International Journal of Information, Control and Computer Sciences
ISSN: 2517-9942
Vol:13, No:7, 2019

Developing a Web-Based Tender Evaluation System Based on Fuzzy Multi-Attributes Group Decision Making for Nigerian Public Sector Tendering

Bello Abdullahi, Yahaya M. Ibrahim, Ahmed D. Ibrahim, Kabir Bala

Abstract**—**Public sector tendering has traditionally been conducted using manual paper-based processes which are known to be inefficient, less transparent and more prone to manipulations and errors. The advent of the Internet and the World Wide Web has led to the development of numerous e-Tendering systems that addressed some of the problems associated with the manual paper-based tendering system. However, most of these systems rarely support the evaluation of tenders and where they do it is mostly based on the single decision maker which is not suitable in public sector tendering, where for the sake of objectivity, transparency, and fairness, it is required that the evaluation is conducted through a tender evaluation committee. Currently, in Nigeria, the public tendering process in general and the evaluation of tenders, in particular, are largely conducted using manual paper-based processes. Automating these manual-based processes to digital-based processes can help in enhancing the proficiency of public sector tendering in Nigeria. This paper is part of a larger study to develop an electronic tendering system that supports the whole tendering lifecycle based on Nigerian procurement law. Specifically, this paper presents the design and implementation of part of the system that supports group evaluation of tenders based on a technique called fuzzy multi-attributes group decision making. The system was developed using Object-Oriented methodologies and Unified Modelling Language and hypothetically applied in the evaluation of technical and financial proposals submitted by bidders. The system was validated by professionals with extensive experiences in public sector procurement. The results of the validation showed that the system called NPS-eTender has an average rating of 74% with respect to correct and accurate modelling of the existing manual tendering domain and an average rating of 67.6% with respect to its potential to enhance the proficiency of public sector tendering in Nigeria. Thus, based on the results of the validation, the automation of the evaluation process to support tender evaluation committee is achievable and can lead to a more proficient public sector tendering system.

Keywords**—**e-Tendering, e-Procurement, public tendering, tender evaluation, tender evaluation committee, web-based group decision support system.

Bello Abdullahi is a PhD Student with the Department of Building Ahmadu Bello University, Zaria, Nigeria. (phone: +234 08060357365; e-mail: abdullbello@yahoo.com).

Kabir Bala is a Professor with the Department of Building, Ahmadu Bello University, Zaria, Nigeria (phone: 234 08037264175; e-mail: balakabir@yahoo.com).

Yahaya M. Ibrahim is a Professor with the Department of Quantity Surveying, Ahmadu Bello University, Zaria, Nigeria (phone: +234 08098003151; e-mail: makarfi@gmail.com).

Ahmed D. Ibrahim is a Professor with the Department of Quantity Surveying, Ahmadu Bello University, Zaria, Nigeria (phone: +234 08035925082; e-mail: adibrahim2@yahoo.com).

I. Introduction

PUBLIC sector tendering as in many areas of human endeavour has been transformed by the Internet and the World Wide Web. Across the globe, public procuring entities are gradually adopting web-based e-Tendering systems to replace the traditional manual paper-based system that has dominated public sector procurement over the last several decades. The aim has been to address the numerous problems associated with the manual paper-based tendering processes. Among these problems are lack of transparency and efficiency, corruption, complicated procedures, excessive state interference, and bureaucratic dysfunctional ties [1]. Reference [2] defined e-Tendering as a process of selecting contractors, consultants and other service providers by client organisations through the electronic publishing, communication, submission, receiving, opening, and assessment of all tender related information and documents via the internet. In the last four decades, many governments in both developed and developing countries have implemented to various degrees of automation an e-Tendering/e-Procurement system [3]. Examples of such systems include Korea's KONEPS, Canada's MERX, Malaysia's ePerolehan, Japan's JETRO, FACNET of the United States, Philippines' PhilGEPS, Scotland's ePS, JEPP of Belgium, DOIP of Denmark, and UK Tender Direct [4], [3].

Traditionally, evaluation of tenders by public procuring entities is conducted manually. And despite the increasing automation of the entire tendering lifecycle, the majority of the existing system rarely supports the evaluation part of the tendering process [4]. In addition, the few systems that do support the evaluation of tenders, the process is largely conducted by a single evaluator instead of group of evaluators. However, a key requirement for public sector procurement is that the evaluation of technical and financial bids should be done by a tender evaluation committee consisting of multiple numbers of decision makers appointed from various departments of the procuring entity. This is to ensure transparency, fairness and objectivity of the evaluation process.

A number of techniques have been applied to solve group decision making as it relates to the contractor selection problem. Among the most popular techniques are analytical hierarchy process and fuzzy set theory. The former is part of the family of multi criteria decision making techniques, while the latter is part of the artificial intelligence techniques. One of the techniques based on the fuzzy set theory that has been

applied by a number of researchers [5], [6] to address the selection problem by a group of decision makers is called the fuzzy multi-attributes group decision making technique (FMAGDM). The FMAGDM is a technique based on the concept of fuzzy logic developed by [7]. It allows for the ranking of multiple competing alternatives by multiple decision makers using multiple selection criteria based on fuzzy linguistic terms. However, none of these models have been implemented as part of an e-Tendering system to address the problem of evaluation of tenders by a group of decision makers.

The research presented in this paper is part of a larger study that developed a web-based e-Tendering system called NPS-eTender for Nigerian public sector tendering. The system was developed primarily to support the group evaluation of tenders. Specifically, this paper presented the development of the system component that handles the technical bid evaluation stage of the tendering process. The application of the FMAGDM technique to address the group decision making at this stage of the evaluation process is demonstrated.

II. Tender Evaluation Techniques and Models

Tender evaluation is one of the most critical processes within the tendering stage [4]. It is a stage where the most manipulations can be carried out in favour of one bidder over another [12]. For objective and systematic assessments of tenders, various evaluation techniques and models have been investigated and developed for use at both the prequalification stage and bid evaluation stage [13].

Among the prequalification techniques and models are simple structured model (dimensional weighting, multi attribute analysis); complex structured models (multi attributes utility theory, analytical hierarchy process); artificial intelligence models (knowledge-based expert system, case-based reasoning, artificial neural network, and evidential reasoning) [13]. These various models allowed for the classifications of bidders into 'prequalified' and 'disqualified' classes. On the other hand are models that have been developed to allow for ranking of bidders based on multiple criteria with a view to determining the most suitable bidder for award of a contract. Among these are models based on techniques such as fuzzy set theory, analytical hierarchy process (AHP), and multi attributes utility theory. Other hybrid models developed to address both prequalification and bid evaluations include fuzzy set and AHP [14]. Even though the majority of these evaluation models are purely analytical, some of them have been implemented in tender evaluation in the form of a web-based decision support system based on a single decision maker using AHP [9]-[11]. There are very few systems implemented based on a web-based group decision support system [8]. Other recent related research work is that of [20].

III. Concepts of Fuzzy Set Theory

A. Fuzzy Set

The fuzzy set theory is based on the concept of [7] and it allows for the mathematical modelling of the uncertainty in the human cognitive process, thoughts, and critical reasoning. The fuzzy set is defined as follows by [15]: if X is the universe of discourse and its elements are denoted by x, then a fuzzy set A in X is defined as a set of ordered pairs.

$$\mathbf{A = \{x, \mu_A(x) \mid x \in X\}} \quad (1)$$

where $\mu_A(x)$ is called the membership function (mf) of x in A. The membership functions maps each element of X to a membership value between 0 and 1.

B. Fuzzy Membership Function

A membership function (MF) is a curve that defines how each point in the input space i.e. universe of discourse is mapped to a membership value that indicates its' degree of membership between 1 and 0 [16]. A triangular fuzzy membership function is defined by the parameters (a_1, a_2, a_3), where a_1 is the membership function's left intercept with grade equal to 0, a_2 is the centre peak where the grade equals 1, and a_3 is the right intercept at grade equal to 0 [16], [6], and its membership function is defined as:

$$F_A(x) = \begin{cases} 0 & x < a_1 \\ (x - a_1)/(a_2 - a_1) & a_1 \le x \le a_2 \\ (a_2 - x)/(a_3 - a_2) & a_2 \le x \le a_3 \\ 0 & x > a_3 \end{cases} \quad (2)$$

The equivalent diagram of the triangular fuzzy numbers is shown in Fig. 1.

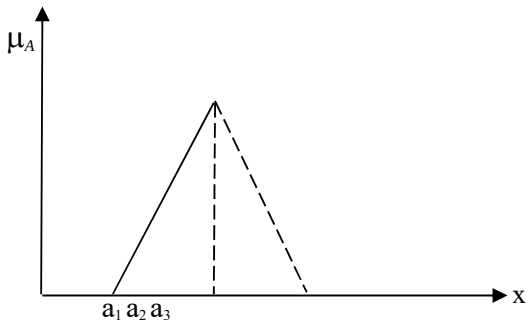

Fig. 1 Triangular Fuzzy Number

A fuzzy number $\mathbf{a_i}$ can be expressed in the form of:

$$a_i = \{a_1, a_2, a_3, a_4\}, \text{ for } i = 1,2\ldots..,m$$

where $a_{1<}\ a_{2<}\ a_{3<}\ a_4$ = scale of preference structure to be used by decision makers and m = number of fuzzy number to be used in the analysis [5].

C. Operations on Fuzzy Numbers

Arithmetic operations i.e. addition, subtraction, multiplication, and division can be performed on any two fuzzy numbers. Let A and B be two triangular fuzzy numbers parameterized by the triplet (a_1, a_2, a_3) and (b_1, b_2, b_3), then the operations (addition, subtraction, multiplication, and division)

are performed according to [6] as follows:

$$A(+)\ B = (a_1, a_2, a_3) + (b_1, b_2, b_3) = (a_1 + b_1, a_2 + b_2, a_3 + b_3) \quad (3)$$

$$A\ (-)\ B = (a_1, a_2, a_3) - (b_1, b_2, b_3) = (a_1 - b_1, a_2 - b_2, a_3 - b_3) \quad (4)$$

$$A\ (\times)\ B = (a_1, a_2, a_3) \times b_1, b_2, b_3) = (a_1 \text{ x } b_1, a_2 \text{ x } b_2, a_3 \text{ x } b_3) \quad (5)$$

$$A(\div)\ B = (a_1, a_2, a_3) \div (b_1, b_2, b_3) = (a_1 / b_3, a_2 / b_2, a_3 / b_1) \quad (6)$$

$$r(\times)A = (ra_1, ra_2, ra_3) \quad (7)$$

$$r\ (+)\ A = (r + a_1, r + a_2, r + a_3) \quad (8)$$

$$1/\ r\ (\text{x})\ A = (a_1/r, a_2/r, a_3/r) \quad (9)$$

The same operations can be performed on a trapezoidal fuzzy number, which has four parameters (a_1, a_2, a_3, a_4) [9].

D.Defuzzification

According [16], defuzzification is the process of representing a fuzzy set with a crisp number. There are many methods of defuzzification such as mean method, maximising and minimising set method [6], [5]. For the triangular fuzzy number given by three parameters $\mathbf{x_1}$, $\mathbf{x_2}$, and $\mathbf{x_3}$, and using the mean method, the defuzzified value e, is given as:

$$e = (x_1 + 2x_2 + x_3)\ /4\ldots \quad (10)$$

IV. Proposed Methodology for Technical Bid Evaluation Based on Fuzzy Multi-Attributes Group Decision Making

Various methodologies for implementation of the FMAGDM technique have been implemented [5], [6]. Based on these methodologies, the following steps were implemented in the development of the technical bid assessment model within the NPS-eTender.

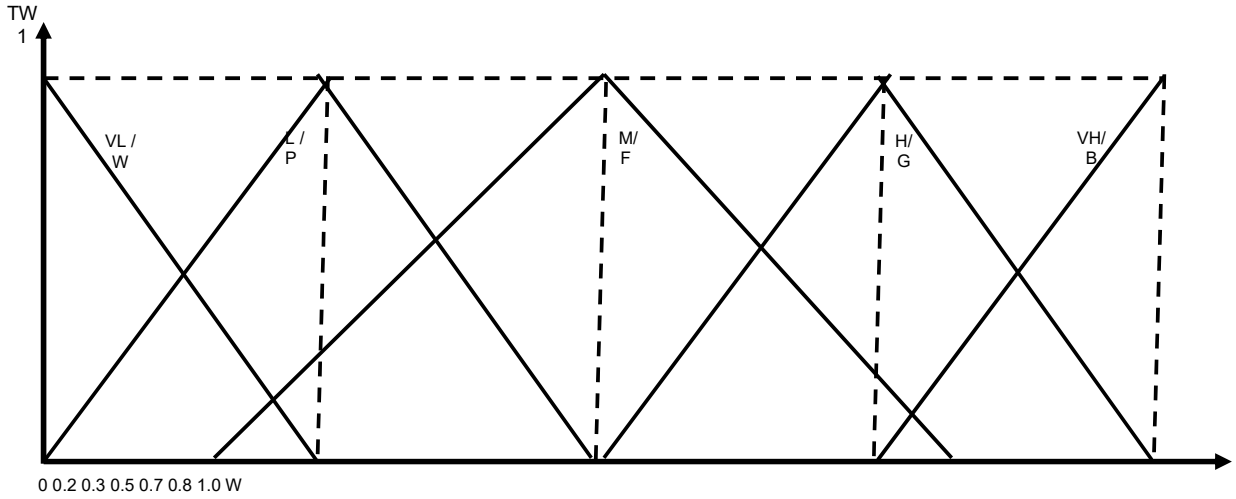

Fig. 2 Membership Function for Linguistic Weighting and Rating Values

Step1. Assign membership function for linguistic criteria weighting value using Fig. 2 by members of the Tender Evaluation Committee (TEC) to determine the relative importance of each criterion. The fuzzy numbers for the linguistic weighting variables are: Very Low Importance (VLI) = (0, 0, 0, 0.3); Low Importance (LI) = (0, 0.3, 0.3, 0.5); Moderate Importance (MI) = (0.2, 0.5, 0.5, 0.8); High Importance (HI) = (0.5, 0.7, 0.7, 1); Very High Importance (VHI) = (0.7, 1, 1, 1).

Step2. Assign membership function for linguistic performance rating values using Fig. 2 by members of the TEC to assess the performance of each bidder against a given set of criteria. The fuzzy numbers for the linguistic rating variables are: Very Poor (VP) = (0, 0, 0, 0.3); Poor (P) = (0, 0.3, 0.3, 0.5); Fair (F) = (0.2, 0.5, 0.5, 0.8); Good (G) = (0.5, 0.7, 0.7, 1); Very Good (VG) = (0.7, 1, 1, 1).

Step3. Decide on the evaluation criteria to be used for the specific project.

Step4. Evaluate the importance of the evaluation criteria across decision makers using MFs in Step 1.

$$W_t = (1/n) \otimes (W_{t1} \oplus W_{t2} \oplus \ldots\ldots \oplus W_{tn})\ t=1,2,\ldots k \quad (11)$$

where, W_t = the aggregated weight for criterion t; W_{tn} = the important weighting given by decision maker n to criterion t; k = the number of criteria; n = the number of decision maker.

Step5. Assign rating R_{itn} of bidder i under criterion t by decision maker n using linguistic terms in Step 2.

Step6. Determine the individual rating F_{IR} and ranking for each alternative by weighting the R_{itn} with the aggregated weight W_t for all decision makers n.

$$F_{IR(i)} = (1/k) \otimes [(R_{i1} \otimes W_1) \oplus (R_{i2} \otimes W_2) \oplus \ \oplus (R_{ik} \otimes W_k)] \quad (12)$$

where i = 1,2,……m; m = the number of alternatives; k= the number of criteria; R_{ik} = the assigned rating of alternative i under criterion k by a decision maker

To arrive at a ranking, the $F_{IR(i)}$ is defuzzified as per (10) above and converted into a percentage using (5). The Crisp Weighted Score is given as:

$$CWS_{(i)} = e\ (x)\ 100\% \quad (13)$$

where e = defuzzified value from (10).

Step7. Obtain the group final rating $F_{GR(i)}$and ranking of each alternative. The weighted individual rating $F_{IR(i)}$ are aggregated across multiple committee members to arrive at a group weighted rating and ranking.

$$F_{GR(i)} = (1/n)\otimes[(\ F_{IR(i1)}\oplus F_{IR(i2)}\oplus.....\oplus F_{IR(in)})] \quad (14)$$

where, $F_{IR(i)}$ = Final individual weighted ratings determined in Step 6; n = the number of decision makers; i = 1,2,……m; m = the number of alternatives.

To arrive at a final ranking for each alternative, the $F_{GR(i)}$ is defuzzified as per (10) above and converted into a percentage score.

V. Software Development Methodology

Object oriented development based on RIPPLE methodology was adopted for the development of the software system [17], [18]. The methodology is based on spiral, iterative and incremental methodologies of the software development lifecycle and uses unified modelling language (UML) to graphically illustrate the software artefacts. Fig. 3 shows the simplified steps followed in the development of the software.

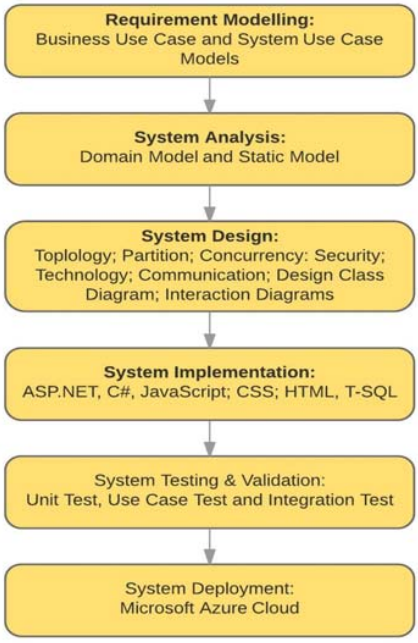

Fig. 3 Software Development Methodology

VI. Development of NPS-eTender

The system was developed as a web-based 3-tier system consisting of User Interface (UI), Domain Logic Layer (DLL), and Data Access Layer (DAL). The UI contains webpages for use interactions; the DLL implements the tendering processes logic; and the DAL stores all persistent data. The physical system architecture is shown in Fig. 4, which illustrates the various physical components of the NPS-eTender i.e., client machines, web-server and database server. In general, the NPS-eTender system was developed as an ASP.NET web application [21]. The NPS-eTender was implemented using ASP.NET Webforms and C# programming language.

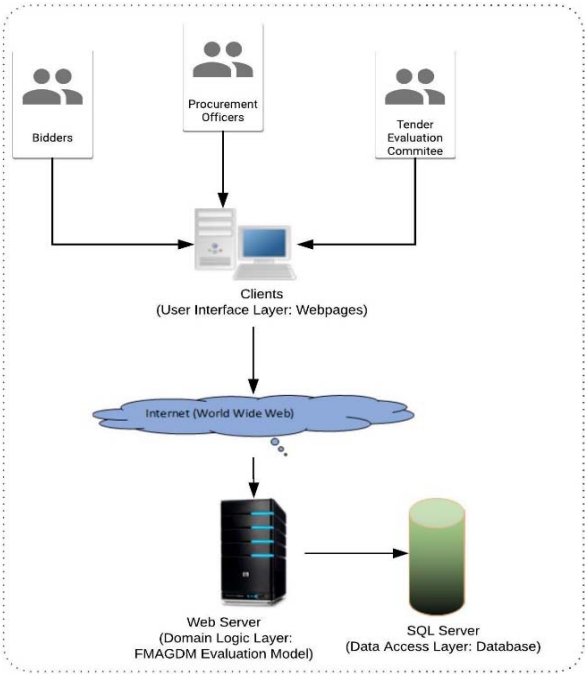

Fig. 4 Physical Architecture of NPS-eTender

VII. Working Process and Hypothetical Application of NPS-eTender

The NPS-eTender was designed to support the whole tendering lifecycle i.e., tender notification, submission, opening, evaluation, approval and award notification. In this paper, only the implementation of the FMAGDM model that implements group decision making at the technical bid evaluation stage is presented. There are five essential steps in the implementation of the FMAGDM model based on the methodology outlined above:

1. Procuring entity formed Tender Evaluation Committee
2. Committee chairman selects the technical evaluation criteria
3. Committee members rate the criteria relative importance
4. Committee members technical bids criteria performance
5. Committee chairman aggregates members' results to arrive at a group ranking

The developed NPS-eTender was hypothetically

implemented and the following snapshots show the implementation of these five steps.

Step 1: Procuring Entity formed Tender Evaluation Committee

Here, the Procurement Officer assigned the role of administrator by the procuring entity formed the Tender Evaluation Committee responsible for evaluation of the technical bids submitted by interested companies. Fig. 5 shows the members of the committee added by the administrator.

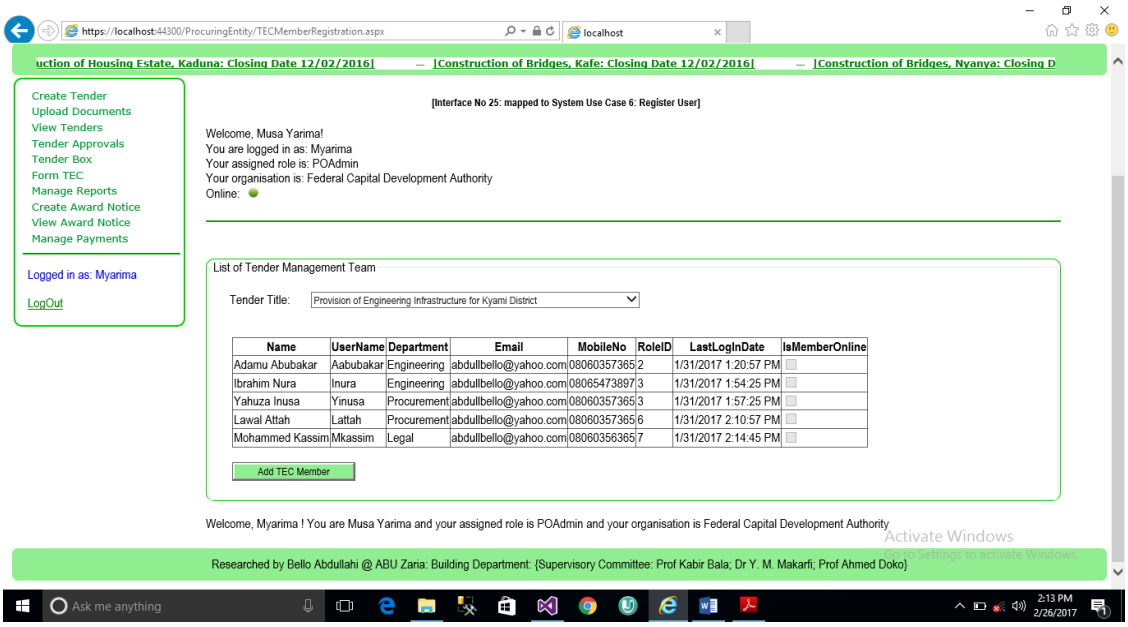

Fig. 5 Snapshot of Webpage showing the Members of the Tender Evaluation Committee

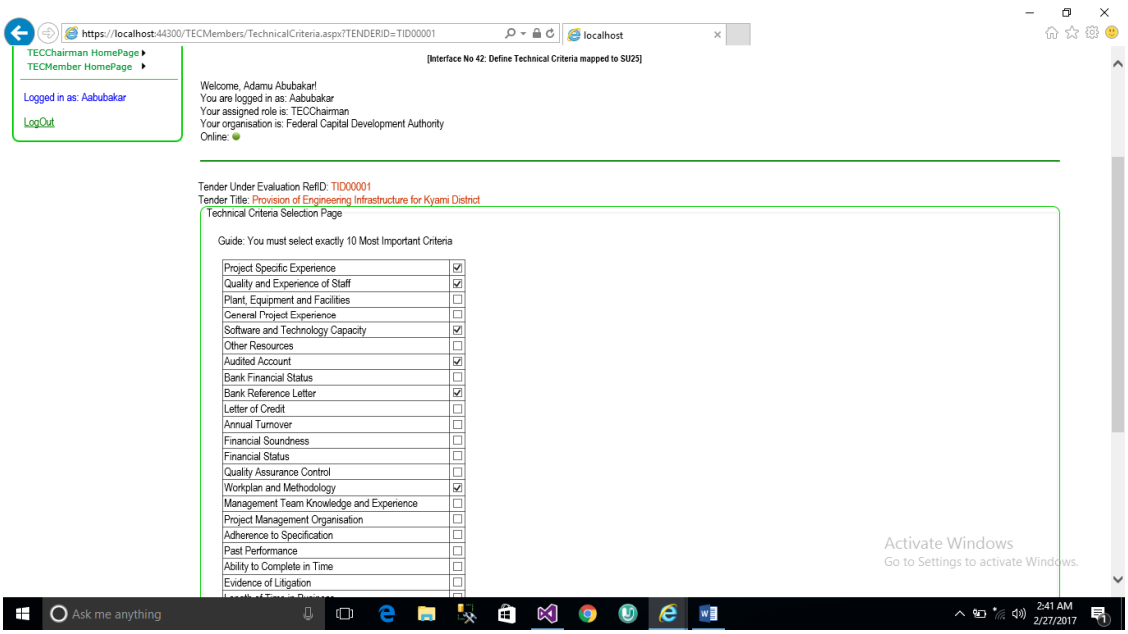

Fig. 6 Snapshot of Webpage showing Selected Technical Bid Evaluation Criteria

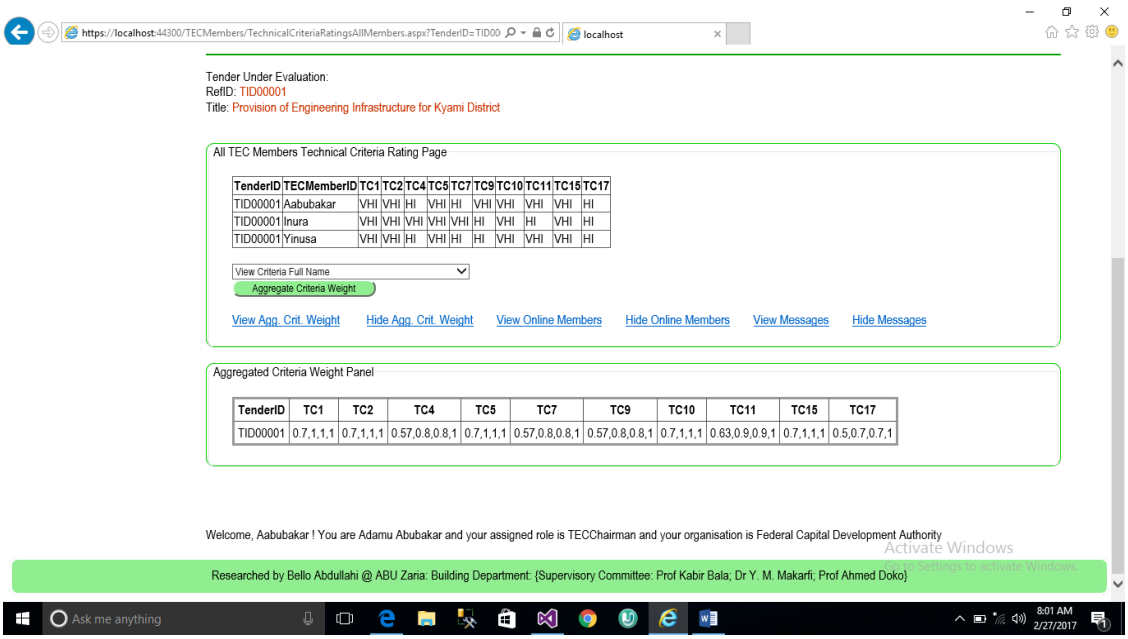

Fig. 7 Snapshot of Rating of Criteria Relative Importance by Committee Members and the Aggregated Criteria Weight

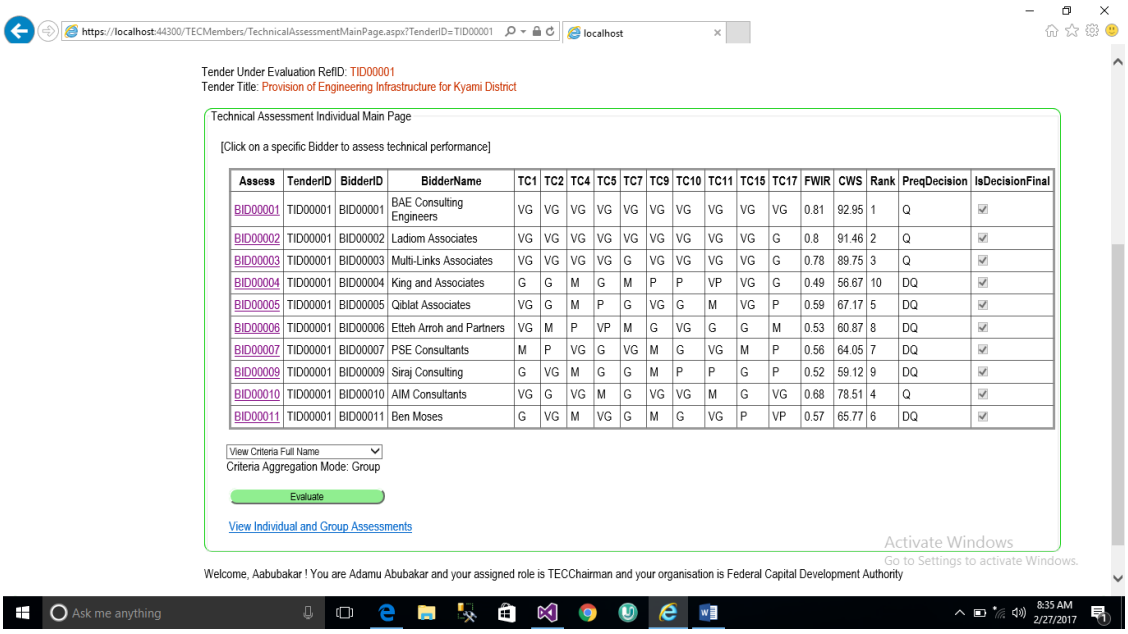

Fig. 8 Snapshot of Evaluated Performance Rating of all Bidders by a Committee Member

Step 2: Committee Chairman Select Evaluation Criteria

In this step, the chairman of the committee logs in to NPS-eTender and selects the applicable criteria from a list of available criteria. This corresponds to Step 3 of the FMAGDM methodology. Fig. 6 shows the various technical bid criteria (scorable using linguistic terms) selected by the chairman for the mock-up tender i.e., project specific experience, qualification and experience of staff, work plan and methodology, etc.

Step 3: Members Rate Technical Bid Criteria Importance

Here, members of the committee log in to NPS-eTender after the chairman has finished selecting the criteria and rate the relative importance of the selected evaluation criteria using linguistic terms as in Step 4 of the FMAGMD methodology. Fig. 7 shows the rated criteria by all committee members and also the aggregated criteria weight in fuzzy number which is used in computing the bidders' performance.

Step 4: Members Rate Technical Bids Criteria Performance

Under this step, each member of the committee logs in to NPS-eTender to assess the performance of each bidder using the linguistic terms as in Step 5 of the FMAGDM methodology. The individual assessment ratings are combined with the aggregated criteria weight to determine the ranking of each bidder for each member. Fig. 8 shows the performance rating of all bidders by one of the committee members.

Step 5: Chairman Aggregate Members Individual Rating into Group Rating

After all members have assessed the performance of each of the bidders, the chairman of the committee then instructs the system to aggregate the members' individual ratings into a group rating for the purpose of ranking of bidders and the determination of the bidders that are 'qualified' and those that are 'disqualified'. This stage corresponds to Step 7 of the FMAGDM methodology.

Fig. 9 shows the group evaluated decision for each bidder after the committee chairman has aggregated the individual performance ratings of all members (Step 7 of FMAGDM methodology). As can be seen, only four bidders were prequalified to the financial evaluation stage i.e., BID00001, BID00002, BID00003 and BID00010. The rest of the bidders have scored less than the prequalification threshold of 70 marks and are disqualified from further evaluation. The four bidders are thus automatically prequalified by the NPS-eTender to the financial evaluation stage where their respective financial bids are assessed. The technical scores from the FMAGDM evaluation model are then combined with financial scores to arrive at aggregated scores for use in making the ultimate decision of the winning 'bid'. Fig. 10 shows the final outcome of the NPS-eTender evaluation for the hypothetical mock-up tender. As can be seen, Bidder002 has been recommended for award of contract as it has the highest combined technical and financial scores of 90.05.

VIII. Validation of NPS-eTender

The purpose of validation is to find out the degree to which a given model is in conformance with reality and whether it achieves its stated objective or not. The model validation process proposed by [19] was used as a guideline in validating NPS-eTender. Therefore, NPS-eTender was evaluated using two set of criteria. The first set of criteria are used to evaluate the NPS-eTender performance with respect to addressing the first research question which is the extent to which the developed NPS-eTender in general and the evaluation module in particular can be used as an alternative to the existing tendering system. The second set of criteria were used to evaluate the NPS-eTender with respect addressing the second research question which is the extent to which the NPS-eTender can enhance the proficiency of tendering by Nigerian public procuring entities. The respondents that participated in the validation include four procurement officers representing various procuring entities; three staff of consulting firms and three staff of contracting firms, and all with experience in public sector tendering.

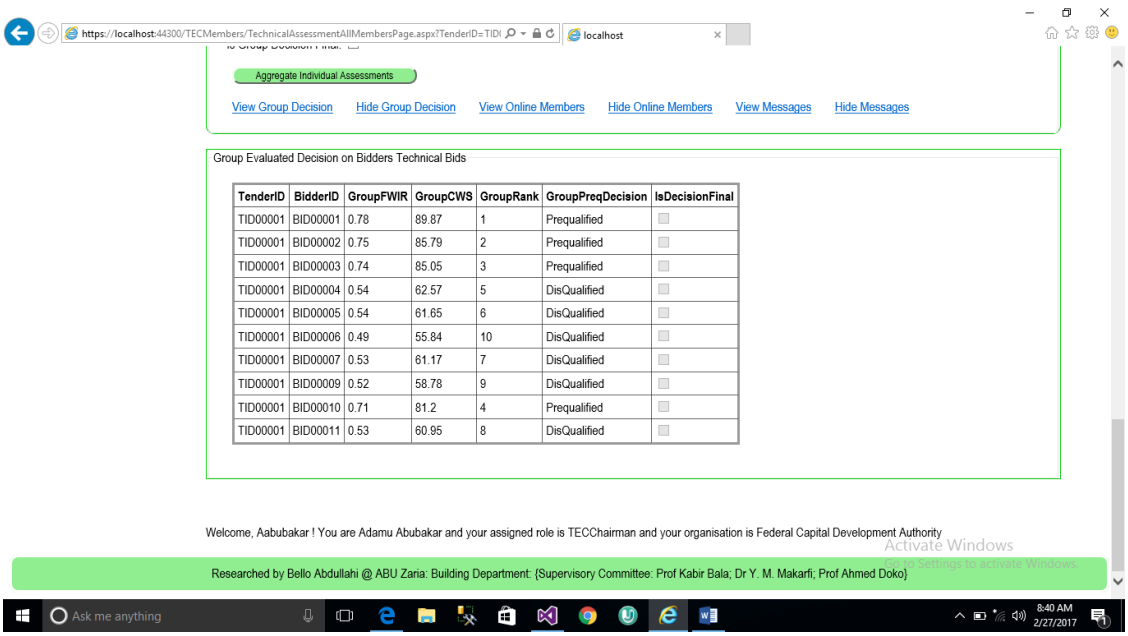

Fig. 9 Snapshot of the Final Output of the Implemented FMAGDM Model showing 'Qualified' and "Disqualified' Bidders at the end of the Technical Bid Evaluation Stage

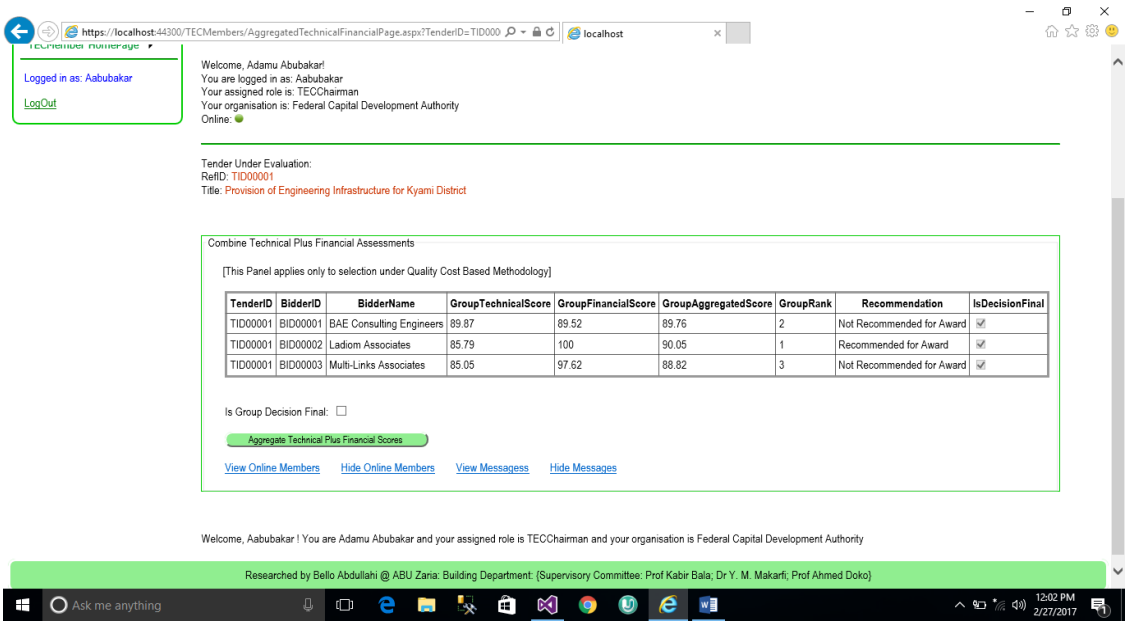

Fig. 10 Snapshot of the Final Outcome of NPS-eTender Evaluation Process

The first set of criteria used in evaluating the system are clarity, logical structure, comprehensiveness, applicability in public sector tendering, and practical relevance. Generally, it can be seen in Fig. 11 that the means for all the evaluation criteria are greater than 3.5 and the standard deviation values are quite small which means that the ratings are closely distributed around the means. In addition, the mean of means of the five criterion is 3.70 which is equivalent to a 74% average rating. And as such, it can be stated that the respondents are of the opinion that NPS-eTender has to a good extent, correctly modelled the existing manual tendering system. This can be interpreted to mean that the system could be a good replacement for the existing manual tendering system.

The second set of criteria was used to measure NPS-eTender usefulness. As stated by [19], a model's validity should also be measured based on its usefulness.

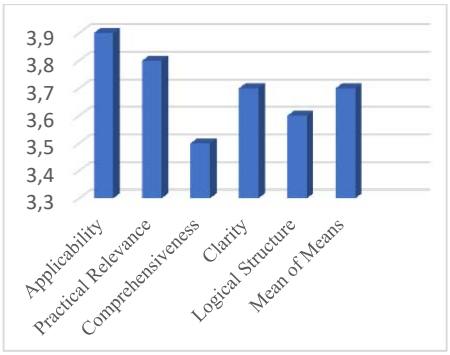

Fig. 11 Means of NPS-eTender Performance Evaluation

With respect to NPS-eTender, the usefulness can be expressed in terms of its ability to improve the proficiency of public sector tendering in particular and procurement in general. Overall, as presented in Fig. 12, the mean of means is 3.38 which is equivalent to an average rating of 68% and this can be interpreted to mean respondents are of the opinion that NPS-eTender can to a good extent help improves the proficiency of the public sector tendering in Nigeria.

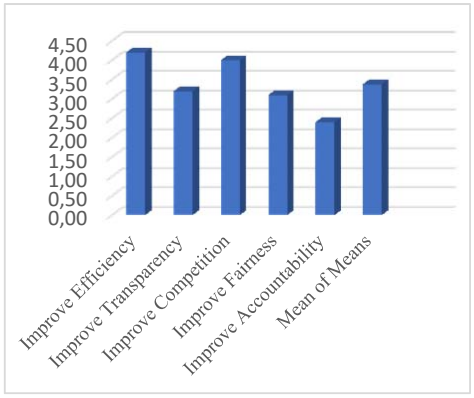

Fig. 12 NPS-eTender Potential to Enhance Proficiency of Public Sector Tendering

IX. Conclusion

In this paper, the design, implementation and application of a technical bid evaluation model using fuzzy multi-attributes group decision making (FMAGDM) technique was presented. The system was validated by professionals with extensive experience in Nigerian public sector tendering. The results of validation suggested that the evaluation module along with other components of the system have a good potential to enhance the proficiency of the existing manual paper-based tendering system employed by the Nigerian public procuring

entities.

REFERENCES

[1] Ng, L. L. N., Chin, D. K. W. and Hung, P. C. K. (2007). Tendering process model (TPM) implementation for B2b integration in a web services environment. Proceedings of the 4th Annual Hawaii International Conference on System Sciences. IEEE Computer Science.

[2] Betts M., Black, P., Christenden, S., Dawson, E., Du, R., Duncan, W., Foo, E., Nieto, G. J. (2006). Towards secure and legal tendering. Itcon Vol II, pg. 89.

[3] Expert Group Meeting Report (EGMR, 2011). E-procurement: Towards transparency and efficiency in public service delivery. Department of Economic and Social Affairs, Division for Public Administration and Development Management, United Nation Headquarters, New York. 4-5 Oct. 2011. ST/ESA/PAD/SER.E/171.

[4] Mohemad, R., Hamdan, A., Othman, Z. A. and Noor, N. M. M. (2010). Decision support system (DSS) in construction tendering processes. International Journal of Computer Science, vol 7, iss. 2, No 1.

[5] Singh, D and Tiong, R. L. K (2004). A fuzzy decision framework for contractor selection. Journal of Construction Engineering Management, 131, 62.

[6] Wang, T., and Lin, Y (2005). Application of fuzzy group decision making method on contractor selection for information system outsourcing. Available at http://www.iceb.nccu.edu.tw/proceedings/APDSI.../DSS--14.pdf.

[7] Zadeh, L. A. (1965). Fuzzy sets. Information and Control, 8, 338-353.

[8] Fong, S. and Yan, Z. (2009). Design of a web-based tendering system for e-government procurement. ICEGOV2009, Nov. 10-13, 2009, Bogota, Colombia. ACM 978-1-60558-663-2/09/11.

[9] Padumadasa, E. U. and Rehan, S. (2009). Investigation into decision support system and multiple criteria decision making to develop a web-based tender management system. Proceedings of the International Symposium on the Analytical Hierarchy Process.

[10] Noor, N. M. M. and Man, M. (2010). iWDSS – Tender: Intelligent web-based decision support system for tender evaluation. Decision Support System, advances in, Book edited by: Gerdevlin, pp342.

[11] Noor, N. M. M. and Mohemad, R. (2010). Decision support for web-based prequalification tender management system in construction projects. Decision Support System, Book edited by: Chiang S. Jao, pp. 406.

[12] Procurement Procedures Manual for Public Procurement in Nigeria (2008). Bureau of Public Procurement, Federal Republic of Nigeria.

[13] Mangitung, D. M. (2010). Typical contractor prequalification characteristics of public procurement practices in Indonesia. Construction Building Research Conference (COBRA). Published by The Royal Institution of Chartered Surveyors.

[14] Hatush, Z. (1996). Contractor selection using multi attribute utility theory. A Phd thesis, University of Salford, UK.

[15] Jang, J. S. R. and Gulley, N. (1997). Matlab fuzzy logic toolbox: Users guide. The Mathworks, Inc. Natick.

[16] Hines, J. W. (1997). Fuzzy and neural approaches in engineering matlab supplement. John Wiley and Sons, New York.

[17] Larman C. (2011). Applying UML and Patterns: An Introduction to Object-Oriented Analysis and Design and Iterative Development. 3rd Edition, Pearson, New Delhi, India.

[18] O'Docherty, M. (2005). Object oriented analysis and design: Understanding system development with UML 2.0. Wiley.

[19] Martins, M.S (2006). Validation of simulation based models: A theoretical outlook. The electronic Journal of Business Research Methods, 4(1), 39-46.

[20] Afolabi, A., Owolabi, D., Ojelabi, R., Oyeyipo, O., & Aina, D. (2017). Development of a web-based tendering protocol for procurement of construction works in tertiary institution. *Journal of Theoretical and Applied Information Technology*, 95(8), 1595-1606.

[21] Macdonald, M. (2012). Beginning ASP.NET 4.5 in C#. Apress.