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Project Cost Risk and Uncertainties: Towards a Conceptual Cost Contingency Estimation Model

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Abstract The challenge of risk understanding and simulation in the built environment has resulted in the lack standardized methods in the estimation of cost contingency. To date, most built environment professionals apply deterministic approaches, which dwell greatly on subjectivity, experience and organisational process asset. In response to the above challenge, a systematic risk methodology for the estimating of cost contingency based on empirical judgment has been the driving force behind this research. The failure mode effect analysis (FMEA) and the theory of evidence are presented as qualitative and quantitative risk tools respectively. The research adopted quantitative methods with data gathered through structured questionnaires distributed to built-environment professionals based on the theoretical framework. Analysis of data using FMEA and evidential reasoning method revealed that systemic risk accounted for approximately two-thirds of the cost drivers related to construction cost uncertainty with three work sections revealing a high propensity to causing cost overruns. To this end, a four stage conceptual model was developed which translated into a 3-phase implemented model. The proposed risk management framework for the estimation of cost contingency is presented by an integrated cyclical evolutional process contemporaneous with the design management process derived from Dempster's combination hypotheses. Using the hyper text pre-processor (php) as the as the system requirement, the model was tested and evaluated using an action exercise which found values to be realistic in comparison to the actual closing account figures of completed projects. Testing the model using an action exercise revealed results range of between 13.36% to 28% to cover physical and price contingency for projects with limited project duration of 18months.

Keywords Cost risk, Systemic risk, Project specific risk, Mass, Belief, Plausibility, Hyper-text pre-processor

1. Introduction

The concept of risk and uncertainty in project management has been construed by many practitioners as a rather congruent analogy. Risks are activities of uncertain future outcomes [1]. They are dynamic event which takes place within a complex systemized framework of numerous interconnected cause and effect loop which generate feedback within the project system [2]. [3] holds that managing uncertainty on a project cannot be paralleled with risk. Traditional risk management is associated with planning and taking measures to mitigate systemic ("known-knowns") and project specific("known-unknowns ") risks on a project. The concept of uncertainty management which is rather associated with "unknown-unknowns" risk of a project is very difficult to predict. Over the years however, the risk identification process for estimation of cost contingency has been more analytically inclined towards systemic risk (known-unknowns) at the neglect of project specific risk (unknown-unknowns).

According to [4], most firms have adopted a rule of thumb which is applied during contingency estimation to take care of risk in relation to project cost. [5], revealed that these deterministic methods takes the least time and effort but currently held as the most popular and unambiguous method applied by estimators. In the case where the project goes is packaged for competitive tendering, the subjectivity of the various tender sums submitted has a reflection on the contingency sum thus resulting in the tenderers submitting different contingency sums. [6], from [7], held that one of the simplest methods of estimating contingency margins for construction projects is to consider a percentage of the estimated bid or contract value such as 10% for contingencies. Typically, this method is derived from intuition, past experience, historical data, organizational process asset, enterprise environmental factors and or expert judgment.

[8], hold that deterministic methods however does not justify the degree of confidence that the contingency will provide against cost overruns thus making it very difficult to defend figures generated from this method. [9], postulated that this method is an unscientific approach and a reason why so many projects are over or under-budgeted. According to

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[10], applying deterministic approaches in determining contingency such as a fixed percentage of the project cost is not appropriate because it provides an arbitrary value based on only project cost. This method of estimating cost contingencies should be restricted to preliminary design cost estimates such as blue sky estimates, feasibility estimates or order of magnitude estimates.

2. Theoretical Framework

The theoretical framework for the above work is based on the Dempster-Shafer Theory (DST) also known as the theory of belief functions, a mathematical theory of evidence, which is a generalization of the Bayesian theory of subjective probability. [11], holds that whereas Bayesian theory requires probabilities for each question of interest, the belief function permits the use of degrees of belief for one question on the probabilities for related questions. The research also uses the failure mode effect analysis (FMEA) as a qualitative tool for the first stage of risk analysis. During the application of the FMEA, risk priority numbers (RPN) were determined using the likelihood of occurrence of a risk, the possible impact if it occurs and the detectability of a risk prior to its occurrence. With respect to the DST, the mass, belief and plausibility functions of the qualitatively selected risk were estimated based on various data sources using probabilistic analysis of these hypothesis.

3. Empirical Review and Conceptual Framework

[4], indicates holds that the method of cost estimating using risk analysis with a systematic methodology such as risk identification, risk analysis, risk quantification and risk monitoring and control is ideal. In the above method, risk identification is carried out as preliminary risk planning process to identify factors that may affect project cost. Risk measurement and assessment are used as tools for risk analysis and quantification to help determine the maximum and average risk-based allowance for each risk factor in relation to contingency estimation. [12], proposed with various tools, a risk management framework of risk identification, risk analysis, risk mitigation, risk allocation and risk monitoring and control for the cost risk management process. To this end [13], held that brainstorming, scenario planning, expert interviews, Delphi methods and influence diagramming were strong risk identification tools.

Adopted and modified from [1]

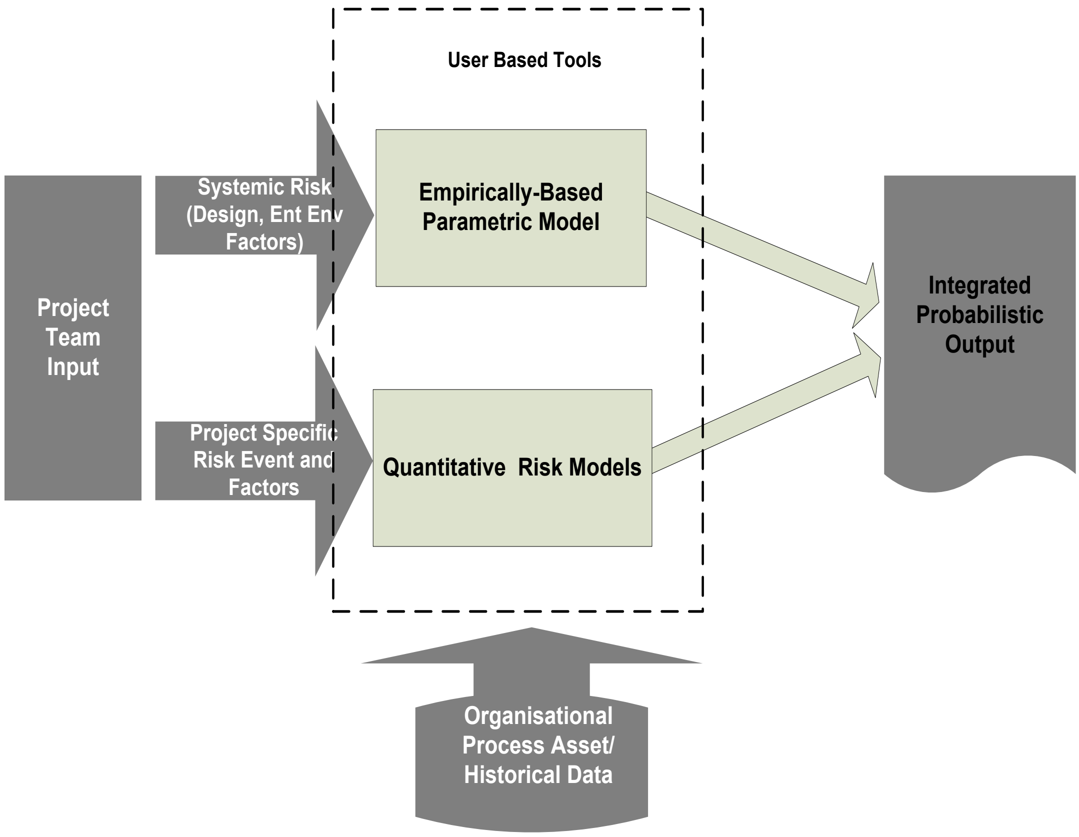


Figure 1. Conceptual framework

The conceptual framework for this research in relation to the estimation of contingency is depicted in figure 1 above. The process is hinged on an integrated team effort commencing with risk management planning which has risk identification for the purpose of developing a risk breakdown structure as the main output. Due to the peculiar nature of the cost contingency estimation process, there is the need to undertake risk categorization using the risk breakdown structure by means of empirically based models. This helps to estimate empirically, using parametrically based models, through the application of systemic project risk, whilst modelling historical data. Ideally, cost risk analysis should commence at the concept formation stage evolving to the project implementation stage through an unending cyclical evolutional process with cost planning, cost forecasting, cost estimating and the financial treatment of cost risk. Along the same cyclical evolution, the risk management process commences with risk management planning process through risk quantification evolving to risk update of secondary and residual risk. The above cost risk process is rather thorough, evolutional and systematic, intertwined to cover the entire risk framework. Taking a cue from [1], the initial risk identification process is to categorise risk into endogenous and exogenous risk or systemic and project specific risk. [14], thus postulates that whereas the best approach to measuring systemic risk is by the use of empirically based parametric models, an expected monetary value can be deduced from Monte Carlo Simulation for the estimation of project specific risk. Based on data hypothesis, project specific risk could be modeled contemporaneously with systemic risk based on evidential reasoning methods.

4. Research Method

The main objective of this paper is to determine develop a conceptual model for the estimation of project cost contingency. To achieve this, an FMEA was conducted to select the most significant risk factors affecting contingency qualitatively. These factors were then modelled quantitatively using Dempster's combination hypothesis to determine the probabilities of these risk factors for the purpose of cost contingency modelling.

This paper is based on quantitative methodological research procedures. Based review of related literature review and ethnographic studies, a survey questionnaire was designed and administered to stakeholders and professionals in the built environment in Ghana. A sample size of 184 was determined using the statistical relation by [15], [16]. A response rate of 118% was achieved following the distribution of 204 questionnaires to built-environment professionals.

Based on the theoretical framework, the first question of the survey instrument listed 31 risk factors identified during literature affecting project cost contingency for respondents to rate on a scale of 1 to 10. The second question of the instrument sought to collect data on the extent to which cost variability occurs on the various work sections of a project. In both questions respondents were to develop their basic belief assignment on the scenarios based on experience, historical antecedent and field knowledge. These hypotheses are the likelihood of occurrence (L) of a risk factor, possible impact or severity effect (I) of risk and detectability/ hideability (D) of the risk. Each of these concepts was expressed as an integer between 1 to 10, with 1 = low probability/severity/impact and 10 = high probability / severity/ impact.

5. Data Analysis and Discussions

Data analysis was undertaken based on the theoretical framework, using FMEA as a qualitative risk tool and evidential reasoning method as a quantitative risk tool for the purpose of probabilistic risk analysis. Based on the basic belief assignment of the respondents: the likelihood of occurrence (L) of a risk factor, possible severity effect (I) of risk and detectability/ hideability (D) of the risk, the Risk Priority Numbers (RPN) were estimated as follows and displayed in table 1 and 2:

$$\text{RPN} = \text{severity} \times \text{hideability} \times \text{likelihood} \tag{1}$$

Example: problem — RPN for delayed payment $= 7.32 \times 7.08 \times 5.2 = 269.99$

RPN for finishes $= 7.65 \times 7.64 \times 7.75 = 452.96$

The RPN for the risk factors and the work sections are displayed in table 2 and 3 respectively.

Quantitative risk analysis begun with the estimation of the risk of occurrence for each factor as:

$$\text{Risk} = L \times I \tag{2}$$

Example: the risk estimate for inclement weather $= 4.06 \times 8.6 = 0.35$

Using the evidential reasoning method, the probabilistic estimation of risk was used to estimate the masses of the various risks:

$$\text{The Probability of a Risk factor/work sections} = \frac{\text{Risk}}{\sum \text{Overall risk}} \tag{3}$$

Example the estimated probabilistic estimate for quality of works = 0.19/10.51= 0.0177

Where 10.79 is the summation of all risk = 0.23 + 0.21 + 0.35 +……..+ 0.19 + 0.24

Table 1. Qualitative and Quantitative Risk Analysis-Factors Affecting Cost Contingency Factors

ITEM	Possible Risk Factor	QUALITATIVE ANALYSIS				QUANTITATIVE ANALYSIS		Interpretation
		L	I	D	RPN	RISK	PR	
A	**Natural/ Environmental Risk**							
1	Floods	3.42	6.87	8.6	202.06	0.23	0.0224	Mod. Relevant
2	Earth quakes, volcanic, landsides	2.83	7.49	8.87	188.01	0.21	0.0202	Mod. Relevant
3	Inclement weather	4.06	8.6	8.53	297.83	0.35	0.0332	Mod. Relevant
B	**Technical Risk**							
4	Design Failure/ Defective design	5.46	7.08	6.88	265.96	0.39	0.0368	Mod. Relevant
5	Human resource management challenges	4.68	4.72	4.31	95.21	0.22	0.0210	Irrelevant
6	Equipment Failure	4.49	5.02	4.37	98.50	0.23	0.0214	Irrelevant
C	**Economic Risk**							
7	Material supply challenges	4.5	5.14	5.23	120.97	0.23	0.0220	Irrelevant
8	Labour Supply challenges	4.2	4.88	4.68	95.92	0.20	0.0195	Irrelevant
9	Equipment availability challenges	3.72	4.87	4.63	83.88	0.18	0.0172	Irrelevant
10	Equipment productivity	4.09	5.08	4.74	98.48	0.21	0.0198	Irrelevant
11	Market conditions	5.3	6.41	5.62	190.93	0.34	0.0323	Mod. Relevant
D	**Financial Risk**							
12	Interest rate challenge	5.57	7.1	6.66	263.38	0.40	0.0376	Mod. Relevant
13	Delayed payment problems	7.32	7.08	5.2	269.49	0.52	0.0493	Highly Relevant
14	Inflation/micro economic indicators	7.09	7.81	6.02	333.34	0.55	0.0527	Mod. Relevant
15	Global economic pressure	6.13	6.13	5.96	223.96	0.38	0.0357	Mod. Relevant
E	**Design Risk**							
16	Differing site conditions	7.08	7.57	7.9	423.41	0.54	0.0510	Highly Relevant
17	Design completeness or status	8.03	8.59	7.52	518.71	0.69	0.0656	Highly Relevant
18	Changes scope	8.52	8.96	7.2	549.64	0.76	0.0726	Highly Relevant
19	Project complexity	6.09	4.88	6.52	193.77	0.30	0.0283	Irrelevant
20	Incomplete scope definition	8.62	8.93	5.8	446.46	0.77	0.0732	Highly Relevant
21	Construction technology	5.07	4.72	5.37	128.51	0.24	0.0228	Irrelevant
22	Changes in specification	6.55	6.26	5.57	228.39	0.41	0.0390	Highly Relevant
23	Estimation errors/ method	5.81	5.15	3.87	115.80	0.30	0.0285	Irrelevant
F	**Governmental/Social Risk**							
24	Contractual/procurement related	5.6	5.21	4.16	121.37	0.29	0.0278	Irrelevant
25	Governmental influence/intervention	.93	4.88	4.68	135.43	0.29	0.0275	Irrelevant
26	Legislative/ statutory	5.04	4.37	4.72	103.96	0.22	0.0210	Irrelevant
27	Customary rights and litigation	4.25	3.63	4.31	66.49	0.15	0.0147	Irrelevant
G	**Construction Risk**							
28	Defects in supervision	6.67	3.92	4.52	118.18	0.26	0.0249	Irrelevant
29	Safety	4.87	4.58	3.85	85.87	0.22	0.0212	Irrelevant
30	Quality of work	4.57	4.06	3.76	69.76	0.19	0.0177	Irrelevant
31	Location	5.22	4.68	4.6	112.38	0.24	0.0232	Irrelevant

L = likelihood, I = impact, D = detectability, PR = Probability of risk

Table 2. Qualitative and Quantitative Risk Analysis- Work Sections Prone to High Scope Changes

ITEM	Possible Risk Factor	QUALITATIVE ANALYSIS				QUANTITATIVE ANALYSIS		REMARKS
		L	I	D	RPN	RISK	PR	
1	Substructure	7.93	7.94	8.06	507.49	0.63	0.11376	HR
2	Floor space designation	5.4	5.4	5.40	157.46	0.29	0.05269	Irrelevant
3	Structural framework	6.02	6.98	6.02	252.96	0.42	0.07592	MR
4	Block work	6.85	6.85	6.85	321.42	0.47	0.08478	HR
5	Carpentry	5.02	5.02	5.02	126.51	0.25	0.04553	Irrelevant
6	Joinery	5.44	5.44	5.44	160.99	0.30	0.05347	Irrelevant
7	Roofing	6.49	6.49	6.49	273.36	0.42	0.07610	MR
8	Finishes	7.65	7.64	7.75	452.96	0.58	0.10560	VR
9	Electrical and IT	7.83	7.9	7.90	488.67	0.62	0.11176	HR
10	Mechanical installations	7.89	7.86	7.77	481.86	0.62	0.11205	HR
11	External works	6.83	6.82	6.78	315.82	0.47	0.08416	MR
12	Furniture/ Fenestration/ Installations	6.83	6.82	6.78	315.82	0.47	0.08416	Irrelevant

HR= highly relevant, VR= very relevant, MR= moderately relevant

Table 3. FMEA on Factors Affecting Scope Management

Failure Mode No	Identification of Item	A. Failure mode B. Failure cause	Failure Effects A. Local or subsystem B. Next higher level C. End Effect	Severity Class	Remarks. A. Failure detection Method B. Compensation features/ C. action. Others
E.17	Substructure	A. Changes in substructure work quantities and cost due variations B. Incomplete design and lack of technical site survey. C. The sudden eruption of rare ground conditions	A. Changes in substructure design B. Changes in associated cost of ground work C. Varied secondary risk of variations, specification changes, etc	2	A. Resurvey of ground works B. Overdesign of substructure work C. Proper geological survey and ground survey
D.13	Electrical and IT installations	A. Sudden introduction of various elements into the work inflation cost B. Unavailability of design of for services during tendering	A. New work sections and items introduced into the work B. Delays in the work and unbudgeted variations C. Inadequacy of contingency	2R	A. Unavailability of services design B. Critical estimation of quantities for substructure work
E. 18	Mechanical installations	A. Sudden introduction of various elements into the work inflation cost B. Incomplete scope definition and late design delivery during tendering	A. New work sections and items introduced into the work B. Delays in the work and unbudgeted variations C. Inadequacy of contingency	2R	A. Unavailability of services design B. Critical estimation of quantities for substructure work and early services designs
E. 20	Finishes	A. Changes in specification of finishes B. Changes in taste of the client Incomplete definition of specification. Poor specification definition at project initiation	A. High scope creep resulting from indecision B. Challenged planning and late procurement of materials C. Project time overruns resulting from lat delivery of finishes delivery	3	A. Changes in final floor, wall and ceiling finish in comparison to documented B. Minimization of client dualisation in taste and certainty in scope definition

Table 1 displays the qualitative and initial quantitative analysis of risk factors affecting cost contingency estimation. The table displayed the RPN for each risk factor and the estimated probabilistic risk value for each parameter. From table 1, the RPN calculated revealed differing site condition, design completeness and status, changes in scope, incomplete scope definition, changes in specifications and delayed payment problems as the critical risk factors affecting project cost contingency. Table 2 as well displays the RPN, and estimated risk for each work sections yielding to scope changes. Consequent to table 2, an FMEA was conducted using the failure mode, failure cause, failure effect, severity class, failure detection method and compensation features of the scope factors affecting contingencies as depicted in table 3. The failure mode in terms of cost overruns can be deduced from changes in substructure work primarily due to sudden varied eruption in substructure conditions resulting from uncertainties in geotechnical conditions. Failure mode for essential building services can be attributed to the use of prime cost sums in the contract documentations resulting from late design development. Failure mode for finishes could be resulted from scope creep and changes in taste of the client during construction process. Failure mode in relation to the substructure has a failure effect of changes in substructure designs, changes in ground works with the end effect of variations in relation to substructure, changes in specifications, and etc. The failure effect of building services is the introduction of many new items into the work which results in undue delays in the work and unbudgeted variations which has an end effect of inadequacy funds to support the contingency management process. Thus from table 2, the substructure, essential building services and finishes were identified as the main work sections prone to high scope changes and scope creep.

6. Proposed Construction Cost Contingency Model

Based on the literature review and ethnographic studies, the stages of development of the above framework were broken into formulation (conceptual), implementation and evaluation stages, with direct interconnectivity in a feedback loop. On a broad spectrum, the CCC framework went through a systematic process of identifying significant factors for framework, establish relationship between the stages and factors, proposed framework development, testing of framework, validation reviews and, final documentation and recommendation for improvement. The conceptual model was formulated and conceived based on a myriad of virtual ideas designed to consist of four parts including Ms CAD Inter-phase, Ms Master-Bill Inter-phase, Ms Project Primavera Interface and Ms Hyper Text pre-processor Inter-phase. The above sections were linked together in an iterative and figurative manner to enhance information flow. The above process kicks with project initiation through project scope planning and management, design development, cost modeling and risk management process. The risk management phase simulates risk identification, risk analysis, risk evaluation, risk response planning and risk review into an iterative process. The automated model is available at www.cccmodel.tk for further consideration.

6.1. Graphical User Inter-Phase

The graphical user interface for the above CCC Model as depicted in figure 2 is the hyper-text pre-processor (Php). This provides several modes including a tester- where a user attempts to verify the validity of the system; a tutor- where the system provides a stock of information for a user to run through the system for acquaintance. The above interface also provides the user with a convenient medium for interaction. The basic task performed the GUI is to receive information from the user and interpret it. It again provides a platform where useful information is transmitted from the system to the user as depicted in figure 2 below. At the graphical user interface of the system, a user inserts a set of project parameters dubbed the cost risk contingency parameters. The proposed model then process the above data at the visualization stage to link up with other data to be processed into a mathematical function which resulting in the production of tables and graphs to be returned to the user at the visual inter-phase.

6.2. Data Entry and Processing

The first stage of the data simulation phase of the above model is the development of a risk register with the cooperate effort of the project team as depicted in figure 3 below. [17], posits that the most important aspect of project risk management is risk identification which commences contemporaneously with risk management planning. The process of risk identification brings to fore the need for risk categorization and the eventual development of a risk breakdown structure. During the process of risk identification, risk can be categorised as endogenous and exogenous risk, i.e. internal or external, enterprise environmental factors or organisational process asset.

Considering the predictability of the risk in relation to the project, a further sub-categorization is systemic and project specific groupings. Systemic risk as already discussed are related to the artifact of the system which can be predicted across projects while project specific risk has their impact varying by project. The essence of the risk breakdown structure is to enable further assessment of the risk based on their likelihood of occurrence, magnitude/consequence and detectability, to assist further risk response planning decision to be taken. [18], posits that risk identification results in description of risk as either systemic and project specific, endogenous and exogenous risk or known unknown risk or unknown un-known risk. The process of qualitative risk management in relation to the above model aims at prioritizing the risk identified earlier for further quantitative analysis. By the use of the theoretical framework, FMEA, the risk priority number (RPN) for each risk is internally generated by the model by multiplying the values of three concepts (likelihood of occurrence, possible impact and detectability of risk) expressed as integers as depicted in figure 3 and 4. The above forms the basis of selecting the most important risk for further risk analysis to continue (refer to section 5.0).

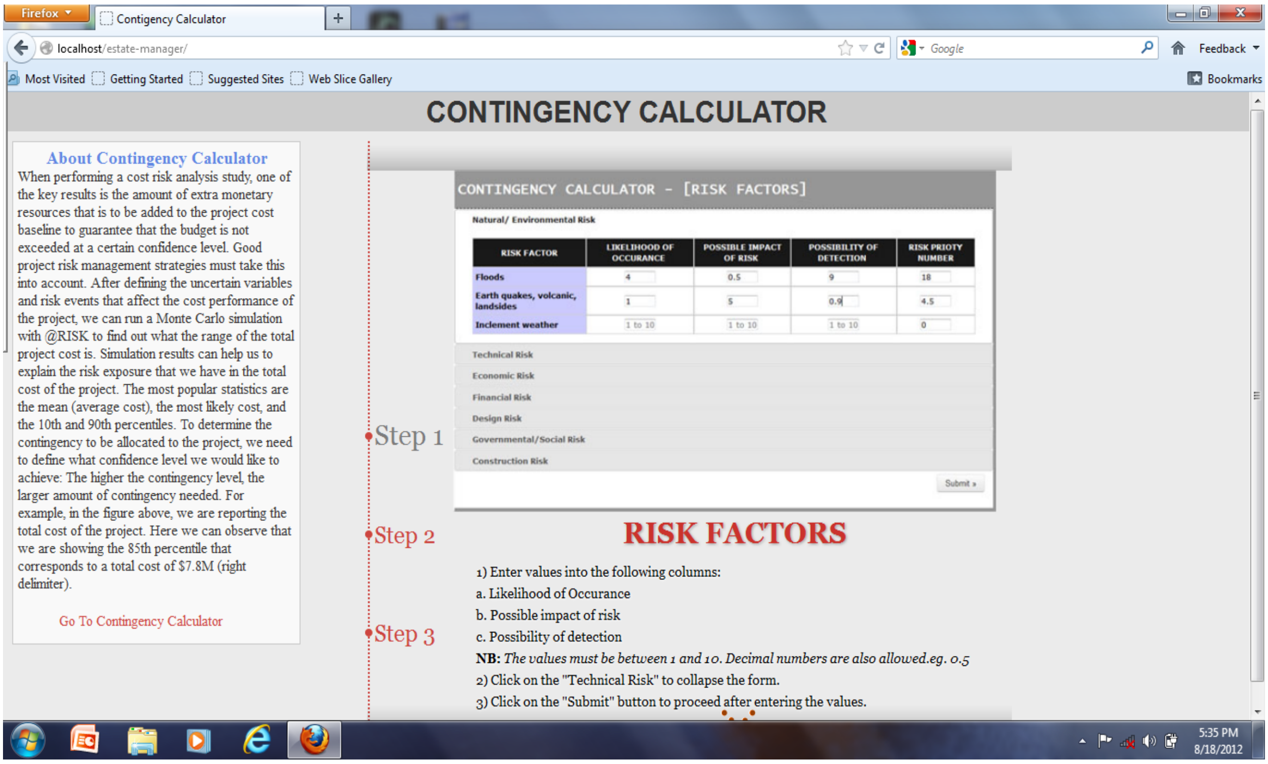
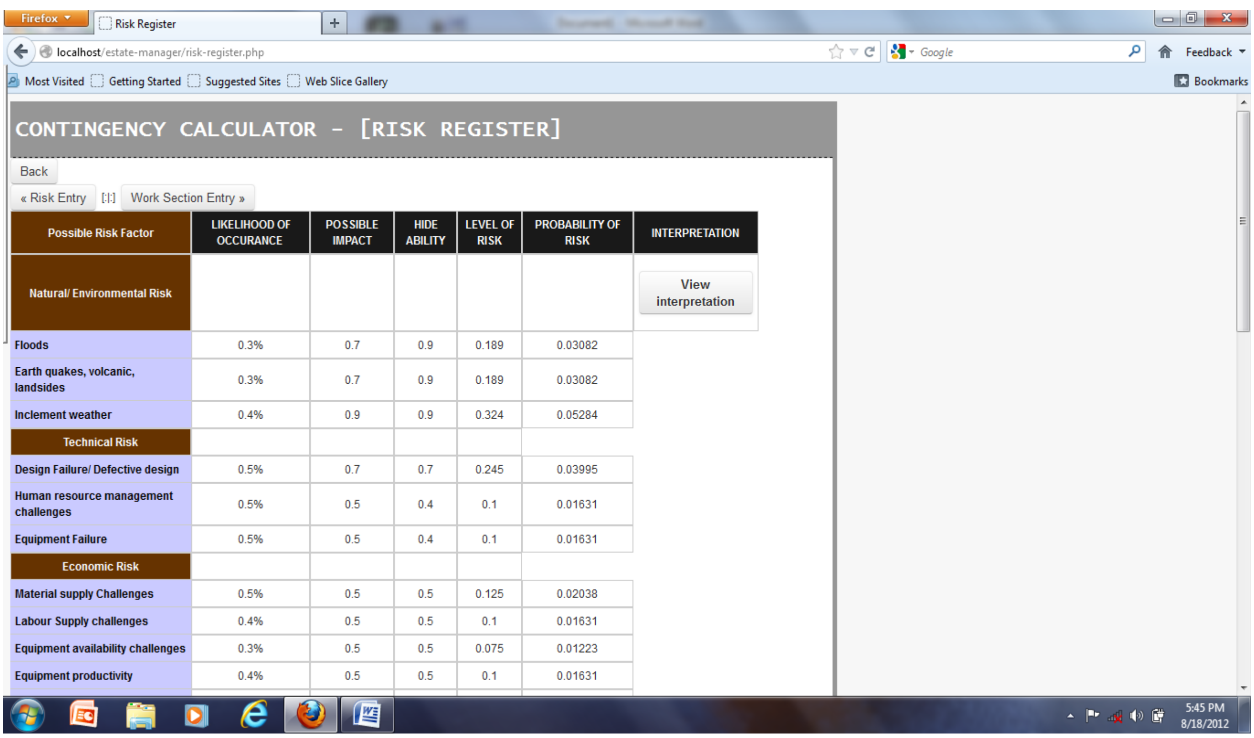


Figure 2. Graphical user inter-phase



Possible Risk Factor	LIKELIHOOD OF OCCURANCE	POSSIBLE IMPACT	HIDE ABILITY	LEVEL OF RISK	PROBABILITY OF RISK	INTERPRETATION
Natural/ Environmental Risk						View interpretation
Floods	0.3%	0.7	0.9	0.189	0.03082	
Earth quakes, volcanic, landsides	0.3%	0.7	0.9	0.189	0.03082	
Inclement weather	0.4%	0.9	0.9	0.324	0.05284	
Technical Risk						
Design Failure/ Defective design	0.5%	0.7	0.7	0.245	0.03995	
Human resource management challenges	0.5%	0.5	0.4	0.1	0.01631	
Equipment Failure	0.5%	0.5	0.4	0.1	0.01631	
Economic Risk						
Material supply Challenges	0.5%	0.5	0.5	0.125	0.02038	
Labour Supply challenges	0.4%	0.5	0.5	0.1	0.01631	
Equipment availability challenges	0.3%	0.5	0.5	0.075	0.01223	
Equipment productivity	0.4%	0.5	0.5	0.1	0.01631	

Figure 3. Data entry for risk factors affecting cost contingency

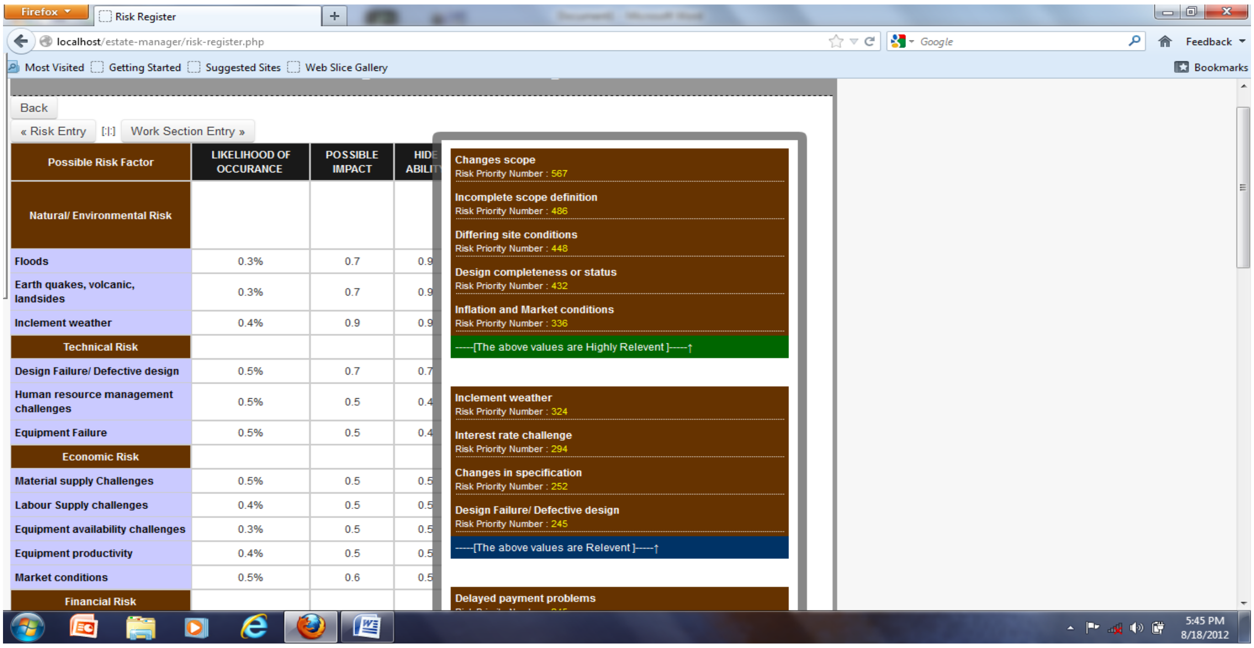


Figure 4. Qualitative risk analysis for risk prioritisation

Data from the qualitative risk management process is forwarded to the next stage of the model for risk quantification to commence. The model undertakes risk quantification using probabilistic risk analysis (PRA) where effect of risk was analysed using probability estimation. The above process computes the quantitative risk values based on the theoretical framework for the research, the Evidential Reasoning Method (Dempstar Shaffer Theory). The above computations enables a user to determine the magnitude of the impact of the various risk to enable further risk modeling and risk response planning to be effected. The magnitude of the quantitative risk values determines the risk response strategy to be adopted for the contingency estimation process. High impact risk determined by the system through probabilistic analysis would be modeled to the next stage for the basic belief and plausibility values to be determined.

Other less critical risk would receive appropriately a response attention. Subsequent to the risk management process adopted by the project team, the integrated project parameters with respect to work sections are identified and entered into the model. The integrated project parameters include the critical factors that control the estimation process of the construction cost contingency. These data includes the estimated cost per work section (substructure, structural frame, masonry, carpentry, joinery, roof covering, finishes, electrical installations, plumbing/mechanical installation, external works and other sundry installations). Other data inserted includes the total estimated cost of the project, and a factor to take care of the enterprise environmental factors and organizational process asset.

6.3. Information Flow-Implemented Model

At the process visualization stage of the model, the integrated project parameters entered at the graphical user interface is now exported to the next stage for processing to begin. The proposed model processes these data at the visualisation stage and links up with other risk data sources to be processed into a matrix function which would finally result in the production of tables and graphical displays to be returned to the user at the visual interface of the model as depicted in figure 5 and 6. A thorough risk management framework for the estimation of project cost contingency estimation is depicted in the system architecture in figure 7 below. Risk identification for the process of contingency estimation must start as early as the project conception and initiation stage. This would help unveil all possible risk factors incident to the project adopting the appropriate risk categorization (exogenous and endogenous risk) strategy. Using a coherent risk breakdown structure, all possible risk related to the project can be discovered by the project team [17].

Using the appropriate quantitative and qualitative risk measurement tools, the impact of systemic and project specific risk are estimated to enable the adoption of an appropriate financial treatment. The above would be the basis for the computation of the basic belief and plausibility values for the appropriate risk response planning to be undertaken in relation to the extent of scope changes with respect to work sections. Concurrent to the above process, a comprehensive scope definition and cost modeling process would be critical for issues related to technology, specification, procurement and contract type likely to be adopted for the project. Since the procurement process for any construction project is not sacrosanct; every system may have some flaws and challenges associated with it. Owners always strive to provide adequate contingency through their representatives to address risk related issues and to provide a safeguard for the contractor, designer and owner to complete the project on budget and within schedule.

6.4. Testing and Validation of Model

As a means of testing the model, a pilot test was undertaken using team of 10 cost engineers selected for an action exercise. Based on available historical data and their intrinsic basic belief assignment, each cost engineer tested the model based on their own individual hypothetical project parameters. The pilot validation test was carried out to ascertain the validity of results generated from the model and to verify the usability and reality of the results obtained from the model. It is worth noting that verifying the objectivity of results obtained from a model is one of the most difficult exercises to undertake. The essence of evidential reasoning theory is that the users define their own hypotheses and postulates their own basic belief assignment. The variability of data inserted with respect to the risk factors and work sections would results in variability of results depending on the source of data, pieces of evidence and their related hypotheses. Contrary to the usual 10% contingency estimate, an approximate overall physical contingency range of between 13.36% and 17.88% was determined using evidential reasoning methods. The exercise also revealed results range of between 13.36% to 28% to cover physical and price contingency for projects with limited duration of 18months. The above ranges for the above two scenarios were consistent with data gathered during preliminary stage of this research with respect to cost overruns in Ghana.

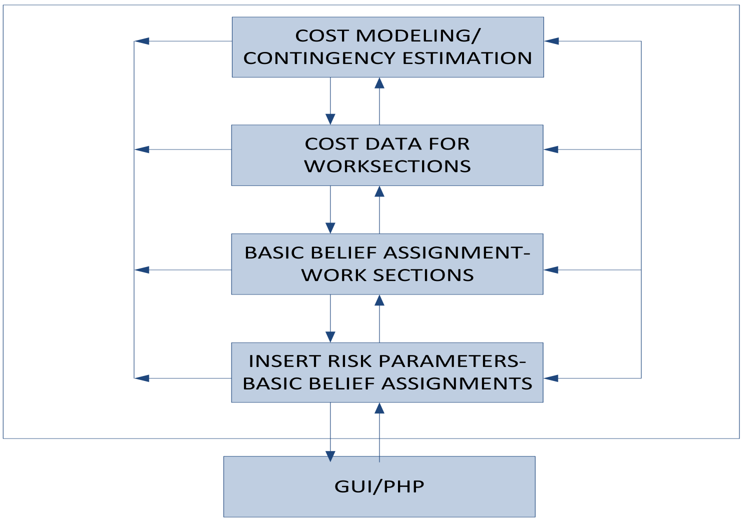
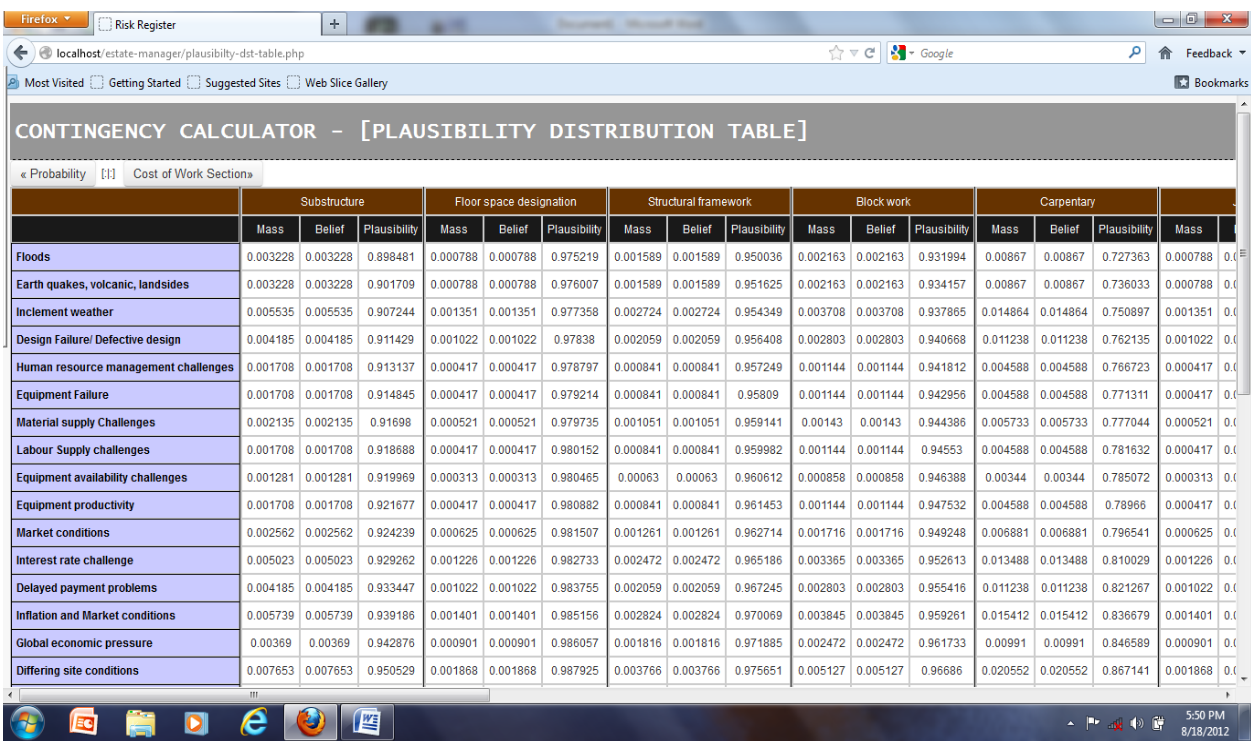


Figure 5. Sequence of data entry and processing for implemented model



	Substructure			Floor space designation			Structural framework			Block work			Carpentary			
	Mass	Belief	Plausibility	Mass	Belief	Plausibility	Mass	Belief	Plausibility	Mass	Belief	Plausibility	Mass	Belief	Plausibility	Mass
Floods	0.003228	0.003228	0.898481	0.000788	0.000788	0.975219	0.001589	0.001589	0.950036	0.002163	0.002163	0.931994	0.00867	0.00867	0.727363	0.000788
Earth quakes, volcanic, landsides	0.003228	0.003228	0.901709	0.000788	0.000788	0.976007	0.001589	0.001589	0.951625	0.002163	0.002163	0.934157	0.00867	0.00867	0.736033	0.000788
Inclement weather	0.005535	0.005535	0.907244	0.001351	0.001351	0.977358	0.002724	0.002724	0.954349	0.003708	0.003708	0.937865	0.014864	0.014864	0.750897	0.001351
Design Failure/ Defective design	0.004185	0.004185	0.911429	0.001022	0.001022	0.97838	0.002059	0.002059	0.956408	0.002803	0.002803	0.940668	0.011238	0.011238	0.762135	0.001022
Human resource management challenges	0.001708	0.001708	0.913137	0.000417	0.000417	0.978797	0.000841	0.000841	0.957249	0.001144	0.001144	0.941812	0.004588	0.004588	0.766723	0.000417
Equipment Failure	0.001708	0.001708	0.914845	0.000417	0.000417	0.979214	0.000841	0.000841	0.95809	0.001144	0.001144	0.942956	0.004588	0.004588	0.771311	0.000417
Material supply Challenges	0.002135	0.002135	0.91698	0.000521	0.000521	0.979735	0.001051	0.001051	0.959141	0.00143	0.00143	0.944386	0.005733	0.005733	0.777044	0.000521
Labour Supply challenges	0.001708	0.001708	0.918688	0.000417	0.000417	0.980152	0.000841	0.000841	0.959982	0.001144	0.001144	0.94553	0.004588	0.004588	0.781632	0.000417
Equipment availability challenges	0.001281	0.001281	0.919969	0.000313	0.000313	0.980465	0.00063	0.00063	0.960612	0.000858	0.000858	0.946388	0.00344	0.00344	0.785072	0.000313
Equipment productivity	0.001708	0.001708	0.921677	0.000417	0.000417	0.980882	0.000841	0.000841	0.961453	0.001144	0.001144	0.947532	0.004588	0.004588	0.78966	0.000417
Market conditions	0.002562	0.002562	0.924239	0.000625	0.000625	0.981507	0.001261	0.001261	0.962714	0.001716	0.001716	0.949248	0.006881	0.006881	0.796541	0.000625
Interest rate challenge	0.005023	0.005023	0.929262	0.001226	0.001226	0.982733	0.002472	0.002472	0.965186	0.003365	0.003365	0.952613	0.013488	0.013488	0.810029	0.001226
Delayed payment problems	0.004185	0.004185	0.933447	0.001022	0.001022	0.983755	0.002059	0.002059	0.967245	0.002803	0.002803	0.955416	0.011238	0.011238	0.821267	0.001022
Inflation and Market conditions	0.005739	0.005739	0.939186	0.001401	0.001401	0.985156	0.002824	0.002824	0.970069	0.003845	0.003845	0.959261	0.015412	0.015412	0.836679	0.001401
Global economic pressure	0.00369	0.00369	0.942876	0.000901	0.000901	0.986057	0.001816	0.001816	0.971885	0.002472	0.002472	0.961733	0.00991	0.00991	0.846589	0.000901
Differing site conditions	0.007653	0.007653	0.950529	0.001868	0.001868	0.987925	0.003766	0.003766	0.975651	0.005127	0.005127	0.96686	0.020552	0.020552	0.867141	0.001868

Figure 6. Data processing for implemented model

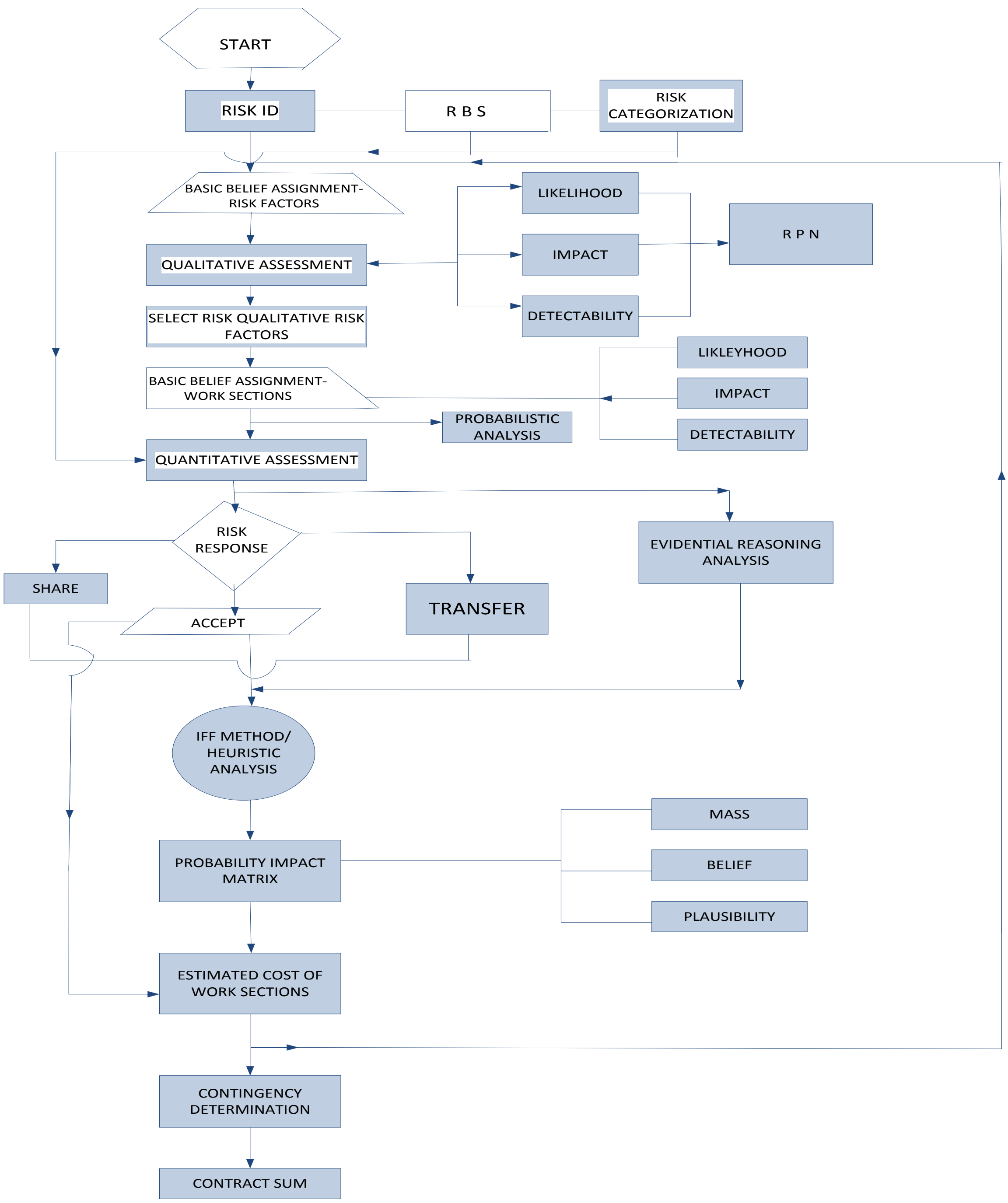


Figure 7. System Architecture- Implemented model

6.5. Limitation of Developed Model

No research based model is unlimited and for that matter sacrosanct in usage. The research has identified the following limitations with respect to the developed model:

- With the application of evidential reasoning method, it is possible to model multiple scenarios for a particular risk event for the introduction of Dempster-Shafer rule of combination to yield a combined basic assignment. This was however not included in the model development for the sake of simplicity. Thus the model takes into consideration only a single basic belief assignment, with a single assigned evidential weight, a single assigned belief, and a single deducible plausibility.
- Different projects would require different risk breakdown structure and categorization. The extent to which a user can re-model the risk is to some extent limited
- Due to the iterative reliance of the quantitative risk modeling on the qualitative analysis of the risk priority estimation some level of inference of Bayesian estimation cannot be ruled out of the analysis. For the sake of simplicity, the model

depends on the same set of data entered at the GUI for both quantitative and qualitative analysis. For more complex modeling, the above process would require different sets of data.

- The model does not depend on an inherent set of fixed set of variables. Each project would require that the user inserts different data for the modeling process making it ambiguous for users. Differently stated however this could be cited as a strength since it requires some amount of work to be done by the project team with respect to the risk planning stage.

7. Summary and Conclusions

The development of a framework for the estimation of cost contingency for construction projects, just like other models is to help minimise if not eliminate the deterministic nature of estimation process of cost risk. From [19] it was evident that the level of knowledge and application of risk in professional work is limited. Since this research is not a panacea to the challenges in the estimation of cost contingency, the development of a simple model based on the theoretical frame would be starting point for further ethnographic studies in the construction industry to begin. Since research work is an on-going iterative process, recommendations have been made for the improvement of these limitations in further research work. The above notwithstanding, the implementation of this research would offer the built environment professionals the opportunity to review and address the existing challenges.

The major risk factors affecting cost contingency and the major work sections with a high propensity to scope changes formed the basis for the development of the model. The framework for the model comprises three stages- the formulation/conceptual stage, the implementation stage and the validation and testing stage. The formulation/conceptual stage was developed to inform stakeholders the abstraction of ideas culled from reviewed literature and in consultation with other experts on what can be done to develop a buoyant model. The implemented model is an extraction from the conceptual model to develop a model based on the available data and limitations of the research work. The implementation stage outlines activities which are undertaken to ensure that the model produces realistic results and it is accepted by all stakeholders to enable an appropriate implementation. The final stage of the above model is the evaluation stage which subjects the model to scrutiny and criticism to ensure its ease of adaptability in the built environment. The testing and evaluation process of the model used a focused group and structured interviews for an action exercise. It is imperative to note that the process of evaluation is an ongoing process and further recommendations would form a basis of future research work.

The model developed is suitable for all projects building, civil engineering, heavy duty steel work and etc provided the user has knowledge with respect to risk analysis and estimation. It could be used with variability anywhere in the world after the key risk factors have been edited and other parameters incorporated. A key factor that determines the authenticity of the figures is the data source with respect to the basic belief function related to likelihood of occurrence of a factor, and its impact and detecatability ranges.

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