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Article

The Application of Heuristic Reasoning in the Risk Analysis of Unforeseen Risk Events in Construction Projects in Nigeria

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Abstract: Heuristic reasoning is used to deduce Fuzzy Decision Variables that could give rise to unforeseen risk in a proposed construction project for a selected client. The case study of some selected projects was undertaken to determine the sources of unforeseen risks in the domain and deduce the impact of the unforeseen risks that could occur in the domain of projects. Fuzzy set analysis was utilised to calculate the likely impact of the risk of unknown unknown. The work items which were unforeseen in the projects included additional foundations, burglar-proofing to windows, omission of work items, additional fixtures, builder's work, additional external works, additional electrical installations, additional mechanical installations, etc. The likely consequence of the occurrence of the risk of unknown unknown in a domain could be estimated as a fuzzy number. The magnitude of the likely consequence could be obtained by converting the fuzzy value into a crisp value. The concept of Fuzzy Decision variables could be utilized in the identification of events that could lead to unforeseen risk; and fuzzy set analysis could be used to estimate the impact of the risk due to unforeseen events.

Keywords: Heuristic reasoning; unknown unknown risk; Fuzzy Decision Variables; fuzzy set analysis.

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1. Introduction

Risk is inherent in construction projects. Risk management requires the identification and quantification of risks. Flanagan and Norman (1993) have argued that forecasting the future is possible by considering that what has happened in the past could happen in the future if the same conditions that precipitated the past events present themselves again in the future.

According to the Project Management Institute (2008), risk is "an uncertain event or condition that, if it occurs will have either a positive or negative effect on one or more project objectives". The construction industry is besotted with different scenarios that constitute many unpredictable, uncertain and unforeseen occurrences (Odeyinka, 2003). Keshk et al (2018) have emphasized the need to be proactive in undertaking risk management for proposed construction projects and to maintain such perspective throughout the tenure of the project.

This paper seeks to present a methodology that utilizes heuristic reasoning in the prediction of the occurrences of unforeseen risk in construction projects.

The aim of the study is to utilise heuristic reasoning in the risk analysis of building construction projects in a selected domain.

The objectives of the study are as follows:

- To identify the sources of unforeseen risks that cause financial impacts on construction projects
- To identify the Fuzzy Decision Variables that give rise to these risks
- To assess the likely magnitudes of the consequences of the Fuzzy Decision Variables

2. Literature Review

The concept of Fuzzy Decision Variable (FDV) has been utilized by Ibrahim (2008) in predicting the occurrence of risks in construction projects. An FDV for a risk connotes a a particular disposition in a risk environment that predisposes the occurrence of a certain risk (Bala and Yakubu, 2008). An FDV is derived by canvassing through project information such as drawings, bills of quantities, and specifications to determine the likelihood of the occurrence of a particular risk (Ibrahim, 2008). Ibrahim (2007) and Ibrahim (2008) have utilised FDVs to carry-out the risk analysis of construction projects. The Reason's model of organisational accident could be used to portray the nature of FDVs.

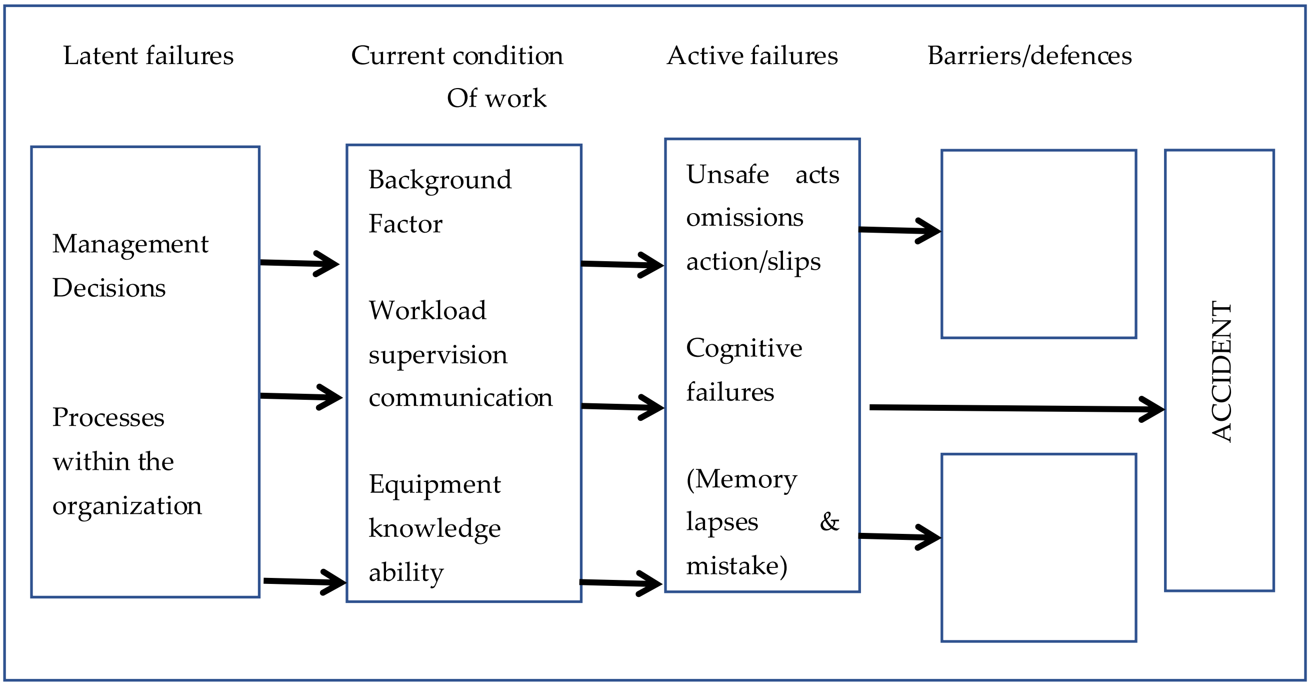

Figure 1 Reason's model of organisational accidents

Source: Reason (1995)

The purpose of the model is to represent the scenario when an accident occurs; including the defences put-up to prevent such accidents and the active failures that cause the accidents.

In the process of making decisions, human beings must utilize certain skills. According to Dewhurst and Gwinnet (1992), logical deduction applies principles based upon mathematical models or propositional logic as a technique in decision-making.

Reasoning has been modelled by Polya (1969) based upon the rule:

IF A THEN B

The pattern defined by the model could be used in an argument. Sometimes, more than one symptom could persist in a situation. The rule then becomes:

$$A \Rightarrow B_1, B_2, B_n$$

Evidence of a single symptom Bi tells little about A. however, a plausible line of reasoning is (Hart, 1986): "B_3 is true. I also know that B_1 and B_2 are true, and that B_3 is different from them so this makes A more credible" The various symptoms that foretell the existence of a condition could be construed as heuristics.

A heuristic is information acquired by experience which can be applied to decisions in future situations which are similar, but not quite the same. Expert persons and ordinary laymen utilise heuristics to make estimates about certain events; rather than compute such estimates statistically (Slatter, 1987).

Production rules are used to elicit decisions. According to Siler (2000), a set of rules are utilized in the development of knowledge-based systems. Such rules are of the type:

IF (certain patterns are present in the data)
THEN (execute certain actions; including altering data or confirming new data)

Risk manifest in its consequence. Hence the difference between initial contract sum and the final contract could occur as a result of the occurrence of risk. This difference must be investigated to identify the FDVs that cause the risks that result into a difference between the initial contract sum and the final contract sum. According to Goble (1981), structured system analysis involves "taking the problem area in the most general form and then refining it in a structured and systematic manner until the finest levels of details are obtained.

In the final account preparation, the adjustment of the contract sum is executed under the following headings:

Variations
Remeasurement of provisional quantities
Nominated subcontractors' accounts
Nominated suppliers' accounts
Loss and expense caused by disturbances of regular progress of the works
Fluctuation in rates of labour and prices of materials

Unforeseen Conditions connotes latent and adverse conditions present in a project or on a project site that were not known to the contractor at the time of contract. Smith et al (1999) have categorized risk into three categories: known risks, known unknowns and unknown unknowns. The frequency and effects of known risks are known. In known unknown, either the effect or frequency is known. In unknown unknowns, both the effects and probability are unknown.

Kim (2012) has proposed that the unknown unknowns are not truly unknown unknowns; that it is possible to identify the unknown unknowns and subsequently convert them to known unknowns. This could be done by classifying risk events by identification and certainty as illustrated in Table 1.

Table 1: Categorization by identification and certainty

Identification \ Certainty	Certain (Known)	Uncertain (Unknown)
Identified (Known)	Known known (identified knowledge)	Known unknown (identified risk)
Unidentified (Unknown)	Unknown known (untapped knowledge)	Unknown unknown (unidentified risk)

Source:
Kim (2012)

Khosravi and Bin Mohammed (2012) have characterized unexpected events as being unpredictable, uncontrollable, and having serious impact on the construction projects. Reasons for the occurrence of unforeseen events include human involvement, excessive cost of projects, environmental causes, unique projects, and long construction periods with associated complex processes. Contractors routinely find substructure conditions that have been foreseen (Halligan, 1987). Examples include the occurrence of ground water, presence of utilities pipes and electrical cables, and rocky material lying beneath the surface of earth. Such findings could cause substantial impact on project schedule and costs.

Some standard conditions of contract recognize the possibility of unexpected events occurring in the course of carrying-out the project and prescribe appropriate course of action to take. According to the FIDIC Conditions of Contract for Construction (2017), unforeseeable physical conditions could arise during the execution of the Works. These physical conditions could adversely affect the progress of the Works and/or add to the cost of the project. Physical conditions are "natural physical conditions and physical obstructions (natural or man-made) and pollutants, which the Contractor encounters at the Site during execution of the Works, including sub-surface and hydrological conditions but excluding climatic conditions at the Site and the effects of those climatic conditions". Clause 4.12 of the FIDIC Conditions of Contract stipulates that the contractor shall notify the engineer who will assess the conditions and give instructions towards the conditions. The contractor shall then be reimbursed for any consequential delays or costs that might arise.

The JCT Standard Building Contract with Quantities 2016, JCT SBC/Q (2016) does not specifically mention unforeseen conditions. However, its variation clause 5.1.1 defines the term variation as "the alteration or modification of the design, quality or quantity of the Works. This includes:

".1 the addition, omission or substitution of any work;

.2. the alteration of the kind or standard of any of the materials or goods to be used in the Works;

.3 the removal from the site of any work executed or Site Materials other than work, materials or goods which are not in accordance with this Contract;"

Clause 5.1.1 could be used to compensate the contractor for losses and expenses that arise from unforeseen events that are not due to negligence on the part of the contractor.

Bai and Bukhanenko (2025) have suggested a need for a systematic approach towards risk management that encompasses innovative technologies with their attendant beneficial effects. Rule-based logic and fuzzy logic have been applied in the development of industrial control systems, creation of complex models, and fuzzy knowledge-based systems (Dutta, 1993). Kaoutar and Lahcen (2015) have proposed a framework comprising of stakeholder analysis, Fuzzy Analytic Hierarchy Process (FAHP), and the elimination and choice translating reality method in fuzzy Multi-Criteria Decision Analysis (MCDA) to carry-out the environmental impact assessment of risk. Fikri and Ibrahim (2019) have developed a conceptual framework that presents risk list and their ranking for planning large-scale transportation projects. Generally, in contemporary artificial intelligence research, it is expedient to construct new paradigms based on existing theories rather than create new theories, substantiate claims on robust theorems or concrete experimental evidence, and articulate the utility of real-life applications as against petty similitudes (Russell and Norvig, 2010)

3. Research Methodology

3.1 Details of Projects

Project: Hostel

Construction Type: Reinforced concrete frame with blockwork cladding

Initial contract sum: N31, 159, 672.50

Final contract sum: N37, 095, 629.52

Contract period: 58 weeks

Completion period: 121 weeks

3.2 Identification of the Risk of Unknown unknown

An FDV is a variable that is measured by its intensity or concentration. The concentration indicates the likelihood of occurrence of the FDV. Keller (1987) has argued that experts derive their decision-making capability based upon the large number of heuristics they have accumulated in a particular domain.

According to Smith (1999), risk can be classified in three broad groups: known risks, known unknowns, and unknown unknown. Known risks occur regularly and they include changes in productivity levels and costs of materials. Known unknowns are predictable risks whose probability of occurrence or impact of occurrence could be measured. The risk of unknown unknown is unpredictable; as its likelihood and extent of impact cannot be ascertained.

It is useful to define the FDV of the unknown unknown as an unknown latent condition that cannot be defined, nor identified and is not estimable in terms of effect; yet it could cause significant adjustment in the contract sum (Ibrahim, 2008). A provisional sum has been defined as a sum provided for a cost which cannot be entirely foreseen, defined or detailed at the time of tendering (NIQS, 2015). Consequently, an FDV that results in the adjustment of provisional sums is the FDV for the risk of the unknown unknown (Ibrahim, 2008).

The final contract sum increased over the initial contract sum by 19.05%.
Table 1 gives the cost constituents of the final contract sum.

Table1. Breakdown of final contract sum

S/no.	Description	Percentage difference in contract sum caused by item (%)
1.	Adjustment of PC sum	+3.46
2.	Adjustment of provisional sums	-5.49
3.	Variations	+3.41
4.	Remeasurement	-2.70
5.	Fluctuations	+20.37
	Total percentage difference in contract sums	+19.05

The initial contract sum has been decreased by -5.49% as a result of the adjustment of the Provisional sums. Table 2 lists the items of work covered by provisional sums and the cost effects of the on the initial contract sum.

Table 2. Items of work covered by provisional sums and the cost effects of the on the initial contract sum

S/no	Description	Percentage contribution of item to total provisional sum (%)	Percentage difference in contract sum caused by item (%)
1.	Additional foundations	13.08%	-0.80%
2.	Burglar-proofing	2.17%	+0.12%
3.	Contingencies	83.85%	-4.81%
		Net difference to the initial contract sum caused by total provisional sums	-5.49

Consequently, the FDV of unknown unknown had precipitated a decrease of 5.49% to the initial contract sum.

3.3 Evaluation of the Magnitude of the Risk of Unknown unknown

For the purpose of evaluating the consequences of risk, fuzzy set analysis is utilized.

Fuzzy set analysis is used in evaluating the impact of the risk. According to Borgardi and Bardossy (1983) fuzzy set analysis could be applied situations where the data available is not probabilistic. Fuzzy set analysis is used in estimating where there is insufficiency of data Paek et al (1993); since it uses human judgment, rather than probabilistic reasoning. Most real-life decisions are made by experts using data that could be inadequate (Keller, 1987). The concept of fuzzy sets denotes partial membership of sets to represent partial truth or falseness Zadeh (1965). Membership values are shown by a value on the range [0.0, 1.0], with 0.0 indicating absolute non-membership and 1.0 representing absolute membership (Ibadov, 2015).

The fuzzy analysis of a variable could be carried-out using five samples of a variable (Paek et al 1993). Fuzzy set analysis could be used in scenarios where data is adequate in quantity.

Lee et al, 1991 have shown that the total net loss, T, can be assessed as a fuzzy number labelled with two values, $T_{h=0}$ and $T_{h=1}$, with the membership functions:

$\mu(T) = 1, \quad \alpha < T < \beta$ ……………………………………………………………………… (1)

$\mu(T) = (T-A)/(\alpha-A), \; A<=T<\beta$ ……………………………………………………………. (2)

$\mu(T) = (T-B)/(\beta-B), \; \beta<=T<=B$ ……………………………………………………………… (3)

$\mu(T) = 0$, otherwise……………………………………………………………………………….. (4)

where A = the lower-bound value of the $T_{h=0}$

and B = the upper-bound value of the $T_{h=0}$;

and α = the lower-bound values of $T_{h=1}$

and β= the upper-bound value of $T_{h=1}$.

Chen (1985) has developed a ranking method converts a fuzzy number T can into a crisp value (RC):

$RC = (V1+V2)/2(W1+W2)$ …………………………………………………………………… (5)

with V1, V2, W1 and W2 being subjects of the formulae:

$V1 = B^3(B+3\alpha - 3A) - B^2(4\alpha A + \beta A + \alpha\beta)$ ………………………………………………… (6)

$V2 = A^3(3B - 3\beta - A) + A^2(4\beta B + \alpha B + \alpha\beta)$ ………………………………………………… (7)

$W1 = B^2(2B - 7A + \beta + 2\alpha)\,3(AB)(\beta - \alpha)$ … …………………………………………………… (8)

$W2 = A^2(7B - 2A - 2\beta + \alpha) - (\alpha\beta)(B-A)$ ……………………………………………………… (9)

For the purpose of calculating the quantitative values of risks, membership functions would be defined for each FDV in accordance to equations (1) t0 (4). To undertake these computations, the most likely interval and the largest likely interval, with each interval defined by its lower and upper bound values, must be determined. Since five values of data are sufficient for fuzzy set analysis, the most likely interval is the range that lies around the average of the five values of the variable. The largest likely interval is the range that lies between the maximum and the minimum values of the data. To determine the impact of the risk, the magnitudes of the impact of all the FDVs, calculated as crisp values for all the identified FDVs, would be summed-up.

Five projects were analysed to determine the values of the consequences of the Unknown unknown FDV. The lower bound value and upper bound values of largest likely interval and the most likely interval were obtained for the purpose of calculating the RC value of the FDV of the unknown unknown utilizing equations (5) to (9).

Table 3 shows the percentage differences to the initial contract caused by each FDV of the Unknown unknown in all the five projects.

Table3. The FDV of Unknown unknown and their percentage adjustment to the initial contract sums of the five projects

S/No.	Fuzzy Decision Variable	Percentage difference to the initial contract sum in Project I (%)	Percentage difference to the initial contract sum in Project II (%)	Percentage difference to the initial contract sum in Project III (%)	Percentage difference to the initial contract sum in Project IV (%)	Percentage difference to the initial contract sum in Project V(%)	Average absolute value of percentage difference to the initial contract sum in all projects (%)
1.	Unknown unkown	-5.00	+1.48	0.00	-5.39	-5.49	3.47

The next step is to determine the most likely interval and the largest likely interval for the FDV of the unknown unknown. The largest likely interval is given by the range between the highest value and the lowest value among the set of values obtained from the five projects

This is denoted by 0.00 to -5.49.

The most likely intervals the range between the two values that surround the average of the five values.

This is given by 0.00 to 5.00.

Inserting these values in equations (5) to (9) yields a crisp value of 2.52 (see table 4)

Table 4. Crisp values for the FDV of unknown unknown

S/No	Fuzzy Decision Variable (FDV)	V1	V2	W1	W2	V1+V2	2(W1+W2)	RC
8	Unknown Unknown	908.43	0.00	180.24	0.00	908.43	360.48	2.52

Consequently, a project being proposed in this domain could likely have its contract sum increased by 3.00 per cent as a result of unforeseen events

4. Conclusion

The Fuzzy Decision Variable of the Unknown unknown risk is undefined but its effect could be ascertained after the occurrence of the unforeseen risk. For a particular domain of projects, the likely magnitude of the risk of Unknown unknown could be estimated from the domain characteristics.

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