $u_{42}$	3.61	0.239		
Force majeure, $u_{43}$	3.40	0.225		
Inadequate distribution of responsibilities and risks, $u_{44}$	3.68	0.244		
<b>Natural, Relationship and Residual PRF4, <math>u_4</math></b>			15.09	0.19
<b>Total of Means/normalized values of PRF</b>			79.30	1.000

Source: Authors (2025)

**Table 3:** Membership Functions of SRFs and PRFs for BOT Highways (risk probability).

Significant Risk Factors (SRF) and PRFs	Weightings	Membership Functions for	Membership Functions for
Macro-economics and Project Finance, PRF1, $u_1$	for SRFs	Level 3 SRFs	Level 2 SRFs
Inflation rate Volatility, $u_{11}$	0.146	[ 0.00, 0.00, 0.00, 0.51, 0.49]	[0.000 0.002 0.223 0.666 0.109]
Exchange rate Fluctuation, $u_{12}$	0.132	[ 0.00, 0.00, 0.07, 0.79, 0.14]	
Interest rate volatility, $u_{13}$	0.130	[ 0.00, 0.00, 0.04, 0.90, 0.06]	
High Finance costs, $u_{14}$	0.126	[ 0.00, 0.00, 0.14, 0.83, 0.03]	
influential economic conditions, $u_{15}$	0.116	[ 0.00, 0.01, 0.43, 0.53, 0.03]	
Bankruptcy of Concessionaire, $u_{16}$	0.115	[ 0.00, 0.01, 0.46, 0.50, 0.03]	
Poor financial market, $u_{17}$	0.116	[ 0.00, 0.00, 0.43, 0.57, 0.00]	
Availability in Finance, $u_{18}$	0.119	[ 0.00, 0.00, 0.32, 0.68, 0.00]	
<b>Policy of State and Socio-legal PRF2, <math>u_2</math></b>			[0.000 0.013 0.251 0.666 0.070]
Corruption and lack of respect for rule of law, $u_{21}$	0.212	[ 0.00, 0.00, 0.12, 0.74, 0.14]	
Lack of standard model for PPP agreement, $u_{22}$	0.207	[ 0.00, 0.00, 0.18, 0.74, 0.08]	
Public opposition to toll payment, $u_{23}$	0.197	[ 0.00, 0.03, 0.26, 0.67, 0.04]	
Unsteady legal and regulatory framework, $u_{24}$	0.200	[ 0.00, 0.00, 0.28, 0.64, 0.08]	
Unstable government, $u_{25}$	0.184	[ 0.00, 0.04, 0.44, 0.52, 0.00]	
<b>Construction and Operation PRF3, <math>u_3</math></b>			[0.00 0.005 0.383 0.584 0.028]
Material/labour availability, $u_{31}$	0.261	[ 0.00, 0.00, 0.25, 0.71, 0.04]	
Tariff change, $u_{32}$	0.254	[ 0.00, 0.01, 0.28, 0.71, 0.00]	
Operational revenues below expectation, $u_{33}$	0.248	[ 0.00, 0.00, 0.46, 0.48, 0.06]	
Insolvency/default of sub-contractors or suppliers, $u_{34}$	0.237	[ 0.00, 0.01, 0.56, 0.42, 0.01]	
<b>Natural, Relationship and Residual, <math>u_4</math></b>			[0.000 0.005 0.321 0.531 0.144]
Geo-technical conditions, $u_{41}$	0.292	[ 0.00, 0.00, 0.06, 0.48, 0.46]	
Delay in project approvals and permits, $u_{42}$	0.239	[ 0.00, 0.01, 0.38, 0.60, 0.01]	
Force majeure, $u_{43}$	0.225	[ 0.00, 0.01, 0.60, 0.36, 0.03]	
Inadequate distribution of responsibilities and risks, $u_{44}$	0.244	[ 0.00, 0.00, 0.32, 0.68, 0.00]	

Source: Authors (2025)

Tables 3 and 4 illustrate the trapezoidal membership functions of each of the significant risks for risk probability and risk severity at levels 3 and 2. Inputting the weightings and level 3 membership functions into MATLAB 2023a yielded level 2.

**Table 4:** Membership Functions of SRFs and PRFs for BOT Highways (risk severity)

Critical Risk Factors (CRF) and Category	Weightings	Membership Functions for	Membership Functions for
	for SRFs	Level 3 SRFs	Level 2 SRFs
<b>Macro-economics and Project Finance PRF1, u<sub>1</sub></b>			[0.000 0.005 0.160 0.640 0.195]
Inflation rate Volatility, u <sub>11</sub>	0.142	[ 0.00, 0.00, 0.00, 0.46, 0.54]	
Exchange rate Fluctuation, u <sub>12</sub>	0.135	[ 0.00, 0.00, 0.02, 0.65, 0.33]	
Interest rate volatility, u <sub>13</sub>	0.129	[ 0.00, 0.00, 0.00, 0.86, 0.14]	
High Finance costs, u <sub>14</sub>	0.132	[ 0.00, 0.00, 0.03, 0.72, 0.25]	
influential economic conditions, u <sub>15</sub>	0.122	[ 0.00, 0.03, 0.13, 0.76, 0.08]	
Bankruptcy of Concessionaire, u <sub>16</sub>	0.116	[ 0.00, 0.01, 0.31, 0.67, 0.01]	
Poor financial market, u <sub>17</sub>	0.114	[ 0.00, 0.00, 0.44, 0.46, 0.10]	
Availability in Finance, u <sub>18</sub>	0.110	[ 0.00, 0.00, 0.47, 0.53, 0.00]	
<b>Policy of State and Socio-legal PRF2, u<sub>2</sub></b>			[0.000 0.016 0.134 0.759 0.091]
Corruption and lack of respect for rule of law, u <sub>21</sub>	0.206	[ 0.00, 0.00, 0.05, 0.85, 0.10]	
Lack of standard model for PPP agreement, u <sub>22</sub>	0.199	[ 0.00, 0.06, 0.08, 0.75, 0.11]	
Public opposition to toll payment, u <sub>23</sub>	0.207	[ 0.00, 0.00, 0.10, 0.73, 0.17]	
Unsteady legal and regulatory framework, u <sub>24</sub>	0.194	[ 0.00, 0.02, 0.19, 0.79, 0.00]	
Unstable government, u <sub>25</sub>	0.194	[ 0.00, 0.00, 0.26, 0.67, 0.07]	
<b>Construction and Operation PRF3, u<sub>3</sub></b>			[0.000 0.015 0.281 0.670 0.007]
Material/labour availability, u <sub>31</sub>	0.263	[ 0.00, 0.00, 0.07, 0.83, 0.10]	
Tariff change, u <sub>32</sub>	0.248	[ 0.00, 0.00, 0.24, 0.73, 0.03]	
Operational revenues below expectation, u <sub>33</sub>	0.243	[ 0.00, 0.00, 0.29, 0.71, 0.00]	
Insolvency/default of sub-contractors or suppliers, u <sub>34</sub>	0.246	[ 0.00, 0.00, 0.25, 0.74, 0.01]	
<b>Natural, Relationship and Residual u<sub>4</sub></b>			[0.000 0.020 0.254 0.576 0.150]
Geo-technical conditions, u <sub>41</sub>	0.294	[ 0.00, 0.00, 0.03, 0.46, 0.51]	
Delay in project approvals and permits, u <sub>42</sub>	0.243	[ 0.00, 0.03, 0.24, 0.73, 0.00]	
Force majeure, u <sub>43</sub>	0.244	[ 0.00, 0.00, 0.28, 0.72, 0.00]	
Inadequate distribution of responsibilities and risks, u <sub>44</sub>	0.219	[ 0.00, 0.06, 0.54, 0.40, 0.00]	

Source: Authors (2025)

### 3.1.4 Evaluating the Risk Level of PRFs

Having shown that the three tiers of membership functions in this study's FSE approach are levels 3 through 1. The survey evaluation of the experts yielded Level 3. Equation (3) was used to generate a fuzzy matrix in order to evaluate the risk level of a particular PRF. By considering the weighting functions of the SRFs within the PRF, the matrix equation was further normalised. The weighting and MF values from level 3 were entered into MATLAB version 2023a for processing in order to generate the level 2 membership functions. Table 3 (Column 4) shows the output for every PRF. As shown in Table 4, the same procedure was used for each PRF's risk severity. Additionally, the MFs for Level 2 obtained from Tables 3 and 4 were entered into MATLAB version 2023a for processing in order to determine the membership function of overall risk level 1 of Nigerian BOT highway projects. As indicated in Table 5, this yields the level 1 membership function (MF).

The fuzzy evaluation matrix  $D_i$  can be derived thus:

$$D_i = W_i \cdot R = (d_{i1}, d_{i2}, \dots, d_{in}) \quad \text{eq. (3)}$$

$$R = (w_{i1}, w_{i2}, \dots, w_{in}) \circ \begin{bmatrix} x_1 u_{i1} & x_2 u_{i1} & x_3 u_{i1} & x_4 u_{i1} \\ x_1 u_{i2} & x_2 u_{i2} & x_3 u_{i2} & x_4 u_{i2} \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ x_1 u_{in} & x_2 u_{in} & x_3 u_{in} & x_4 u_{in} \end{bmatrix}$$

$$= (d_{i1}, d_{i2}, \dots, d_{in})$$

This procedure was carried out for risk probability and risk severity.

**Table 5:** Determination of Membership functions of Overall Risk Level (Level 1)

Significant Risk Groups (SRFs)	Weightings (W) for PRFs	Membership functions of Level 2 (PRFs)	Membership function of level 1
<i>Risk Probability (From level 2 to 1)</i>			
Macro-economic and Project Finance (PRF1): $u_1$	0.372	[0.000 0.002 0.223 0.666 0.109]	(ORL) [0.0000 0.0060 0.2765 0.6269 0.0907]
Policy of State and Socio-legal (PRF2): $u_2$	0.270		
Construction and Operation (PRF3): $u_3$	0.175	[0.000 0.013 0.251 0.666 0.070]	
Natural, Relationship and Residual (PRF4): $u_4$	0.183	[0.000 0.005 0.383 0.584 0.028]	
<i>Risk severity (From level 2 to 1)</i>			
Macro-economic and Project Finance (PRF1): $u_1$	0.376	[0.000 0.005 0.321 0.531 0.144]	[0.0000 0.0124 0.1907 0.6661 0.1370]
Policy of State and Socio-legal (PRF2): $u_2$	0.272		
Construction and Operation (PRF3): $u_3$	0.173	[0.000 0.005 0.160 0.640 0.195]	
Natural, Relationship and Residual (PRF4): $u_4$	0.179	[0.000 0.016 0.134 0.759 0.091] [0.000 0.015 0.281 0.670 0.007] [0.000 0.020 0.254 0.576 0.150]	

Source: Authors (2025)

### 3.1.5 Defuzzification

Equation (4) was used to calculate the overall risk level of Nigerian BOT highway projects. The membership function acquired in level 1 for the PRFs and ORL is multiplied by the risk probability and severity grading scales (Sadiq and Rodriquez, 2004).

Overall risk level (ORL) is obtained as follows:

$$ORL = \sqrt{\{\sum_{i=1}^5 D_p \times V^T\} \times \{\sum_{i=1}^5 D_s \times V^T\}}$$

$$1 \leq ORL \leq 5 \quad \text{eq. (4)}$$

$V^T =$  adopted grading scale (Sadiq and Rodriquez, 2004). Where subscript ‘ $P$ ’, is risk probability of occurrence and subscript ‘ $S$ ’, is risk severity.

## 4. Results

### 4.1 Socio-economic Characteristics of the Experts

According to the experts' socio-economic data, 64% of respondents were corporate members of their professional associations, and 17% had an HND, 44% had a BSc, 26% had an MSc/MBA, and 3% had a PhD. Highway engineers make up 25% of the respondents, followed by Quantity surveyors (17%), Concessionaires (22%), Contractors (19%), and Bankers (17%). 53% of respondents were employed in the private sector, compared to 47% in the public sector. Seventy-five percent

of those surveyed had worked on BOT highway projects for more than six years. Over 50% of those surveyed had overseen three or more projects. This suggests that the respondents' information can be considered appropriate and reasonable.

### 4.2 Nigerian BOT Highway Projects' Overall Risk Level

In Table 6, the Nigerian BOT highway projects' overall risk level was 3.850. All of the major risk factors (PRFs) had a high probability and severity score. The linguistic interpretation of all the PRFs reveal that they were all of great importance. On a scale of 1 to 5, this is a high result. Ameyaw (2014) used a similar scale: <1.50 = extremely low, 1.50-2.49 = low, 2.50-3.49 = moderate, 3.50-4.49 = high, and  $\geq 4.50$  = very high. As a result, both public and private stakeholders could see BOT highway projects as risky.

### 4.3 Implication of the Study

This study holds both theoretical and practical implications. Firstly, there has never been a data base for establishing the risk level of BOT highway projects in Nigeria. Therefore, it has been established that the overall risk in BOT highway project is high. Further research efforts would deepen the extent of this using other methods or approaches to investigate impact of risk on BOT projects. Generally, the findings of this study clearly offer valuable insights for shaping future research on evaluating overall risk level of highway projects, not only in

**Table 6:** Nigerian BOT Highway Projects' Overall Risk Level

Principal Risk Factors (PRFs)	Probability of Occurrence		Severity		Overall Risk	Level	Ranking
	Index	Linguistic	Index	Linguistic	Index	Linguistic	
Macroeconomics and Project Project (PRF1)	3.882	High	4.025	High	3.953	High	1
Policy of State and Socio-Legal (PRF2)	3.793	High	3.925	High	3.858	High	2
Construction and Operation (PRF3)	3.725	High	3.588	High	3.655	High	4
Natural, Relationship and Residual (PRF4)	3.817	High	3.856	High	3.836	High	3
<b>Overall Risk Level (ORL) of BOT Highways in Nigeria</b>	3.804	High	3.905	High	3.850	High	-

Source: Authors (2025)

Nigeria but other developing countries facing similar challenges. Secondly, the study offers significant practical implications for all stakeholders; be it Government, Concessionaires, Bankers, Consultant and Contractors, particularly in emerging economies where provision of highway project is very challenging. It will also, help make practical decisions on how to review risks inherent in BOT highways to establish a benchmark for managing and sustaining BOT highways. Though, this study was carried out in two cities, it could be used to evaluate other areas and sectors in the economy.

## 5. Conclusion

This study has been able to establish the overall risk level of BOT Highway projects in Nigeria. The BOT highway project in Nigeria is risky considering the results obtained from the analyzed data. This is due to the fact that different project characteristics evolve with each of the subsector. Though, some risks affect all projects, there are risks that are peculiar to each project. This issue explains the sector's underinvestment since the private sector would not want to make investments where there would be complete loss. There is need for concerted effort from the stakeholders to synergize and ensure proper and adequate participation of the private sector participants through creation of enabling environment that will make the sector attractive. The need to organize training and workshop for stakeholders in the industry is crucial so that participants in the sector can obtain value for money. The research findings in this study might have limited in application for other Build-Operate-Transfer projects. The findings from this research remains valuable for guiding future research and serves as a guide for stakeholders such as government, donor agencies, financial institutions, concessionaires in policy formulations and implementation.

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