An expert system for contractor qualification criteria selection (ES_QS)

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Selecting a suitable bidder for construction projects is one of the major decisions taken by clients, however, most contractor selection methods overemphasize the acceptance of the lowest bid as the tender price is usually perceived as a major prerequisite to winning a contract. Selecting the lowest bidder has been overly criticized in works procurement literature, leading to the incorporation of a contractor evaluation phase focused on assessing the financial and technical capabilities of bidders. However, there are some drawbacks in the evaluation phase as the selection of suitable criteria for evaluating bidders is hugely subjective. Even though qualification criteria selection is project specific, there are issues of repetition of qualification criteria for different projects leading to the use of unjustified criteria for evaluating bidders. The knowledge required for selecting suitable qualification criteria exists in books, journals, and the minds of few human experts. Expert system technology is a tool that uses human cognitive capabilities to store knowledge electronically for decision making that can be accessed anywhere and at any time. This study aimed at developing an Expert System (ES) tool for Selecting Qualification Criteria for bid evaluation (ES_QS). The development of the system, ES_QS, was based on extensive literature review and knowledge elicited from an expert survey to provide recommendations for the rules. This system is developed to assist decision-makers (clients) in objectively selecting suitable qualification criteria for bid evaluation. Additionally, bidders can gain prior knowledge on their selection criteria for making a bid/no-bid decision and reduce disqualification events. The system provides an objective way of selecting contractor qualification criteria.

Keywords: Construction projects, Contractor Qualification Criteria, Expert Systems, Decision Making.

1.0 INTRODUCTION

The construction industry plays a significant role in the development of every country; hence, it is imperative to constantly expedite construction procurement processes to improve the industry's overall performance. One of the significant factors that affect the performance of a construction project is the suitability of the selected construction firm to execute the project (Fong and Choi, 2000; Afshar et al., 2017, Acheamfour et al., 2020). Selecting a suitable contractor is one of the major decisions taken by the client during the design phase of a project. According to Holt (2010), contractor selection consists of a theoretically infinite group of contractors whose qualities are often based on past performance and assessed based on the client’s objectives. However, most contractor selection methods overemphasize the acceptance of the lowest bid as the tender price is usually perceived as a major prerequisite to winning a contract (Fong and Choi, 2000). Over the years, many researchers have indicated flaws in over-emphasizing on lowest tender price (Turskis, 2008; Ballesteros-Perez et al., 2015). Hence, organizations have devised different strategies to select a suitable contractor while harnessing the benefits of the lowest tender price. This is achieved by first qualifying bidders based on pre-determined criteria and subsequently, the lowest evaluated bidder is selected. However, this approach has inherent challenges characterized by uncertainties, non-linearity, subjectivity, and competitiveness (Fong and Choi, 2000). In the quest to reduce this difficulty, numerous studies have focused on developing models for contractor selection, including the lowest price method, the weighted comprehensive scoring method, fuzzy sets, Artificial Neural Network (ANN), Support Vector Machine (SVM), Multiple Kernel Learning (MKL), Analytic Hierarchy Process (AHP) among others (*see* Lam et al., 2000; Lam and Yu, 2011, Afshar, 2017).

Idrus et al. (2011) opined that selecting a suitable contractor depends on the choice of qualification criteria. This was iterated by Nieto-Morote and Ruz-Vila (2012) by acknowledging that the criteria from which the capabilities of contractors are judged are crucial to the success of the contractor selection process. Furthermore, Acheamfour et al. (2020) postulated that the performance of every contractor selection model primarily relates to the measurement and judgment of prospective contractors based on a set of decision criteria. Thus, the adequacy of a contractor selection model depends on the suitability of the selection criteria used. Hence even the most effective and efficient contractor selection model and decision-making method can fail if appropriate selection criteria are not used. The selection of appropriate qualification criteria has been identified as an area with a significant risk of subjectivity and corruption (Korytarova et al., 2015). For instance, there have been reports on the use of unjustified technical requirements for contractors (in case of insulation of five buildings in a hospital complex) and unreasonable requirements for turnover of the contractor (delivery of IT services) (Kamenik and Petrakova, 2012; Korytarova et al., 2015). The use of unnecessarily strict qualification criteria to the subject of the contract results in the elimination of effective competition and contracts can even be tailored to pre-selected contractors (Kamenik and Petrakova, 2012). To reduce the subjectivity and tendency for corruption, a scientific model must be developed to aid in automated decision-making for qualification criteria selection.

Existing studies tend to focus on the development of contractor selection models rather than the qualification criteria to use for the selection process. In a review study conducted by Acheamfour et al. (2023), it was apparent that a model for selecting appropriate contractor qualification criteria will aid in the selection of a suitable contractor for a project. Hence, there is the need to turn attention to the development of a model that selects appropriate qualification criteria for contractor selection. Due to the Multiple Criteria Decision Making (MCDM) nature of contractor qualification criteria selection, automated decision-making methodologies can aid in selecting suitable contractor qualification criteria. This has driven this research to develop an expert system to automate the process of selecting suitable contractor qualification criteria.

2.0 CONTRACTOR QUALIFICATION

Contractor qualification involves the use of pre-determined criteria defined by law and the contracting entity to determine the capability of a contractor to perform a contract (Korytarova et al., 2015). Prior to the selection of a contractor, there are series of qualification criteria that contractors are appraised with, based on evidence that they provide for each criterion. The criteria used in evaluating contractors for selection can be categorized into three (3) namely basic requirements, professional requirements, and project-specific requirements. They are discussed as follows.

The basic requirements for contractor selection depict the probity of the construction firm to the country (Koryarova et al., 2015). These requirements are mandatory prerequisites in evaluating contractors. Thus, the procurement entity must always demand their fulfilment. In Ghana, the Public Procurement Act, 2003 (Act 663), as Amended with (Act 914), stipulates that to meet the basic requirements, a construction firm must be solvent and not subject to insolvency proceedings and fulfilled tax payment obligations and social security levies. According to Koryzrova et al. (2015), a construction firm must not be convicted of a criminal offence, pay all outstanding tax, and not be subjected to insolvency proceedings in the Czech Republic to meet the basic requirements.

The professional requirements for contractor selection show the professional capabilities of the construction firm to execute the construction project. Similar to the basic requirements, the professional requirements are mandatory pre-requisites in evaluating contractors, and the procurement entity must always demand their fulfillment. The Public Procurement Act, 2003 (Act 663) as Amended with (Act 914) in Ghana indicates that a construction firm must have the legal capacity to enter a contract and meet all ethical and other standards applicable in the country. In Ghana, sustainability considerations were added as an amendment to the Public Procurement Act (2003) due to the recent awareness of sustainable development. Sustainable considerations are therefore considered as a professional requirement for qualifying contractors. Currently, there is no indication of how sustainability should be accessed in the PPA Amendment (2016), however, its general consideration borders on the environmental friendliness of the construction and methods adopted. According to Act 22 PPL (2), to be eligible to compete in a construction contract in Poland, the firm must have the authorization to perform certain activities that may include concessions and licenses needed to perform certain activities.

The project-specific requirements refer to contractor qualification criteria that change based on the project's characteristics. These include technical requirements, and financial requirements. The technical requirements indicate the adequacy of plant and human resources (experience and number of personnel). It also considers the number of similar projects executed by the construction firm (Alptekin and Alptekin, 2017). The financial situation of the construction firm is assessed through its financial credibility and financial strength. This aids in assessing the financial structure of the construction organization.
Both the basic and professional requirements for contractor qualification are mandatory and must be always present, however the project specific requirements may change depending on the nature of the project. Hence, in developing an expert model for selecting criteria for contractor qualification, only the project-specific criteria must be considered. Consequently, the expert knowledge elicitation focused on only the project specific requirements.

Antecedents of contractor qualification criteria selection

In order to develop an expert system for contractor qualification criteria selection, it is important to have a comprehensive understanding of the antecedents of contractor qualification criteria selection. According to Banaitiene and Banaitis (2006), qualification criteria for choosing contractors must be selected considering the size and complexity of a construction project. Thus, the selection of qualification criteria is affected by the characteristics of the project, which may include project scale, type of project, percent of repetitive elements, funding source, among others. Numerous studies have investigated construction project characteristics and how they affect variables like project performance (*see* Ling et al., 2004; Cho et al., 2009; Alhazmi and McCaffer, 2000), construction project delivery system (*see* Liu et al.,2016; Chan 2007; Chen et al., 2011) and risk associated with client's cash flow prediction (*see* Ojo, 2012). Even with the scanty empirical evidence on how project characteristics affect contractor qualification criteria selection, existing documentary evidence has shown its criticality. For instance, Liu et al. (2016) indicated that large construction projects require huge funds hence only construction firms with a solid financial capacity can be considered. Additionally, Liebowitz and Suen, (2000) indicated that complex projects require an enhancement in productivity and improvement in risk management practices which can be achieved by a construction firm with sound financial backing. Remington and Pollack (2007) opined that traditional project management methods might not be sufficient to address complex projects as they may require high technical expertise of the construction firm. Also, Thomas and Mengel (2008) indicated the need for an advanced project management skill level to navigate complex projects. Hence, to achieve a high-performance level in complex projects, construction managers must have sufficient technical skills. A similar assertion was made by Whitty and Maylor (2009), who suggested that reflective personal skills, competencies, and thinking processes underpin the ability of project managers to achieve high performance in complex construction projects. This suggests the criticality of construction project characteristics in deciding qualification criteria to be used in contractor selection.

3.0 METHODOLOGY

The study was conducted based on a cross-sectional time horizon in collecting the required data for the model development. The study was based on the qualitative research method involving purposively selected registered Quantity Surveyors (QS's) in the Ghana Institution of Surveyors (GhIS). Thus, only QS's with postgraduate qualification, more than 15 years of experience, involved in more than 20 pre-contract proceedings and worked on more than 15 public projects were deemed as experts to participate in the data elicitation process for the development of the model. An interview approach was adopted for eliciting knowledge from the experts. To adequately elicit knowledge from the respondents, a semi-structured typology was adopted for the study. The interview guide comprised of project characteristics and contractor qualification rating scale. The respondents were asked about the appropriateness of the ratings, the inputs needed to select specific outputs, and considerations in making the software-based model user-friendly. A total of 12 professionals passed the expert selection criteria, however, after further probing of availability, only 4 were chosen. The dedication and availability of participants was crucial as the interviews involved an iteration process to ensure a comprehensive development of the rule-based system. Since more than one expert was involved, it is crucial to combine the knowledge of the experts to facilitate the development of the model (O'Hagan, 2019). The study adopted the content analysis method of qualitative data analysis for this study.

Tender documents were also collected to supplement the results of the qualitative data analysis. The public institutions that were contacted included Ghana Ports and Harbor Authority (GPHA), Architecture and Engineering Service Limited (AESL), Ghana Education Trust Fund (GetFund), Metropolitan, Municipal and District Assemblies (MMDAs), Kwame Nkrumah University of Science and Technology (KNUST), and University of Education, Winneba. A total of 96 tender documents were collected and analyzed based on its content. The content analysis focused on the qualification information section of the tender documents where various criteria used in assessing the bidders were documented.

4.0 DEVELOPING THE EXPERT SYSTEM TOOL

The development of the expert model followed a six-step approach which included knowledge elicitation, knowledge representation, programming of the expert model, prototype development, validation, and development of complete system.

4.1 Knowledge elicitation

The first step focused on knowledge elicitation. Knowledge elicitations comprise a set of methods that focus on explicating knowledge from domain experts (Cooke 1999). Tolun and Oztoprak (2018) acknowledged judgmental biases as a major setback in a knowledge elicitation process, however, Brownstein et al. (2018) argued that there are some levels of subjectivity in every phase of scientific inquiry hence, knowledge elicitation processes should focus on ways of eliminating potential sources of bias. The process for knowledge elicitation adopted for this study involved interviews with selected domain experts. The outcome of the knowledge elicitation process is shown in Appendix 1.

4.2 Knowledge representation

The results of the knowledge elicitation process were used to design rules (*see* Table 1), which served as the knowledge base for the expert system, ES-QS. This was subsequently used in the development of a contractor qualification criteria selection model (*see* Appendix 2).
Prior to incorporating the rules in the development of ES-QS, the established rules were sent back to the experts involved for validation. The experts were asked to comment on the appropriateness of rules developed and suggest adjustments where required. The interview results showed a general acceptance of the rules; hence, it was deemed appropriate to develop the system. The rule statements were added as variables with static values as “Yes” and “No” to represent the decision path in the system’s knowledge base and built as logic blocks.

Table 1: The representative rules for contractor qualification selection

Rules	**Description**
RULE 1	IF: The project value is less than GHC 200,000.00 THEN: Select RFQ
RULE 2	IF: The project value is less than GHC 15,000,000.00 *AND: greater than GHC 200,000.00* THEN: Select NCT
RULE 3	IF: The project value is greater than GHC 15,000,000.00 THEN: Select ICT
RULE 4	IF: The project value is less than GHC 450,000.00 *AND: the project is not complex* THEN: Select D4 & above
RULE 5	IF: The project value is less than 1,200,000.00 *AND: greater than GHC 450,000.00* *AND: the project is not complex* THEN: Select D3 & above
RULE 6	IF: The project value is less than 3,000,000.00 *AND: greater than GHC 1,200,000.00* *AND: the project is not complex* THEN: Select D2 & above
RULE 7	IF: The project value is greater than 3,000,000.00 *AND: the project is not complex* THEN: Select D1
RULE 8	IF: The project value is less than 1,200,000.00 *AND: the project is not complex* THEN: Select option A
RULE 9	IF: The project value is less than 3,000,000.00 *AND: greater than GHC 1,200,000.00* *AND: the project is not complex* THEN: Select option B
RULE 10	IF: The project value is greater than 3,000,000.00

	AND: the project is not complex THEN: Select option C
RULE 11	IF: The project is complex THEN: Select D1 & option C
RULE 12	IF: The frame type is concrete THEN: Select concrete mixer, vibrator, and steel cutting bench
RULE 13	IF: Water table is low *OR: Ground conditions is waterlogged* THEN: Select Water pumps
RULE 14	IF: Ground conditions is rocky THEN: Select hydraulic breaker
RULE 15	IF: Approximate site clearance area is greater than 5000 THEN: Select Bulldozer
RULE 16	IF: The project value is greater than 0 *AND: the project duration is greater than 0* THEN: compute annual turnover as $\frac{Project\ value}{Project\ duration} x\ 12\ months$
RULE 17	IF: The project source of funding is reliable THEN: compute liquidity as $\frac{Project\ value}{Project\ duration} x\ 2\ months$
RULE 18	IF: The project source of funding is not reliable THEN: compute liquidity as $\frac{Project\ value}{Project\ duration} x\ exp.pmt.delay\ duration$

4.3 Programming of the expert model

Once the knowledge of the proposed expert system was elicited and represented, it was then programmed. QS-ES was developed using Php and JavaScript. In building the action blocks, the IF (condition) and THEN (action) aspects were structurally represented before building the command blocks. The system could then run to see the recommended actions of suitable contractor qualification criteria.

4.4 Prototype development

The model was developed as a web-based tool to facilitate the ease of assessing. The actual programming began with the immediate goal of developing a demonstration prototype expert system that focuses on selected portions of the problem. This is done to test the design and functioning of the system. With several design changes and alterations, the full-scale system that incorporates a complete and detailed knowledge base and inference system was developed.

4.5 Validation and development of complete system

The validation aided in assessing the usability and practicality of the developed model. The validation was conducted with Procurement Officers within various Public Institutions in Ghana. A total of ten (10) respondents were involved in the validation process. Each respondent was sent a mail that comprised of the following.

- A user manual for the software
- A web link for the software
- A web link for the validation questionnaire survey

The respondents were asked to rate the appropriateness of the qualification criteria generated by the system, user experience, and the usefulness of the software. The respondents were allowed to provide any further notes for each of the questions. The results are discussed in subsequent sections. Generally, the results indicate the suitability of the model for practical application in the construction industry.

5.0 CONCLUSION

The study demonstrated the need for an automated model for selecting contractor qualification criteria. The expert system approach was adopted in the development of the model named ES-QS. The research process involved in the development of ES-QS led to theoretical and practical contributions. Theoretically, the study's outcome has provided a baseline knowledge that can be used to develop a reliable database for contractor qualification criteria selection. Practically, ES-QS reduces the subjectiveness associated with qualification criteria selection. The outcome of the study offers construction professionals a broader understanding of the factors that affect contractor qualification criteria for better decision making. Based on the outcome of the study, it is recommended that Procurement Authorities must facilitate the objective selection of qualification criteria by developing a policy manual that directs procurement entities on qualification criteria selection and mandates the objective selection of qualification criteria for procurement entities

A limitation in the usage of Expert Systems methodology is the conversion of expert knowledge into rules. Hence there was inadequate knowledge to develop rules with some aspects of the decisions taken by the experts. Addressing this limitation involves future longitudinal studies to create an adequate database to facilitate the use of machine learning techniques to compensate for the knowledge inadequacy from experts. Additionally, there is an avenue to incorporate Tender Price Indices and Locational Indices and merge with Building Information Modelling platforms to aid in providing project-specific user inputs to reduce its subjectivity further. The capabilities of the system can further be enhanced to assess the environmental, social, and economic viability of construction projects for sustainability purposes.

REFERENCES

Acheamfour, V.K., Adjei-Kumi, T. and Kissi, E., 2023. Contractor selection: a review of qualification and pre-qualification systems. International Journal of Construction Management, 23(2), pp.338-348.

Acheamfour, V.K., Kissi, E., Adjei-Kumi, T. and Adinyira, E., 2020. Review of empirical arguments on contractor pre-qualification criteria. Journal of Engineering, Design and Technology, 18(1), pp.70-83.

Afshar M. A., Yagub A., Mohammad H. S. and Weng T.C., (2017). A type-2 fuzzy set model for contractor prequalification, *Journal of Automation in Construction* **84**(1), pp.356-366., https://doi.org/10.1016/j.autcon.2017.10.003.

Alhazmi, T., and McCaffer, R. (2000). Project procurement system selection model. Journal of Construction Engineering and Management, ASCE, 126(3), 176–184.

Alptekin, O. and Alptekin, N., (2017), Analysis of criteria influencing contractor selection using TOPSIS method. In IOP Conference Series: Materials Science and Engineering (Vol. 245, No. 6, p. 062003). IOP Publishing.

Ballesteros-Pérez, P., Skitmore, M., Pellicer, E. and González-Cruz, M.C., (2015). Scoring rules and abnormally low bids criteria in construction tenders: a taxonomic review. *Construction management and economics*, **33**(4), pp.259-278.

Banaitiene, N. and Banaitis, A., (2006). Analysis of criteria for contractors' qualification evaluation. Technological and Economic Development of Economy, 12(4), pp.276-282.

Chan, C.T., (2007). Fuzzy procurement selection model for construction projects. Construction Management and Economics, 25(6), pp.611-618.

Chen, Y.Q., Liu, J.Y., Li, B. and Lin, B., (2011). Project delivery system selection of construction projects in China. Expert Systems with Applications, 38(5), pp.5456-5462.

Cho, K., Hong, T. and Hyun, C., (2009). Effect of project characteristics on project performance in construction projects based on structural equation model. Expert Systems with Applications, 36(7), pp.10461-10470.

Cooke, N.J., (1999). Knowledge elicitation. *Handbook of applied cognition*, pp.479-509.

Fong, P.S.W. and Choi, S.K.Y., (2000). Final contractor selection using the analytical hierarchy process. *Construction management and economics*, **18**(5), pp.547-557.

Holt, G.D., (2010). Contractor selection innovation: examination of two decades' published research. Construction Innovation: Information, Process, Management, 10(3), pp.304-328.

Idrus, A., Nuruddin, M.F. and Rohman, M.A., 2011. Development of project cost contingency estimation model using risk analysis and fuzzy expert system. *Expert Systems with Applications*, *38*(3), pp.1501-1508.

Kameník M, Petráková, L (2012), Risk of corruption in public procurement, Available from: www.bezkorupce.cz/wp.../09/metodika_FINAL.pdf]M. Kameník, L. Petráková, them?), (2012) Available from: www.bezkorupce.cz/wp.../09/metodika_FINAL.pdf.

Korytárová, J., Hanák, T., Kozik, R. and Radziszewska–Zielina, E., (2015). Exploring the contractors' qualification process in public works contracts. *Procedia Engineering*, 123, pp.276-283.

Lam, K.C. and Yu, C.Y., (2011). A multiple kernel learning-based decision support model for contractor pre-qualification. Automation in Construction, 20(5), pp.531-536.

Lam, K.C., Hu, T., Ng, S.T., Skitmore, M. and Cheung, S.O. (2001), "A fuzzy neural network approach for contractor prequalification", *Construction Management and Economics*, **19**(2), pp. 175-180.

Liebowitz, J. and Suen, C.Y., (2000). Developing knowledge management metrics for measuring intellectual capital. Journal of Intellectual Capital, 1(1), pp.54-67.

Ling, F. Y. Y., and Liu, M. (2004). Using neural network to predict performance of design-build projects in Singapore. Build. Environment., 39(10), pp.1263–1274.

Liu, B., Huo, T., Meng, J., Gong, J., Shen, Q. and Sun, T., 2016. Identification of key contractor characteristic factors that affect project success under different project delivery systems: empirical analysis based on a group of data from China. Journal of Management in Engineering, 32(1), p.05015003.

Nieto-Morote, A. and Ruz-Vila, F., (2012). A fuzzy multi-criteria decision-making model for construction contractor prequalification. *Automation in Construction,* **25**(1), pp.8-19.

O'Hagan, A., (2019). Expert knowledge elicitation: subjective but scientific. The American Statistician, 73(sup1), pp.69-81.

Ojo, G. K. (2012). Project Characteristics Influence on Risk Associated with Construction Client‟s Cash Flow Prediction. Journal of Research in International Business and Management, 2(5), pp.142-150.

Public Procurement Act, (2003) (Act 663) of the Republic of Ghana.

Public Procurement Manual (2006). Final manual – Public Procurement Act, 2003 (Act 663). Ghana: Public Procurement Board (PPB).

Thomas, J. and Mengel, T., (2008). Preparing project managers to deal with complexity–Advanced project management education. International journal of project management, 26(3), pp.304-315.

Tolun M. and Oztoprak, K (2018), Expert systems, Kirk-Othmer Enclycloperdia of Chemical Technology, John Wiley & Sons, Inc.

Turskis, Z., (2008). Multi-attribute contractors ranking method by applying ordering of feasible alternatives of solutions in terms of preferability technique. *Technological and Economic Development of Economy*, **14**(2), pp.224-239.

Whitty, S.J. and Maylor, H., 2009. And then came complex project management (revised). International Journal of Project Management, 27(3), pp.304-310.

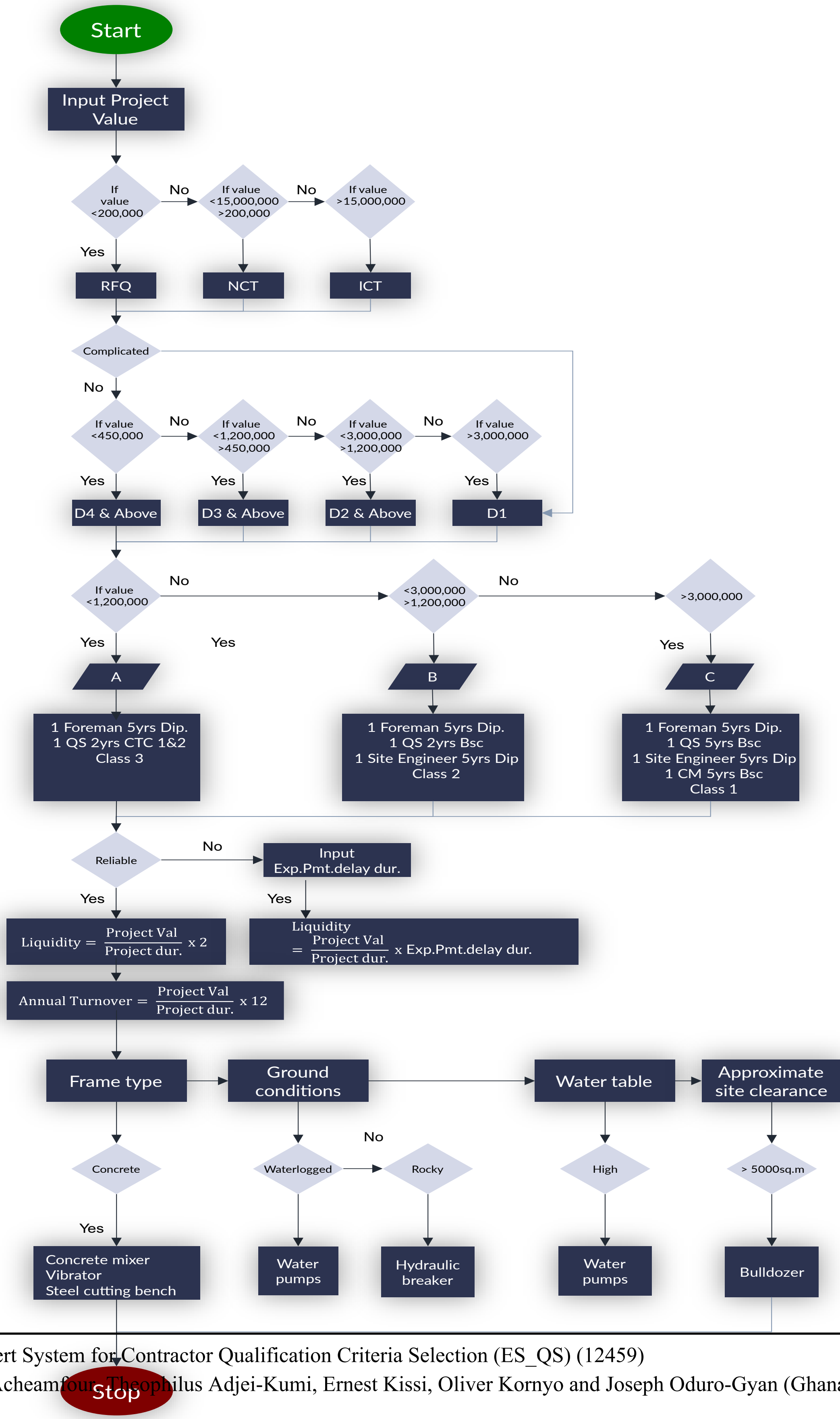
APPENDIX 1

Themes	Expert 1	Expert 2	Expert 3	Expert 4
1	• Explore the PPA Act (663) and Act (914), contractor classification documentation, and the public financial management regulations (2020). They can guide you with the ratings on procurement methods, the number of bidders, human and plant resources.	• The definition of complexity must incorporate monetary values as complex projects have complex requirements that affect the cost of the project. • Also, the PPA Act (663) and Act (914) can guide you in your ratings. • The ratings on-site location must be expanded, recommending regional bases. This is because a change in regional location may require a contractor with experience working in the area. • Even though many professionals measure project size based on value, this approach is time-bound. Thus, a large project today may be small in ten year's time. If possible, develop a permanent way of describing project size. It will not change the outcome of the study, though, but it will be a great addition to the literature.	• If the ratings are going to be based on the PPA Act (663) and Act (914) and contractor classification documentation, then the focus should be on Public Projects as it is mandatory for public projects to go by the Act.	• The adopted ratings are satisfactory; however, expand it to include the source of funding as it is a crucial aspect in determining the credit rating value required from the contractor.
2	• The PPA Act (663) and Act (914) provide thresholds for projects; hence, outputs like technical classification and	• With regards to the number of human resources, some projects may require more than one specific professional depending on the	• The PPA Act (663) and Act (914) stipulate the thresholds for specific procurement approaches that can be adopted.	• For a project, the annual turnover required can be computed as the value

	procurement methods can be based on the thresholds. • The level of experience of human resources depends on the complexity and size of the projects. • The annual turnover relates to the value of the project and the duration of the project; however, the credit rating value of the contractor is dependent on the nature of the source of funding and anticipated payment delays.	project size. Even though the contractor classification documentation is silent on it, explore various tenders documents for such situations. • The annual turnover and credit ratings required for specific projects are computed based on the value of the project and the duration of the project.	• With regards to plant capacity, the category of the contractor will determine the plant holding required. However, the complexity of the project may require other specialized plants. • In determining the amount for the contractor to prove as a credit facility, we normally decide on a hypothetical payment delay period and multiply it with the value of the project per month. • Plant and equipment selection can be based on the scope of the project. For instance, concrete works require concrete mixers on site. Probably, more details are required to give an indication of the nature and kind of plant. (*provided plant requirement thresholds)*	of the project per year. This can serve as the limit that the annual turnover should not be less than. This approach has been used on almost all of the projects I have been on. • It is not always that we require contractors to provide evidence of credit facility, especially in situations where the source of funding is very reliable. However, doing that can put the project at risk. It is prudent to always make it a requirement so as to reduce risk.
3	• Develop a User Manual for the system	• Provide definitions for controversial terms used in the system like project complexity	• There should be room for users to add special plants required for a project.	

Theme 1: The appropriateness of the ratings.
Theme 2: The inputs needed to select specific outputs.
Theme 3: Considerations in making the software-based model user-friendly.

APPENDIX 2



Start
Input Project Value
If value <200,000
No
If value <15,000,000 >200,000
No
If value >15,000,000
Yes
RFQ
NCT
ICT
Complicated
No
If value <450,000
No
If value <1,200,000 >450,000
No
If value <3,000,000 >1,200,000
No
If value >3,000,000
Yes
Yes
Yes
Yes
D4 & Above
D3 & Above
D2 & Above
D1
If value <1,200,000
No
<3,000,000 >1,200,000
No
>3,000,000
Yes
Yes
Yes
A
B
C
1 Foreman 5yrs Dip.
1 QS 2yrs CTC 1&2
Class 3
1 Foreman 5yrs Dip.
1 QS 2yrs Bsc
1 Site Engineer 5yrs Dip
Class 2
1 Foreman 5yrs Dip.
1 QS 5yrs Bsc
1 Site Engineer 5yrs Dip
1 CM 5yrs Bsc
Class 1
Reliable
No
Input Exp.Pmt.delay dur.
Yes
Yes
Liquidity = Project Val / Project dur. x 2
Liquidity = Project Val / Project dur. x Exp.Pmt.delay dur.
Annual Turnover = Project Val / Project dur. x 12
Frame type
Ground conditions
Water table
Approximate site clearance
Concrete
Waterlogged
No
Rocky
High
> 5000sq.m
Yes
Concrete mixer
Vibrator
Steel cutting bench
Water pumps
Hydraulic breaker
Water pumps
Bulldozer
Stop