DEVELOPMENT OF A KNOWLEDGE- BASED SYSTEM FOR UNDERTAKING THE RISK ANALYSIS OF PROPOSED BUILDING PROJECTS FOR A SELECTED CLIENT

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ABSTRACT

A Knowledge-Based System for the risk analysis of proposed building projects was developed for a selected client. The Fuzzy Decision Variables (FDVs) that cause differences between initial and final contract sums of building projects were identified, the likelihood of the occurrence of the risks were determined and a Knowledge-Based System that would rank the risks was constructed using JAVA programming language and Graphic User Interface. The Knowledge-Based System is composed a Knowledge Base for storing data, an Inference Engine for controlling and directing the use of knowledge for problem-solution, and a User Interface that assists the user retrieve, use and alter data in the Knowledge Base. The developed Knowledge-Based System was compiled, implemented and validated with data of previously completed projects. The client could utilize the Knowledge-Based System to undertake proposed building projects

KEYWORDS

RISK ANALYZER, Risk analysis, Knowledge-Based Systems, JAVA, Graphic User Interface

1. INTRODUCTION

Risk management in construction has acquired importance because of the need to harness risk and tame it in order to minimize its likely negative impact or in order to maximize its potential positive consequences. Ibrahim (2010) designed a model entitled 'RISK ANALYZER' for the purpose of undertaking risk analysis for a selected client and has recommended the adoption of the model as a conceptual framework for the development of a Knowledge-Based System that could be used for the risk analysis of construction projects in specific domains. A Knowledge-Based System (KBS) can be defined as a computer system, which relies on extensive domain-specific knowledge for problem-solution (Dutta, 1993). The fulcrum of Knowledge-Based System development is to elicit domain-specific information from experts, represent such knowledge using an appropriate representation and incorporate such representation in a computer program for the purpose of solving human activity problems. According to Smith (1985), a Knowledge-Based System (KBS) develops computational models of human intelligence and reasons with judgmental, imprecise and qualitative knowledge as well as with formal knowledge of established theories. Dutta (1993) has distinguished expert systems as Knowledge-Based Systems in which the dominant source of knowledge comes from the experience and expertise of human experts whilst; generally, Knowledge-Based Systems could incorporate knowledge from experts as well as knowledge from other sources. Sharma (2013) has described how expert knowledge could be obtained from specialists or other sources of expertise such as texts, journal

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articles and databases. Bonnet et al (1988) have highlighted risk evaluation as one of the diagnostic problems that could be handled by an expert system.

The goal desired in this study is the construction of a Knowledge-Based System that could undertake the risk analysis of proposed construction projects for a selected client. The objectives are:

1) To identify the Fuzzy Decision Variables (FDVs) that give rise to the risks at the design stage
2) To write a program for the Knowledge-Based system using JAVA programming language
3) To implement the Knowledge-Based System Program

2. FRAMEWORK

Dutta (1993) has described the general structure of Knowledge-Based Systems as comprising of three main components:

1) The Knowledge Base which serves as a repository of domain-specific knowledge
2) The Inference Engine which is responsible for controlling and directing the use of knowledge for problem solution
3) The User Interface module which serves as the interface between the user and the Knowledge-Based System.

This Knowledge-Based System would be modeled upon the conceptual framework delineated by the RISK ANALYZER model (Ibrahim, 2010).

Construction risk analysis consists of two distinct stages (Flanagan and Norman, 1993):

(1) The identification of risks
(2) The evaluation of likely magnitudes of risk consequences and

The KBS undertakes risk analysis for proposed construction projects as follows:

2.1 RISK IDENTIFICATION

The knowledgeBase holds in storage the Risk Indicators categorized in lots of Fuzzy Decision Variables (FDVs), magnitudes of FDVs and types of risks.Ibrahim (2008) has described an approach that could be utilized in predicting risks in a construction project by perusing project data such as drawings, bills of quantities and specifications and estimating the prevalence of Fuzzy Decision Variables (FDVs). A Fuzzy Decision Variable (FDV) for a particular risk event denotes a condition in a risk environment, which predisposes the occurrence of that risk in the environment (Ibrahim, 2007; Bala and Yakubu, 2008). FDVs are used as variables for assessing monetary consequences of risks. The strength or density of an FDV indicates the likelihood by which that FDV could cause the occurrence of that risk. Therefore, the occurrence of a risk is precipitated if its FDVs are significant in concentration. The risk of unknown unknown (Smith, 1999) is indicated by the FDV of unknown unknown which is an unknown latent condition that cannot be defined, nor identified and is not estimable in terms of effect (examples: items of work covered by provisional sums and provisional quantities in the Bills of Quantities); yet it could precipitate concrete adjustment in the initial contract sum. The FDV of long contract period predicts the likelihood of occurrence of the risk of inflation.

The Inference Engine calls into working memory a lot of FDVs and selects the first Risk Indicator which it would attempt to match to a project characteristic identified through interaction with the user in the User Interface. This procedure is repeated for all the Risk Indicators domiciled in that particular lot of FDVs. If there is no match, the Inference Engine would the call for the second lot of FDVs and the same procedure is executed for all the Risk Indicators in the second lot. If there is a match, between any of the Risk Indicators in the first lot, the Inference Engine would confirm that the particular FDV covered by that lot is prevailing in the proposed project. The inference Engine would then request the user, through the User Interface, to provide the Confidence Value for the identified FDV.

Confidence Value denotes the expert's estimate of his belief in a particular assertion or conclusion (Ibrahim, 2008). Confidence Value is derived from Certainty Factor, which is a quantitative estimate of the relative strength of a conclusion drawn from uncertain premises using approximate inference (Buchanan and Shortcliffe, 1984 and Teft, 1989). Confidence Values are, in effect, membership functions in fuzzy logic; being the confidence vested in the belief that a particular statement or value is true.

2.2 RISK EVALUATION

The Fuzzy computer program for the evaluation of risk magnitudes in the selected domain has been adopted as a sub-program for the KBS (Ibrahim, 2013). For each FDV, the Inference Engine would call from the Knowledge Base the relevant value of the FDV magnitude as calculated using fuzzy set analysis. Fuzzy logic has been applied in creating decision-support and expert system in management and financial decisions (Sharma, 2011).

The KBS would convert the Confidence Value $C_{initial}$ of each FDV to value C_{final} using the formula (Ibrahim. 2008):

$$C_{final}=5C_{initial} \qquad (1)$$

The KBS would also convert $M_{initial}$; the magnitude of each FVD into a value M_{final} using the formula (Ibrahim. 2008):

$$M_{final}=50M_{initial} \qquad (2)$$

The two numbers C_{final} and $M_{final}$are then multiplied together to yield the FDV risk score
For all identified FDVs in a lot, a cumulative Risk Score denoting the summation of all FDV risk scores for the lot would be calculated by the Inference Engine. The Inference Engine would subsequently rank the Risk Scores in a Risk Register in order to identify and rank the risks in the proposed project.

The KBS adopts the risk register of the Standards Association of Australia as shown in Table 1 below:

Table 1Risk Register of the Standards Association of Australia

Risk score	**Level of risk**
15-25	High risk
8-12	Significant risk
4-6	Moderate risk
1-3	Low risk
0	No risk

Source: Thompson and Pretlove (2002)

The KBS would then announce each risk and its level of severity to the user.
The Graphic User Interface was built on the Oracle NetBeans IDE 7.3 Beta using panel swing container.

Each FDV with a set of risk indicators was placed on a panel. The indicators are exhibited as a grouped checklist with each item labeled as a risk indicator. The user peruses through the list of indicators for each FDV and then examines the contract documents for the proposed project (drawings, bills of quantities, specifications, etc).

The user selects a tick box to confirm that the risk indicator is prevailing in the risk environment and highlighted data box receives the Confidence Value inserted by the user against each ticked FDV.

The first FDV is Inadequate Strategic Briefing. Its panel is shown in Plate I. Its risk indicators are as follows:

- Space likely to be converted to functional use
- Car shed likely to be constructed
- Roads and parking space likely to be constructed
- Foundation-laying ceremony likely to be conducted
- Entrance porch likely to be constructed
- Building likely to be unsuitable for future growth.

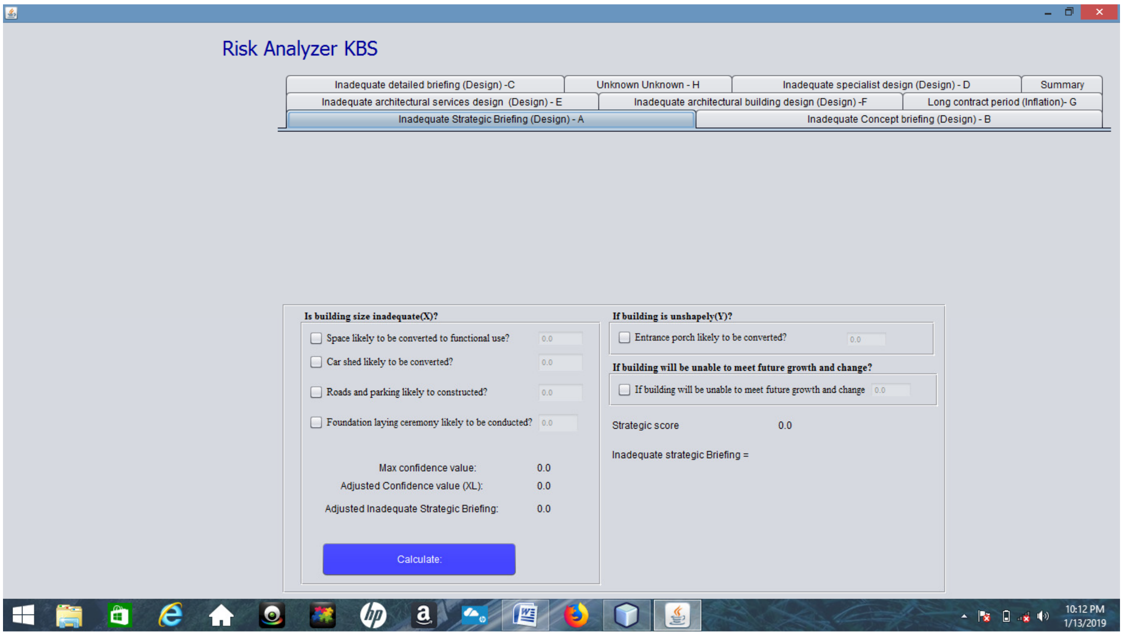

Plate 1 Panel showing the Derivation of the Magnitude of the FDV for Inadequate Strategic Briefing

In the source code, each risk indicator carries a Confidence Value included in the list [CV1,CV2, CV3, CV4, CV5, CV6]. A variable, Maximum_strategic, assumes the value of the highest Confidence Value in the list adjusted in accordance with equation (1).

Another value, magnitude_strategic is obtained by adjusting the crisp value of the percentage likely effect of Inadequate Strategic briefing (Ibrahim, 2008) in accordance with equation (2).
Another variable, Strategic_score is the calculated as follows:

Strategic_score = Maximum_strategic × magnitude_strategic……………………………..(3)

The Strategic_score variable represents the risk score of the FDV of Inadequate Strategic Briefing. Another variable, Design_score represents the risk score of the risk of design. Design_score is initialized to zero but the value of Strategic_score would be added to Design_score after computation.

On the second panel (Plate 2), the FDV of Inadequate Concept Briefing would similarly computated to yield the Fdv score of Concept_score which is then accumulated to Design_score. Subsequent panels would yield Detail_score, Specialists_score, Archservices_scoreandArchbuilding_score which would all be accumulated to Design_score.

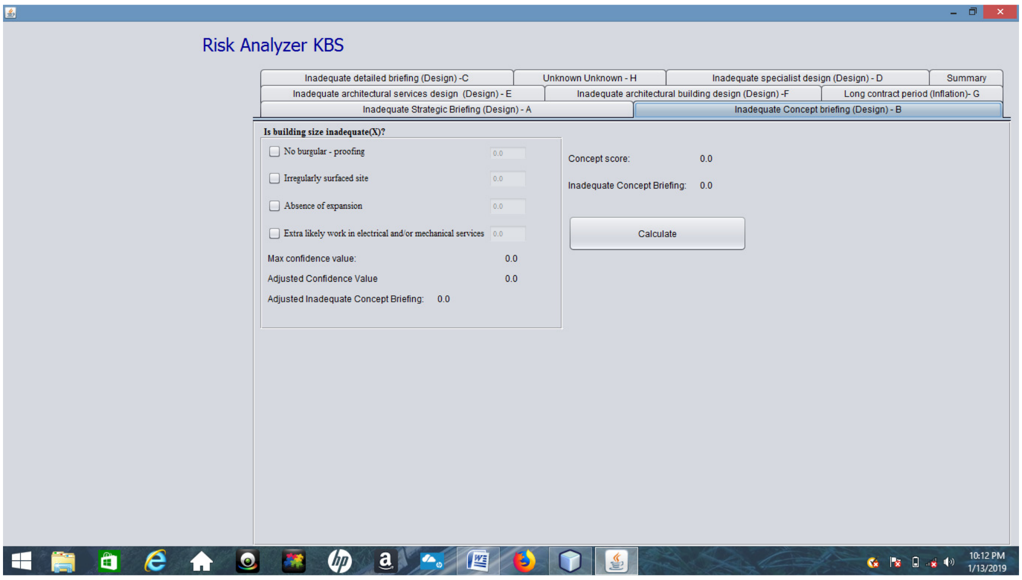

Plate 2 Panel showing the Derivation of the Magnitude of the FDV for Inadequate Concept Briefing

The seventh and eighth panels (Plates 2 & 3) would compute Inflation_score and Unknown_score which represent the risk scores of Inflation risk and Unknown risk respectively.

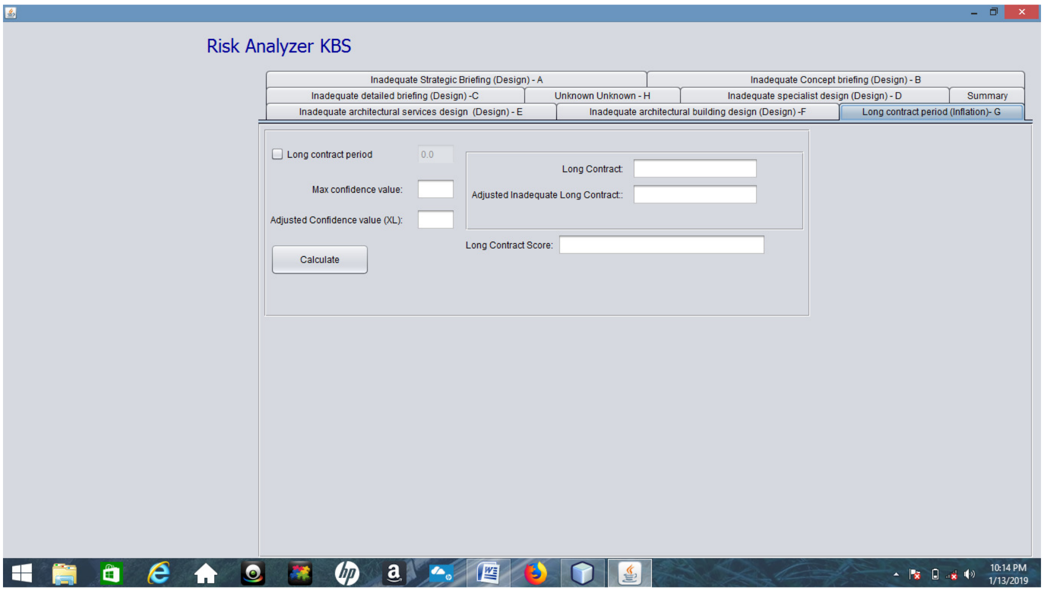

Plate 3 Panel showing the Derivation of the Magnitude of the FDV for Long Contract Period

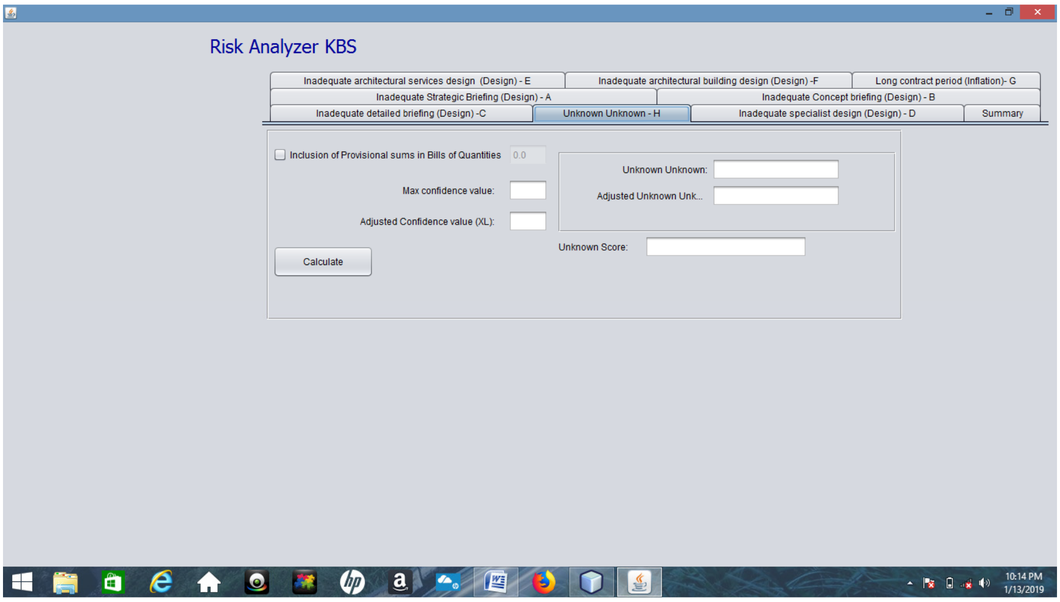

Plate 4 Panel showing the Derivation of the Magnitude of the FDV for Unknown Unknown

In the last panel (Plate 5), RISK ANALYZER will print the type of risk analyzed. The KBS computes the interval of each risk score in the risk register and subsequently prints the type of risk (design, inflation or unknown) and the degree of risk exposure of the individual risks (high, significant, moderate, low or no risk).

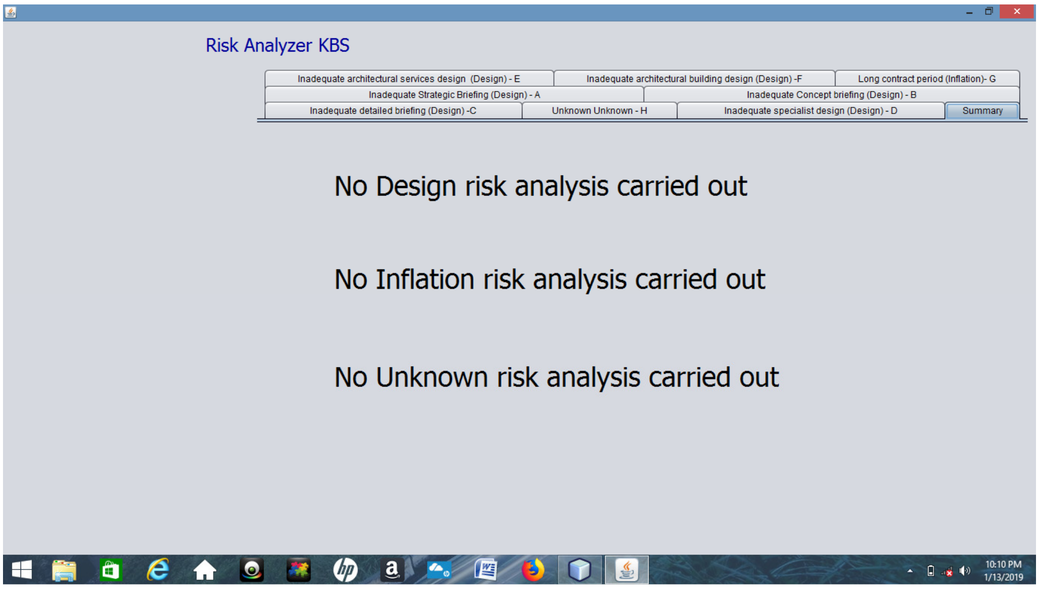

Plate 5 Panel showing the Types of Risks analyzed

3. VALIDATION OF THE KBS

Validation is the most restrictive, most arduous and most time consuming of all stages in the development cycle of the KBS (Bonnet et al, 1988). Validating the KBS would require the validation of its risk identification and risk evaluation processes. The risk identification process is logical and realistic because it is based upon the concept of detecting FDVs using risk indicators. The underlying precept for this approach is that the presence of at least one indicator is a sufficient indicator for the likely occurrence of an FDV (Ibrahim, 2008). This is analogous to the diagnosis of a multi-symptom disease; whereby the disease could manifest with one or more symptoms. In the case of risk analysis, the presence of at least an indicator is sufficient to confirm the likely occurrence of an FDV. Unlike human illness, risk in a construction project could betray no symptoms; hence any indicator that manifests itself at the pre-contract stage should be a portent indicator of the presence of the risk.

The risk evaluation component has been validated (Ibrahim, 2013). The Knowledge Base had been built from data derived from some five projects that had been executed by the client. The period of construction of the five projects commenced from September 1989 and ended October 1999.

3.1 CASE STUDIES

The program was tested with two projects retrospectively for executed projects; a Lecture Theatre and an Administrative Block. The two projects had been executed from October 2000 to September 2013.

The first project was a 1000-seat Lecture theatre with an initial contract sum of N131 million naira (X dollars at prevailing rate) and a contract period of fifty-six weeks. The structure is a two-storey reinforced concrete-framed structure on pad and strip foundations.

In October 1999, briefing for the project commenced when the client instructed the architect to produce design for a lecture theatre which is capable of accommodating activities such as conferences, public lectures, dram, plays, matriculation ceremonies and normal academic lectures.

In October 2000, tenders were opened and the contract was awarded to the main contractor. The sub-contracts of electrical and mechanical installations were also awarded to the electrical and mechanical sub-contractors respectively.

For the purpose of identifying risks in the project, the KBS would peruse through the project characteristics in order to scree-out possible FDVs. The program does this by attempting to match project characteristics with the risk indicators stored in its memory. Where it finds a match, it would request for the user's confidence value (CV) in the truthfulness of the observed project characteristics, does the necessary computations; and subsequently announce the attendant risk.
In searching for the FDV of Inadequate Strategic Briefing, it was found that the designed facility has ample open space under the waist of the inclined suspended slab. The client could quite likely convert this space into some useful function. A confidence value of 55 was assumed for the FDV of inadequate Strategic Briefing.

In searching for the FDV of Inadequate Concept Briefing, it was realized that the site was irregularly-surfaced. A change in floor level could most likely occur. A confidence value of 65 is chosen for this FDV.

For Inadequate Specialist Consultants' Designs, prime cost sums for the lecture theatre seats had been provided in the bills of quantities. From past project data, prime cost sums are definitely likely to change from initial values if design is not finalized. Therefore, the confidence value of 90 is selected for this FDV.

Lack of storm water drainage design and non-detailing of external works design are the matching project characteristics for the FDV of Inadequate Architectural Services Design. These two characteristics elicited a confidence value of 80.

For the risk of Inflation, the contract period is 56 weeks; which is in excess of one year- a matching project characteristic for inflation. However, the vclient's decision to nullify the fluctuation clause in the contract and provide advance payment to the contractors meant that fluctuation would not be paid in this project. Conseqauently, a confidence value of zero was indicated for this FDV.

Provisional sums had been provided in the bills of quantities. A confidence value of 70 would be appropriate in this regard in order to indicate the definite likelihood for the adjustment of provisional sums; or the occurrence of the FDV of Unknown unknown.

Table 2 gives predicted values of likely consequences of FDVs and the actual values obtained during the execution of the 1000 – seats lecture theatre.

Table 2 comparison between Predicted and Actual Values of the Likely Percentage Difference to the Initial Contract Sum of the 1000-Seats Lecture Theatre

s/no.	Fuzzy Decision Variable	Predicted Likely Percentage Difference to the Initial Contract Sum (%)	Actual Likely Percentage Difference to the Initial Contract Sum (%)
1.	Inadequate strategic briefing	+2	+0.16
2.	Inadequate concept briefing	+5	+1.71
3.	Inadequate specialist consultants' designs	+5	+7.01
4.	Inadequate architectural building designs	+1	+0.58
5.	Inadequate architectural services designs	+1	+0.47
6.	Long contract period	0.00	0.00
7.	Unknown unknown	-3	-4.95
	TOTAL	+11.00	+8.93

Source: Ibrahim (2013)

The second project for which the program was retrospectively tested is an office complex to serve as the Administration building for the client.

Table 3 gives predicted values of likely consequences of FDVs and the actual values obtained during the execution of the Administrative Building

Table 3 Comparison between Predicted and Actual Values of the Likely Percentage Difference to the Initial Contract Sum of the Administration Building

s/no.	Fuzzy Decision Variable	Predicted Likely Percentage Difference to the Initial Contract Sum (%)	Actual Likely Percentage Difference to the Initial Contract Sum (%)
1.	Inadequate strategic briefing	0	0
2.	Inadequate concept briefing	+5	+5.24
3.	Inadequate	0	+4.07

	specialist consultants' designs		
4.	Inadequate architectural building designs	0	0
5.	Inadequate architectural services designs	0	0
6.	Long contract period	+17	+13.21
7.	Unknown unknown	-3	-4.04
	TOTAL	+19	+18.46

Source: Ibrahim (2013).

For both projects, the total difference between predicted and actual values lies between plus – minus 5% range required for a quantity surveyor's estimate (Blok, 1982).

This paper is presenting the data for three more projects executed by the client between 2015 and 2018 in order to evaluate the performance of the KBS five years after its development.

Table 4 gives predicted values of likely consequences of FDVs and the actual values obtained during the execution of the Hostel Block I executed between 2015 and 2016

Table 4 Comparison between Predicted and Actual Values of the Likely Percentage Difference to the Initial Contract Sum of Hostel Block I

s/no.	**Fuzzy Decision Variable**	**Predicted Likely Percentage Difference to the Initial Contract Sum (%)**	**Actual Likely Percentage Difference to the Initial Contract Sum (%)**
1.	Inadequate strategic briefing	0.00	0.00
2.	Inadequate concept briefing	0.00	-0.79
3.	Inadequate specialist consultants' designs	0.00	-2.01
4.	Inadequate architectural building designs	0.00	0.00
5.	Inadequate architectural services designs	0.00	+3.53
6.	Long contract period	0.00	0.00
7.	Unknown unknown	-3.00	-0.64
	TOTAL	-3.00S	+0.09

Source: Field work

Table 5 gives predicted values of likely consequences of FDVs and the actual values obtained during the construction of the Hostel Block II executed 2015 and 2017

Table 5 Comparison between Predicted and Actual Values of the Likely Percentage Difference to the Initial Contract Sum of Hostel Block II

s/no.	Fuzzy Decision Variable	Predicted Likely Percentage Difference to the Initial Contract Sum (%)	Actual Likely Percentage Difference to the Initial Contract Sum (%)
1.	Inadequate strategic briefing	0.00	+4.00
2.	Inadequate concept briefing	0.00	-2.13
3.	Inadequate specialist consultants' designs	0.00	+0.44
4.	Inadequate architectural building designs	0.00	0.00
5.	Inadequate architectural services designs	0.00	+2.24
6.	Long contract period	0.00	0.00
7.	Unknown unknown	-3.00	-0.68
	TOTAL	-3.00	+3.87

Source: Fieldwork

Table 6 gives predicted values of likely consequences of FDVs and the actual values obtained for the construction of a two-storey Office Block executed between 2017 and 2018

Table 6 comparison between Predicted and Actual Values of the Likely Percentage Difference to the Initial Contract Sum of the Two-storey Office Block

s/no.	Fuzzy Decision Variable	Predicted Likely Percentage Difference to the Initial Contract Sum (%)	Actual Likely Percentage Difference to the Initial Contract Sum (%)
1.	Inadequate strategic briefing	0.00	-0.82
2.	Inadequate concept briefing	+5	+0.22
3.	Inadequate specialist consultants' designs	0.00	-1.69
4.	Inadequate architectural building designs	0.00	+1.90
5.	Inadequate architectural services designs	+1.00	-0.65
6.	Long contract period	0.00	0.00
7.	Unknown unknown	-3	-0.20
	TOTAL	+3	-1.26

Source: Fieldwork

For the last three projects (Hostel Block I, Hostel Block II and the two-storey Office Block) executed between 2015 and 2018, the total difference between predicted and actual values lies outside the plus – minus 5% range required for a quantity surveyor's estimate (Blok, 1982).

4. DISCUSSION

The two projects that had complied with the expectation of the KBS (where the total difference between predicted and actual values lies between the plus – minus 5% range required for a quantity surveyor's estimate) could possibly share the same risk characteristics with the five projects whose data was used to build the KBS of RISK ANALYZER. This is because most of the FDVs in the database were detectable in the two projects. The fulcrum of a knowledge –based system is to elicit domain-specific information, represent such knowledge using an appropriate representation and incorporate such representation in a computer program for the purpose of solving human activity problems (Ibrahim, 2008).

However, most of the FDVs were not detected were not detected in the analysis of the last three projects (Hostel Block I, Hostel Block II and two-storey office Block). The implication is that the domain risk characteristics have changed over the years. In the analysis of the three projects there were evidences that the client had become risk-conscious (minimizing the use of Provisional sums and Prime Cost Sums in the Bills of Quantities, undertaking full measurement wherever possible, and hedging against inflation by providing advance payments for mobilization). The characteristics of a domain could change (Ibrahim, 2008) with time; new FDVs could be added or old ones could become irrelevant; magnitudes of risk consequences could change as a result of change in risk attitude in the domain. It would be necessary for the KBS to 'learn' of new parameters encountered by the KBS through its Knowledge Acquisition Module; and subsequently incorporate the new knowledge into the Knowledge- Base in order to facilitate the solution of emerging, contemporary problems.

5. CONCLUSION

A Knowledge-Based System that is capable of soliciting for data from a user in order to identify the risks in proposed building projects, quantify the likely magnitudes of the risks and subsequently rank the risks in order of their significance has been developed. The Knowledge-Based System has been implemented and validated as a computer program. Provided that the risk characteristics for building projects for a particular client can be elicited and structured into the framework of Fuzzy Decision Variables, the Knowledge-Based System could be used to undertake the risk analysis of proposed building projects for the client.

Since human activity systems are dynamic, it is imperative that situations in which the KBS is applied must conform to the domain characteristics initially envisaged during the development of the program. Otherwise, the KBS must be able undertake self-learning in order to avoid giving faulty results when it is run.

6. FUTURE SCOPE

The program has been constructed for a specific client-domain. There is a need to develop the program for wider domains in order to enhance the applicability of the program. Segmentation of construction projects based on constructional type (for example, reinforced concrete, steel-framed, brick, and so on) is suggested. Further research could be done on each segmental domain to develop specific programs for the different domains.

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