UNIVERSITY OF NAIROBI

SCHOOL OF COMPUTING AND INFORMATICS

A DECISION SUPPORT SYSTEM FOR SUPPLIER SELECTION

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REGISTRATION No. P56/70352/2007

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A research project report submitted in partial fulfillment of the requirements of the Degree of Master of Science in Information Systems of the University of Nairobi.

DECLARATION

This project, as presented in this report, is my original work and has not been presented for any other award in any other University.

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Signature ________________________________ **Date_________________________**

This project has been submitted as a partial fulfillment of requirements for the Master of Science in Information Systems of the University of Nairobi with my approval as the University supervisor.

Supervisor: MR. CHRISTOPHER A. MOTURI

Signature ________________________________ **Date_________________________**

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My gratitude is to God, you have been Jehovah-Jireh; your love remains measureless and strong

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To Annah, your memories live.

Lastly, my Mum, Jacinta you laid the foundation and I am forever grateful.

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ABSTRACT

Background

Supplier selection is the procedure of selecting the most suitable supplier to deliver the project's goal within the defined parameters of time, cost and quality. In the construction service industry, it has been realized over time that the evaluation of suppliers is a multi-criteria based process used to determine the competence of potential suppliers to perform the work if awarded, as opposed to using a single factor like lowest offered price. In Kenya, procurement in governmental organizations is regulated by the Public Procurement and Asset Disposal act, which requires the evaluation of suppliers to be done both in technical and financial basis, taking into consideration price, quality, time and service. The "quality" and "service" factors are imprecise and subjective during an evaluation process hence fuzzy in nature. The common way of evaluating suppliers is by forming technical committees which may be characterized by biases and the evaluation process itself takes time and have associated costs. Due to the advancement of e-procurement in supply chain management there is a need to automate the supplier selection process to enhance efficiency and effectiveness.

Objectives

The objectives of our study were to determine the most important criteria in supplier selection and to design, develop and assess a decision support system that can be used in supplier selection using the fuzzy set theory.

Method

This study presented an approach to help decision-makers evaluate potential suppliers by utilizing fuzzy inference system. Initially, the main quantitative and qualitative criteria used in supplier selection process in the construction service industry were identified from experts and literatures. A structured questionnaire was designed and sent to experts in the construction industry in Nairobi who scored these criteria based on the importance of their usage and their weightage was used to rank them. The most critical criteria in the evaluation process were picked for our study and subsequently Matlab Fuzzy Inference System (FIS) was utilized to develop the selection model. The applicability of the proposed model was tested using a real tender for government works and the model evaluated by the users.

Results

The most important criteria used for supplier selection in the construction service industry were established and a decision support system developed successfully. The validation of the developed model by the decision makers yielded a score of 79.75 % on testing with sample tenders. Data entry to the system took less than a minute while results were provided within seconds.

Limitation

The proposed prototype can only be accessed via Matlab® software which is not readily available in many governmental organizations and its usage requires technical skills on the software which may limit number of users. Also defining fuzzy sets and membership functions for a given system can be a subjective task. It is normally performed by a collaborative effort of users, process owners and those who possess expert knowledge in the relevant field. There are disagreements among each party when attempting to formulate the fuzzy sets, rules and membership functions and this could compromise the degree of match between system offer and actual user's need.

Conclusion

It was concluded that using the Fuzzy inference system resulted in an optimum solution and thus can support in decision making when selecting suppliers. One major advantage of the proposed method is that the supplier selection process takes a considerable shorter time and the system makes the selection process more systematic and realistic as the use of fuzzy set theory allows the decision maker to express their assessment on contractors' performance in linguistic terms rather than a crisp value.

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Abbreviations

AHP	Analytic Hierarchy Process
AI	Artificial intelligence
CAPEX	Capital Expenditure
CSR	Corporate Social Responsibility
DSS	Decision Support Systems
EPC	Engineering, Procurement, Construction
FLC	Fuzzy logic controller.
GA	Genetic Algorithm
HV	High voltage
LV	Low voltage
LAN	Local Area Network
MV	Medium voltage
OLAP	Online Analytical Processing
PF	Power Factor
TSK	Takagi-Sugeno-Kang
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
UPS	Uninterruptible Power Supply
WAN	Wide Area Network

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Supplier selection is a key pillar in effective procurement and supply chain management and can considerably determine the success of running most organizations. In the selection of a supplier, the purchaser generally creates a list of assessment rules that are used to check and contrast suppliers. A typical criteria used in supplier evaluation compose of pricing options, reliable time delivery, quality of the product, after-sales-support services this are, staff availability, facilities provided, research and higher development services, upgrade capability, etc. (Omar, 2016). Most of the time, the selection factors chosen conflict with one another, and the weight of each factor vary from one project to another. Criteria are primarily categorized as quantitative e.g. price, time or as qualitative e.g. quality, services, etc. this situation can complicate further the evaluation process of the suppliers (Garfamy, 2014).

According to several surveys conducted over the past two decades (Ahmed, et al., 2012), the percentage of using formal statistical and optimization tools in selecting suppliers is still very low level at about 10%. Among the reasons for the non-responsiveness of the industry to the adoption of these tools is that the supplier selection models might not be realistic enough and the technologies have not been commercially deployed (Amindoust, et al., 2012). Most of the mathematical models developed suggest studying historical selection data to characterize the current selection behaviors in designing the appropriate selection tools.

The challenge of suppliers' selection involves many factors with multiple attributes. The fuzzy set algorithm is among the known efficient artificial intelligence tools used to capture and resolve such problems. The fuzzy set mechanism has been recently used successfully to capture the uncertainty of evaluation processes and selecting suppliers in various industries. In this study, a supplier selection process for a construction service industry is generated using an expert system based on fuzzy logic theory.

1.2 Problem Definition

Although the Kenyan government has concentrated efforts in reforming procurement processes in its organizations, there is still problems contributing to huge losses due to improper procurement to the tune of Kenyan shillings 30 billion and public procurement therefore requires a tight or water-proof system to be followed and adopted (EACC, 2015). One of the areas that require enhancing transparency is in supplier selection. Currently, the selection of the right supplier is done by a team consisting of technical and commercial experts which might be characterized by undue influence and bias. It has also been observed that significant time and effort is also used in selecting the suppliers, this process needs to be improved to be more efficient and effective. The goal is determining a qualified supplier with reduced costs as a key element in increasing competitiveness in the market which is naturally desirable.

1.3 Project Objectives

Our key goal for this study was to design, develop and test a decision support systems (DSS) prototype for the selection of suppliers.

Specific Objectives are:

1) To determine the criteria used for supplier selection in construction services.

2) To design and develop a decision support system for selecting suppliers.

3) To test the suitability of the DSS in suppliers' selection.

1.4 Research Questions

The following research questions were used to meet the above objectives;

i. What are the criteria used in selecting suppliers for construction services?

ii. Which AI tools are appropriate for developing a DSS for supplier selection?

iii. How can a DSS for supplier selection be developed using AI tools?

iv. How can the performance of a supplier' selection DSS be measured?

1.5 Scope

The study is limited to development of a decision support system in suppliers' selection used in the construction industry that primarily deal in building services in limited Kenya government organizations. The system was based on suppliers' selection criteria that are fuzzy in nature for the services sourced by the organizations.

1.6 Justification

The existing methods of selecting supplier(s) largely take considerable amount of time, associated manpower costs and disputes thereof. We believe that one way to minimize this cost is to apply an automated decision support system by making use of domain expertise of current evaluators and also historical data of existing suppliers for the organizations in developing the system. This may reduce the wastage in the supply chain and contribute towards business process improvement in governmental organization.

1.7 Research Assumptions

It was assumed that the technology adoption and usage behavior of the DSS reflects the general pattern across the building services engineering in Kenya's governmental organizations.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of Supplier Selection

The decision of supplier-selection is remarkably compound and procurer's utmost challenging responsibility. Firstly, such a task comprises many selection criteria when picking amongst presented suppliers. Secondly, criteria considered during the supplier selection process might contravene each other frequently e.g. low price against a good quality. Thirdly, difficulty encompassing the decision of supplier selection could emanate within internal governance policy constraints of the sourcing organization and constraints imposed externally on the procuring process. Fourth, due to changes in market conditions and organizational requirements, the status of the scrutiny of tradeoffs amongst the criteria selection may be amplified (Weber, et al., 2010). Garfamy (2014) categorizes the key selection criteria as cost, quality, time, service, affiliation and grouping where each criterion is a collection of dissimilar factors. For instance, cost comprise of buying price, transportation, catalog, management, levies, handling and storage, operative costs, after-sales-service costs etc. Kumara, et al (2005) articulated the problem of supplier selection as a Multi-faceted fuzzy issue combining three vital aims: cost-reduction, quality-intensification plus reduction of delivery period with the genuine objectives e.g. satisfying the purchasers' request, required volumes, vendors' ration requirements, etc. In their anticipated prototype, numerous input bounds were taken as imprecise data collection having a linear membership function of fuzzy type with same constraints pointed here earlier. However, every establishment picks its own unique criteria with a distinctive tactic for vendor selection. We hereby discuss some applicable collective approaches that are employed.

2.2 Supplier Selection in Government Organizations

The Kenyan government used to do most of the infrastructure construction until 1990s when the era of liberalization and reduced donor inflows changed the trend. The economy took a downward trend and donors demanded for more stringent control of funds and prudent use of resources. This forced the government to do away with construction departments in government and instead outsourced the construction works (Mbau, 2018). The government depends on various suppliers in construction service industry where the current approach in supplier selection is the common and traditional way of using the technical and financial evaluation approaches. Depending on the technical or quality appraisal, the technical scoring will first be accomplished. In this evaluation step, the supplier's capacity for executing the projects are assessed based on factors such as work experience on effort required, supervision staff, technical staff, industrial abilities, monetary capabilities, similar projects testimonials, inventiveness and innovation, etc. The supplier selection team appraisals the technical score of each supplier considering above criteria. Suppliers earning higher technical marks more than a pre-determined threshold will be ratified technically and then their financial proposals are evaluated. Here, all prices will be compared on one-to-one basis. One way of comparing the quoted prices is that the presented price is divided by the score at technical stage. Another style is by calculating a ratio for technical and financial gain, e.g. 30 % for financial consideration and 70 % for technical consideration. Observably, the ratio can differ subject to the settings of each project. The approaches mentioned above are also prevalent ways used in the government corporations (Omar, 2016).

Thus, making the decision of the right supplier is intricate and takes time and needs a team of technical and commercial experts for intermediary. Decisions building in these teams are established on linguistic measures e.g. the quality of a proposal can "good" while another is "very good". In that situation, linguistic terms are applied in performance evaluation of qualitative metrics from vague and imprecise information. Fuzzy is a suitable modeling technique to deal with imperceptible and qualitative events which uses fuzzy set theory and linguistic values, it has been applied extensively in several areas of Supply Chain Management (Ezutah & Kuan, 2010).

2.3 Criteria Formulation in Suppliers' Selection

Deciding on the suitable supplier is a demanding duty in public procurement and is met by challenges enacted by a range of surrounding factors (external factors) such as market forces, legislation, politics of the day, organizational and socio-economic factors (Musanzikwa, 2013). Though in certain circumstances a single criterion is considered for final decision, multiple criteria consideration during selection will be necessary in several cases. Various researchers have analyzed supplier selection criteria and analysed supplier delivery since

1960s. Here we consider three comprehensive reviews, Weber et al. (1991), Cheraghi et al. (2004) and Ho et al. (2010) on supplier selection criteria.

Ho et al., (2010) published a wide-ranging literature assessment built on 78 research courses on the multiple criteria decision making styles for supplier evaluation and selection models for a period of about ten years. The aim of their publication was to isolate the mostly used criteria by the decision makers while assessing and selecting the best supplier, the summarized result is shown in *table 1* below.

Amongst the many criteria they looked at, *Table 1* below point that the 'quality', 'delivery' and 'price/cost' were the greatest prevalent criteria, they were scored at 88%, 82% and 80% on the research papers. The study showed the significant comparison with earlier studies done by Cheraghi et al., (2004) and Weber et al., (1991) for the critical success criteria used by organizations in selecting suppliers. We have adapted the first three criteria for our study because they are the most popular as per the study. Also based on our observation the three criteria are the most considered factors in the construction company under our study.

Table 1: Suppliers selection criteria, Ho et al., (2010)

Criteria	**Percentage (%)**
Quality	88
Delivery	82
Price/Cost	80
Manufacturing Capability	50
Service	45
Management	33
Technology	33
Research and Development	31
Finance	29
Flexibility	24
Reputation	20
Relationship	4
Risk	4
Safety and Environment	4

The Public Procurement Authority of Kenya (PPOA) defines the requirements to be used in respect to supplier selection as;

(a) The criteria to be objective and quantifiable as much as possible,

(b) The criterion expressed and applied in the selection procedures, should consider price, time, quality and service during evaluation (PPOA, 2015).

A large number of methods using quality, quantity, price, and delivery schedule and service factor has been developed for the purpose of rating the supplier. The weightages vary from item to item depending upon cost criticality, availability of the item and market conditions of demand of supply. Several supplier selection methods are available as follows.

Weighted Point Plan method; here points are allocated for the factors e.g. quality, delivery and price. The number of factors and points can be altered to suit individual products. An addition of weighted average of the performance parameters is known as weighted point plan.

Categorical Method depends primarily on the experience and judgment of the buyer and hence this is more subjective. The buyer makes out a list of all relevant parameters and annual performance of the potential supplier and uses it for selection (Asemi et al, 2014).

Cost Ratio method system involves computing the actual cost incurred in procurement, cashing transportation, packaging etc. costs relating to quality may include factory visit, approval of samples inspection. The selection is based on the cost ratio of the supplier (Bellman, 2010).

Key Questions Approach involves using many questions, what, where, how, why, when, what for and who are asked about the item in this method. When these questions are answered, subsidiary question arise. This question should include issues on management, labour etc. (Bhutta, 2011).

In our context, most government organizations comply by using Weighted Point Plan, a supplier rating index is allocated for parameters to assess the suppliers' ability.

2.4 Fuzzy Expert System

Expert systems are computing solutions proficient of demonstrating and cognitive about a certain knowledge sphere with a goal to unraveling complications and providing intelligence. Decision support system based on Fuzzy is an expert system that applies logic of fuzzy as opposed to use of Boolean logic. Fuzzy is applied in circumstances where the variables are linguistic in nature and there exists a degree of vagueness in the problem.

It offers a platform for treatment of the uncertainties and was created by Zadeh (Mehrdad &Abbas, 2011). Fuzzy logic consists of mathematical ideologies for knowledge illustration founded on degrees of membership and is logic with many values; its reasoning is dealt as an approximate rather than cast stone and exact. In comparison to usual binary sets (true or false values), variables on fuzzy logic have a range of truth value degree say e.g between 0 and 1(Deepak et al., 2011). A Fuzzy Logic System is made up of four core components: fuzzifier, determining rules, engine for inferencing and a defuzzifier. The universal architecture below shows a Fuzzy Logic System with its components in Figure 1 below.

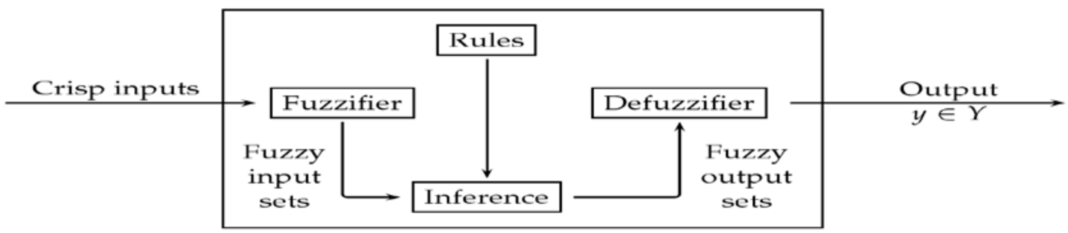

Figure 1: Fuzzy logic system, Chai et al, 2015

The process of fuzzy logic consists of finding a crisp set of input data that are collected and transformed into a fuzzy set by the fuzzy linguistic variables, linguistic fuzzy terms and membership functions, this is the fuzzication step. Based on a set of rules an inference is made and the resultant fuzzy yield is mapped to a crisp output by the membership functions, during the defuzzication stage (Tsoukalas et al, 2003).

2.4.1 Fuzzification

In fuzzy systems, variables of linguistic nature can be the input or output parameters of the system where values are natural language words or expressions as opposed to numerical values. Fuzzification practices the theories of fuzzy set and specifically fuzzy set operations. The fuzzification lump is used to change the crisp values attained from the inputs into ranks of membership for linguistic relations of fuzzy sets (Zadeh, 1965). For instance, the fuzzification of a four feet woman in height might fit into two sets of fuzzy “average” and “tall”. The membership functions μA and μB are the symbols used to portray the two fuzzy sets “average” and “tall” respectively. The woman‘s height, 5.5 feet, goes with a rank of 0.70 on the fuzzy set “average” and a rank of 0.30 to the fuzzy set “tall”. In the fuzzification step we transform the input rate (5.5 feet) into the score of membership (0.70 for “average” and 0.30 for “tall”).

2.4.2 Fuzzy Rules

Rules compare ideas and contrast one event to another one based on if-then statements in computing. In Fuzzy instruments, we use the fuzzy sets and the rules for verdict and as the way of selecting decision and are traded with fuzzy rules which maneuver using sets of if-then statements. For example, if C then X, if D then Y, where C and D are all sets of X and Y i.e. IF variable IS set THEN action. The count of rules generated is given by count of linguistic variables used. Boolean logic operators AND, OR, and NOT are used in fuzzy logic, typically demarcated as the minima, maxima, and complement ("Fuzzy Logic Fundamentals", 2014).

2.4.3 Rule Base Reduction Methods

Rule count lessening is an essential issue in fuzzy system creation, particularly for actual time Fuzzy Logic Control (FLC) plan. The count of rules in a complex fuzzy control system can grow exponentially depending with the count of input variables. For that reason, reducing the rules is a very vital concern in such designs. Several ways of reducing the number of rules have been discovered.

i) Fuzzy clustering is thought as one of the central techniques using numerical examples for creation of fuzzy rules. The algorithm plots data plugs into a set of number clusters (Klawonn, 2003). In the fuzzy system the number of rules depends on the number of cluster centers. Controlling the number of cluster centers aids controlling the count of rules. However, a challenge with control applications is often that there is no enough data to mine a whole rule base for the controller (Klawonn, 2003).

ii) We can use the Sliding Mode Control and Fuzzy Logic Control to decrease the ranting by Sliding Mode Control and enrich vigor in the Fuzzy Logic Control. These amalgamation yields rules size reduction. However, this tactic is disadvantageous since the constraints for the switch utility need to be nominated by an expert or planned over conventional control theory (Manoj et al, 2015).

iii) The minimization way of membership functions are not combined but are changed by a new membership function with minimum and maximum values of the first and the last membership function, the departing point of the two is the peak of the created membership function. This technique is appropriate if the data available is not enough to train the model (Matthews, 2013).

iv) Ledeneva, (2006) proposed a fuzzy control structure in hierarchy where the first-level rules are those connected to the most central variables and are collected to form the first-level of hierarchy. The next second most variables, with the outputs of the first-level, are then selected as inputs to the second level hierarchy. The set of rules are built in a hierarchical manner; the input variables of the fuzzy controller are distributed according to various levels of reasoning and are not treated in parallel anymore. The control difficult is thus resolved serially. First level of hierarchy has the rules associated to key variables and assembled to form the hierarchy. The following key variables, alongside the output of first level are then treated as inputs to the second level of hierarchy and so on (Metaxiotis et al, 2012).

2.4.4 Membership Functions

Membership functions are applied during the fuzzication and defuzzication stages of a Fuzzy Logic System, to convert the input values that are not fuzzy to be in fuzzy linguistic terms and vice versa. Membership function is used to quantify a linguistic term. There are various shapes of membership functions formed using straight lines as discussed below.

2.4.4.1 Triangular Membership Functions

Figure 2.9 depicts membership function of triangular nature. Coordinates a, b and c represent the three vertices x of the fuzzy set A i.e. $\mu A(x)$. The lower boundary of set A with degree of membership zero is expressed by coordinate a, coordinate c is the upper boundary with degree membership of zero. Lastly, coordinate b with degree of membership of one is the third apex of the triangle. The triangular membership functions is well thought to be ample for netting the vagueness of these linguistic valuations (Mehrdad and Abbas, 2011).

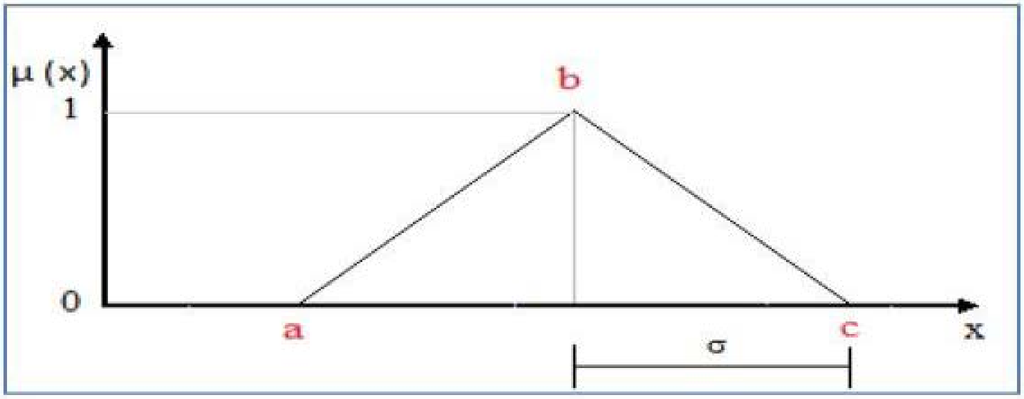

Figure 2: Triangular Membership Function, Chai et al, 2015

Equation (1) below symbolizes the scientific equation used to compute the degree of membership for component x in a set of fuzzy A:

$$f(x,a,b,c) = \begin{cases} 0, & x \leq a \\ (x-a)/(b-a), & a \leq x \leq b \\ (c-x)/(c-b), & b \leq x \leq c \\ 0, c \leq x & \end{cases}$$

2.4.4.2 Gaussian Membership Function

Gaussian membership function is represented in formula 2 below

$$\mu(x)=[x-b/\sigma)^2] \quad (2)$$

x being the input variable, b the membership function Centre while σ is the constant for the width of the membership function. Gaussian fuzzy membership utilities are among the mostly used in fuzzy logic systems (Foundations of fuzzy logic, 2014). Figure below depicts a characteristic Gaussian membership function.

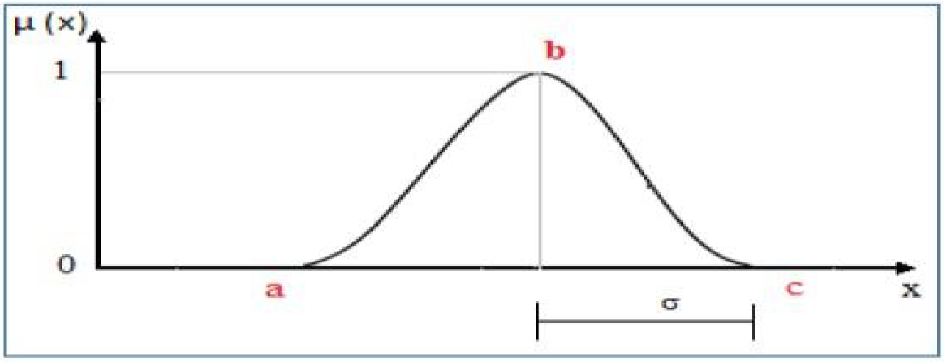

Figure 3: Gaussian Membership Function, Chai et al, 2015

2.4.4.3 Trapezoidal Membership Functions

Equation (3) below shows a membership functions for trapezoidal with four parameters {a, b, c, d} as shown in:

$$trapezoidal(x;a,b,c,d) = \max\left(\min\left(\frac{x-a}{b-a},1,\frac{d-x}{d-c}\right),0\right) \quad ..(3)$$

The four corners of the typical trapezoidal Membership function is determined by coordinates {a, b, c, d} in x axis such that $a < b <= c < d$.

Because of their modest formulas and easy computational, triangular Membership Functions and trapezoidal Membership Functions have been applied extensively in real-time scenarios. However, they are not even at the curve points identified by the parameters (Mehrdad & Abbas, 2011).

2.4.5 Defuzzication

On inferencing, a fuzzy value will be the typical result. This result needs to be defuzzied to achieve a crisp output. The work of the defuzzier component of a Fuzzy Logic System is to do that. Defuzzication is accomplished depending on the membership function of the output variable (Fuzzy Logic Fundamentals, 2011). There are several defuzzication methods existing for this setup, some are discussed below.

2.4.5.1 Centre of Gravity (CoG) Method / Weighted Average Method

This is the methodology for calculating a crisp value (μ) from the central-point of the output fuzzy set by a rated average of the membership grades. With an existing a fuzzy set μ (xi) having a discrete universe, and the membership value being in the membership function. We can represent the rated average of the elements in the support set as below (Foundations of Fuzzy Logic, 2014).

$$Z* = \Sigma \mu c\ (\overline{\overline{\overline{Z}}})\cdot \overline{Z} / \Sigma \mu c(\overline{Z})$$

2.4.5.2 Mean of Maximum (MoM) Method

The Mean of Maximum method is used to discover the medium z where the membership of the fuzzy set is at a maximum. Could be the maximum points occur severally and as such the common training is to take the mean of all maximum values. The calculation complexity is simplified in this method by ignoring the shape of the fuzzy set completely; this yields somewhat good results (Fuzzy Logic Fundamentals, 2011). For a particular setting there occurs a fuzzy set A in a Z universe. The extension opinion says that if there exist a function f, then the fuzzy set B is specified by equation :

$$B = f(A) = \Sigma \mu A(xi)/f(xi)$$

2.5 Conceptual Model

Mostly used fuzzy structures are; fuzzy pure systems, Takagi-Sugeno-Kang (TSK) and combined fuzzy system having the fuzzifying and defuzzifying parts (Li-Xin Wang, 2011). We used the combined fuzzy system in the model we developed because our inputs and outputs are real numbers. This system comprises a fuzzifier part in the inputs for changing intrinsic numbers to fuzzy sets and a defuzzifier part in the output that does the vice versa. Figure 4 below shows architecture of the system developed composing three main blocks. Fuzzy logic systems and expert systems are used in handling complex and difficult tasks, however, fuzzy logic`s ability to handle ambiguity gives it advantage over the expert systems. To effectively handle ambiguities, linguistic rules are used to emulate human operation and assist make decisions. The ability to make decisions in fuzzy logic is time saving and minimizes need for human engagement (Vadiee, 2015).

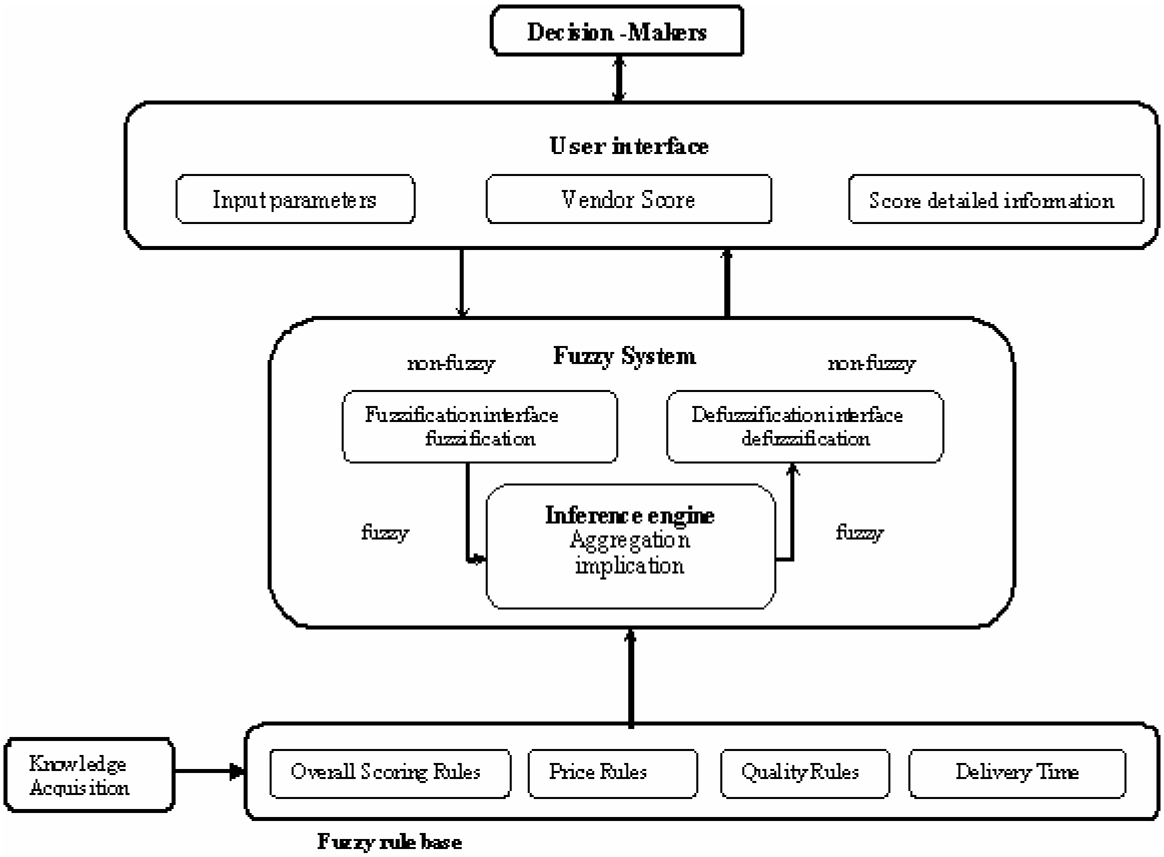

Fig 4: Adopted Architecture for Fuzzy Expert Decision Support System for Supplier Selection, Li-Xin, 2011.

The description of the various elements in the above architecture to be adopted in our study is;

A-Fuzzy inference engine: This is the package that scrutinizes the rules and data accumulated in the database and generates the logical output. We can have different selection from the fuzzy inference depending on the aggregation, implication and operators used for s-norm and t-norms engine (Li-Xin Wang, 2011)

B- User Interface: This is the module that assists the users to interact with the system during data entry and also for viewing the results once generated by the system.

C-Fuzzy rule base: These are qualified statements represented as "IF x is Xi and y is Yi and … THEN o is Oi" Where x and y are linguistic input variables used to determine the inputs interactions and developed from subject matter experts inputs. Xi and Yi are likely linguistic values for x and y respectively.

2.6 Use of Fuzzy in Supplier Selection

An assessment of existing literature on the various techniques employed in the supplier selection in a procurement/ supply chain management has been done and is briefly discussed below.

Cemalettin et al (2010) integrated Analytic Hierarchy Process (AHP) and Genetic Algorithm (GA) to decide the best suppliers. Fuzzy set was exploited in linguistic feature to shape criteria and sub criteria weights, pair wise contrast with fuzzy AHP was exploited to arrange the factors and their achieved weightings for linked factors. Lastly, a supposed supplier selection difficult was resolved using GA algorithm.

Yadav and Sharma (2015) suggested a fuzzy protracted analytical hierarchy method approach to decide the best supplier for an Indian automobile company using the triangular fuzzy numbers. A different way to fashion the fuzzy expert DSS, was used to support companies by enabling supplier selection, the fuzzy expert decision support system was established for deciphering the supplier selection difficultly with numerous purposes, where some of the factors were fuzzy in nature.

P.Priya1 et al (2013) developed a Decision Support System (DSS) to empower the supplier selection in an e-procurement course. The model was based on the Online Analytical Processing (OLAP) and Analytic Hierarchy Process (AHP) systems to sift and select the best suppliers using a web; this was achieved using ASP and SQL server.

Plebankiewicz and Kubek (2016) pronounced the criteria engaged in the evaluation process for building material suppliers and used the fuzzy AHP method to choose the right supplier in this industry. First, they deliberated on the broad application of AHP in real-world situations in combination with sensitivity scrutiny to decide the best supplier. They suggested an AHP model to select the right supplier for a construction company and also ranked the order quantities.

Karimi-Nasab and Bahrololum (2015) designed a group decision-making method for supplier selection built on fuzzy TOPSIS. They established and framed a fuzzy multi-objective integer software design for vendor selection process that included the three vital goals: cost reduction, quality increase and strictness on delivery time considering all possible constraints.

Li and Wu (2015) suggested an amended TOPSIS technique for green supplier selection with intuitionistic fuzzy sets. In order to minimize the cost, reduce rejection rate, increase delivery rate and maximize the flexibility rate, a multi-objective stochastic vendor selection model was proposed based on a typical non-linear mixed integer combinatorial optimization.

When selecting a supplier, the company takes into deliberation a huge number of criteria that are to be considered. More often than not, some criteria are subjective and challenging to measure. Considering them all in the evaluation process may be beneficial and yet in practice it may lead to generation of many complications. We intend to provide a solution by using one of the multi-criteria analysis methods using fuzzy logic as a useful alternative. Supplier selection is a real decisive problem which requires approaches close to human reasoning, described by uncertainty and partiality of evaluation. Building on the previous works done as discussed above, we intend to present fuzzy logic as a practical application to supplier selection in our study since the process can be characterized as a fuzzy set.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Research Philosophy

Philosophy in research deals with the spring, environment and development of knowledge base they are engaged in during a given research assignment (Bajpai, 2011). In essence, secondary and primary data are collected and analyzed to respond to the research questions and thus contributing to new knowledge base. Whileas there are various research philosophies, namely Pragmatism, Positivism, Realism and Interpretivism, we have chosen to use the positivism philosophy where it is restricted to data gathering and analysis through objective style and the research outcomes are usually evident and computable.

3.2 Research Design

There are two fundamental research approaches: qualitative and quantitative approaches. Advancement in research methodologies recently recommend that the two approaches be assimilated in broad research designs to improve research thoroughness and report several of the epistemological and methodological criticisms (Kelle, 2006; Olsen, 2004). This study applied both qualitative and quantitative approaches to satisfactorily answer the research questions.

3.3 Data Collection

Data collection for this project was carried out primarily in Nairobi County, Kenya at 4 consulting and project management organizations dealing in construction service industry. The focus was on the tenders for government and its associated organizations. The data was collected using primary data collection tools which were:-

1) Direct interview with technical and procurement teams. These are the main teams that form the committees when selecting a supplier and are custodian of current parameters used for selection of suppliers.

2) Documents review (tender documents, procurement manuals, contract documents and policy documents). These are the primary documents that provide information on the existing criteria used in selecting suppliers and their scoring methodologies.

3) General observation by participating in supplier selection committee meetings.

3.4 Data Processing and Classification – Fuzzy Method

For fuzzy DSS expert system, it takes in subjective, moderately true actualities randomly disseminated in a given sample universe, and construct a knowledge-based skilled system for generating suitable decisions (Vadiee N, 2015). The procedure established for the creation of our model fuzzy system in the construction service industry is as below.

Algorithm for realization of fuzzy system used for the supplier selection

Step 1: Definition

> Identify and analyze the problem

Step 2: Identification of critical factors in supplier selection

> Acquire technical information from several specialists

> Mine data on supplier selection criteria for government organizations

> Obtain information in literature (tenders, procurement manuals, policy documents)

Step 3: Fuzzification stage

> Outline entry membership functions for inputs and their corresponding fuzzy rules

Step 4: Rules base

> Outline fuzzy rules for all possibilities

Step 5: Inference Stage

> Recording interpretations to fuzzy sets

> Appraise each case for possible fuzzy rules

> Associate the data from the fuzzy rules defined

Step 6: Defuzzification stage

> Outline membership functions and sets of the output

> Outline the defuzzification function

Step 7: Results verification

> Enquire if the results are adequate?

If answer = "No"

> Go to Step 2

If answer = "Yes"

Conclude

The description of the Fuzzy Method to help in the selection of a supplier and its stages of (Fuzzification, Rules creation, Inference and Defuzzification) are discussed below and the system implemented.

3.4.1 Step 1: Definition

During numerous bids and tenders evaluation in diverse Kenyan government organizations, there exists a challenge in applying all the criteria as required by the PPOA act. In some establishments the frontrunner is selected by using the price factor while other significant factors such as 'quality', 'service' and 'time' are not deliberated. In most government projects there is a three–prone approach to the evaluation of the tenders, namely:

i. Determination of Responsiveness

ii. Technical evaluation

iii. Financial Evaluation

3.4.1.1 Determination of Responsiveness

Here, the evaluation involves preliminary examination of the mandatory conditions set out in the advertisement and/or in the tender document sometimes done sometimes in the prequalification stage. The conditions include the suppliers to provide the relevant documents e.g.

-Valid Registration Certificates and licenses with relevant government authorities and statutory bodies' e.g. National Construction Authority (NCA), Energy Regulatory Commission (ERC), Tax Compliance Certificate (TCC) etc.

- The submitted proposals are in the format required by the procuring entity and Statement of Compliance attached;

- Provision of a dully completed and signed Tender Security Declaration Form, fair employment laws and practices.

- Declaration that the firm is not insolvent, in receivership or bankrupt etc.

The technical and financial evaluation ratio is then calculated once suppliers pass the preliminary examination, for example the score ratio is allocated 30% for financials and 70% on technical score. Understandably, the ratios differ depending on the circumstances of each and every project. For financial evaluation , either the cheapest technically viable solution is picked or else a formula like one given below is used to allocate the points for the suppliers depending on their financial proposal e.g. The financial score (Fs) is calculated by likening tender sums from all responsive bidders using the equation below. The financial score will be allocated a maximum of 30%. $Fs = 30 \times Pm/T$. Fs is the awarded financial score, Pm the least responsive price and T the price of current tenderer being evaluated.

The technical score is determined using for example the weighted point plan discussed earlier. Here several factors are allocated scores and each supplier is scored based on their presentation and offer. The factors considered in this stage are imprecise and offer challenges in quantifying them during the technical evaluation, this is the area we will apply fuzzy logic in assisting the decision making.

3.4.2 Step 2: Critical Factors Identification

Determination of crucial factors and their Membership Functions consisted of compiling of a list of acute factors created by a literature assessment and profound interviews with subject matter experts involved in the obtaining, evaluation and selection of suppliers. In the literature review discussed earlier, there were critical factors for vendor selection which were considered by organizations and are obligatory as per the PPOA act. They are price, quality, service and delivery time (PPOA, 2015). Any factor that is precise and can be calculated using a given mathematical formula is not necessary fuzzy and can be determined using Boolean logic (Dwarika, 2014). From the above list of four main factors advised by PPOA act, the price and time proposed by a potential supplier can be easily be determined and differentiated for different suppliers. We can allocate scores on price and time for each supplier using a formula as shown earlier hence the two factors are not considered fuzzy in nature. In our study we will consider “service” and “quality” as advised by PPOA act as the factors that are imprecise and hence fuzzy in nature.

3.4.3 Step 4: Fuzzification

Fuzzification is the procedure of taking a real input number and converting them into the fuzzy degree necessary by the fuzzy definition (Ngai, 2013). The values “fuzzified” are found by transecting the inputs to the fuzzy membership function. In our , triangular membership functions were used to outline the fuzzy sets for the input linguistic values of “Experience”, ‘Facilities”, “After-sales-services”, “quality” and “delivery”. They took “low”, “medium” and “high” as the linguistic terms for each factor. All input values are regularized; the inputs were values between 0 and 1.

3.4.4 Step 3: Fuzzy Rules Construction

DSS expert based on fuzzy makes decisions and produce output values based on knowledge learned by the creator taking the form of IF _condition_ THEN _action_ rules. The rules created stipulates how the output parameter “rating” of the Supplier is generated for several occurrences of the input parameters of “Experience”, “Facilities”, “Quality”, “After sales services” and “Delivery”. 142 rules were created based on our interviews.

3.4.5 Step 5: Generation of Fuzzy Inference

Fuzzy inference is steered by fuzzy rules defined. The regular max–min inference algorithm is a frequently used fuzzy inference scheme (Ngai, 2013). Mamdani inference was used as shown in formula 1 below:

$$\mu_B = \overset{M}{\underset{i=1}{Max}} \left[\underset{x \in U}{Sup} \min \left[\mu_A(x), \mu_A(x_1), \ldots \mu_A(x_n), \mu_B(y) \right] \right]$$

For the max–min fuzzy inference method, the min operator is used for the AND combination (set juncture) and the max operator is used for the OR disjuncture (set merger) to appraise the rank of membership of the precursor part in each rule.

3.4.6 Step 6: Defuzzification

Once the inferencing process is finished, the ensuing data for every output of the fuzzy system is a group of fuzzy sets either as a single or a collective fuzzy set. The procedure of calculating a single number that best epitomizes the result of the fuzzy set assessment is called defuzzification (Ngai, 2013). There are numerous prevailing techniques that are used for defuzzification, including maximum method and the method of average heights among others. These methods however incline to hedge unsteadily on non-monotonic and wide non-contiguous input values (Diego, 1999). We picked the centroid method, sometimes called the “center-of-gravity (COG)” method. It is regularly applied it offers a reliable and well-balanced approach (Klir et al, 2014).

3.4.7 Step 7: Verification

The overall score for the suppliers are attained by passing the determined inputs and their weights through the developed model. The ultimate score for each supplier is calculated in defuzzification process. The system gives the score based on linguistic value of “under_consider”, “reject” and “accept”.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. Identifying the Most Effective Criteria for Supplier Selection

By reviewing tender documents, procurement manuals and Kenya's public procurement and disposal act 2015, we realized that there are many factors that could influence the selection process of the appropriate supplier in construction service industry. Those factors vary in their importance and strength in the selection procedure depending on the organization's procurement policies. The final 32-criteria list that was identified to affect the Supplier selection is shown. These criteria are categorized in seven major groups as shown in figure 5 below. This is as a result after 12 subject matter experts in the construction service industry for Kenyan governmental organizations checked via semi-structured interviews that were conducted.

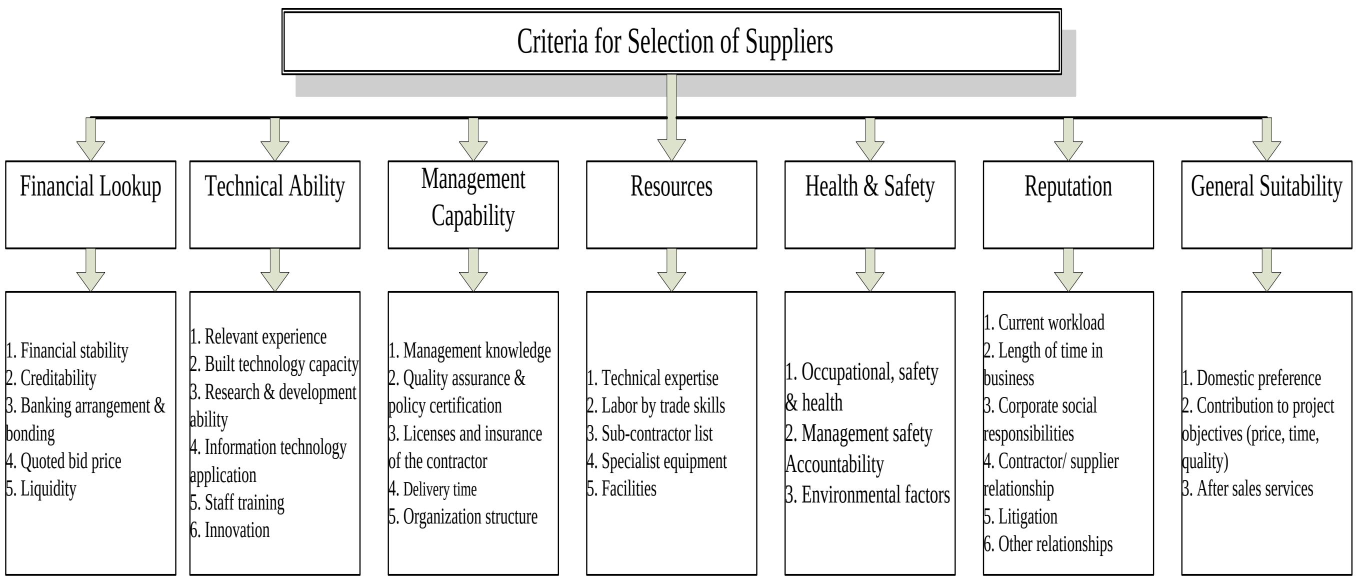

Fig 5: Supplier selection criteria results

After this initial screening, an attempt was made to shorten the 32-criteria list to determine the mostly used criteria. In order to determine the relative score and importance index of each criterion, a questionnaire survey was designed and administered among the stakeholders and professionals engaged in tender evaluation and supplier selection, employed by consulting firms and government within the construction industry. When answering the questionnaires, respondents were requested to score the level of importance on the given list of criteria that is used in the selection of suppliers in Nairobi area. The 5-point Likert scale rating was used, where

1 =Very Low, 2 = Low, 3 = average, 4 = High and 5 =Very High. The respondents were also permitted to add other criteria not highlighted by the questionnaire. The questionnaires were sent to 27 experts who deal with supplier selection and tender evaluations in the construction service projects. Of the 27 questionnaires sent out, 22 responses were received from the target group, representing 81.5% of total sample group. The respondents' jobs were company managers, project managers, construction supervisors, design engineers, site agents and others, field experience level ranges from 4 years to more than 20 years.

Table 2 below shows the position of respondents in their organizations. The Project Managers were the highest representation (40.9%) while site agents and others (9.1%) had the lowest representation. Project managers can help to endorse the findings of our research since they evaluate and select suppliers to deliver the projects.

Table 2: *Respondent's percentage*

Position in the company	**No. of respondent**	**%**
General manager	3	13.6
Project manager	9	40.9
Design engineer	6	27.3
Site agent	2	9.1
others	2	9.1
Total	22	100

Table 3 below shows the experience percentages in construction of the experts engaged. As can be seen over 50% of the respondents have accumulated experience of over 10 years in construction. Respondents with higher working experience in construction industry imply they are well versed with evaluating and selecting suppliers to deliver projects. Their selection adds validity and weight to the discoveries of this study.

Table 3: *Respondent's experience in building service industry*

Respondent's experience in construction (yrs.)	No. of respondent	Respondent %
< 5	3	13.64
5 to 10	7	31.82
10-15	3	13.64
15-20	5	22.73
>20	4	18.17
Total	22	100%

4.2 Ranking the Factors

Ranking of the factors were done using the weighted point plan. The weight was calculated using equation. W= ∑ (F X R)/N…….. (Edyta, 2012). Where; W-weight age of each factor, F-Likert scale weight, R-Respondents number, and N-Total score. It was observed that the main criteria to be considered for the selection of construction suppliers were as shown in the ranking table below. The weightage of these criteria are more than 80%.The ranking of the various criteria is shown in the table 4 below.

Table 4: *Ranking of factors*

No	Factor	Weightage in %	Rank
1	Quality assurance (standards, certification & specifications)	97.44	1
2	Quoted bid price	96.15	2
3	Delivery time	95.51	3
4	Licenses and compliance	95.00	4
5	Equipment and facilities	94.87	5
6	Qualification & skill of Suppliers' key personnel	94.23	6
7	Past & current experience	93.59	7
8	Financial ability/ Liquidity	89.10	8
9	After sales services and warranties	88.46	9
10	Manufacture authorization	87.82	10
11	Litigation	86.54	11
12	Length of time in business	85.89	12
13	Occupational health & safety administration	84.62	13
14	Support , maintenance and spares availability	84.62	14
15	Environmental factors & considerations	81.41	15

In order to simply my design, the top 17 sub-criteria (factors) shown above were picked. These were further combined to form 5 main criteria with assistance of expert in the field that were used to model my system , the list of validated criteria identified and used for further research are shown in table below.

Table 5: Criteria proposed and associated sub-criteria used for supplier selection

Criterion	**Sub criterion**
Quality	Product brochures
	Technical specifications
	Quality certification
	Manufacturers authorization
Facilities	Equipments and tools
	Skilled personnel
	Financial resources
Experience	Current work load
	Previous projects
	Audited accounts
	Litigation
After sales services	Warranties
	Support and maintenance
	Spares availability
Delivery	Delivery speed
	Health and Safety components
	Environmental considerations/policy

The five factors above are the ones used as inputs in our fuzzy logic model.

4.3. Modeling in Fuzzy MATLAB

The prototype model for the supplier selection was established using Matlab fuzzy logic tool (FIS), R2017 student version software. The Mamdani Fuzzy Inference System (FIS) type was chosen for inputs and output. It has five graphical user inter-face tools as shown in overview below.

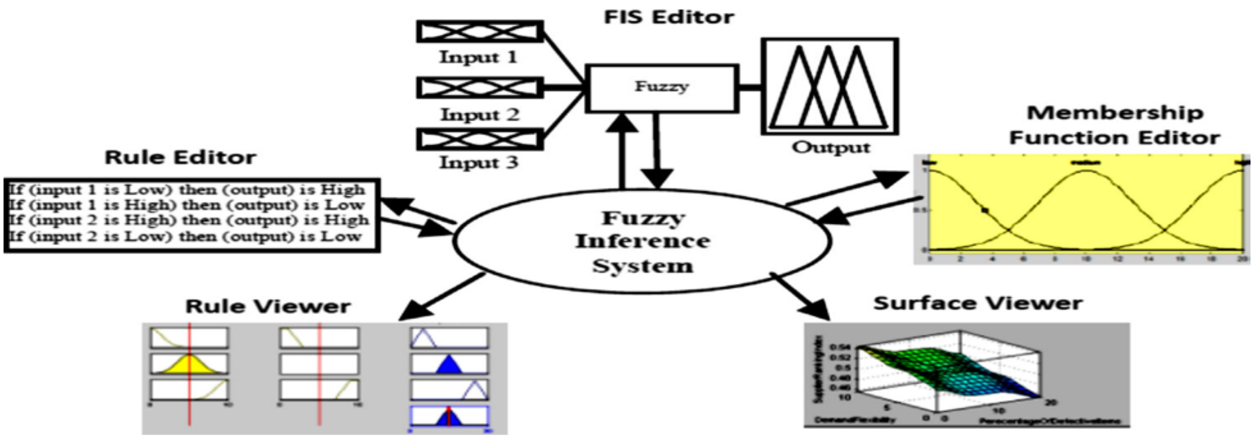

Fig 6: The Matlab Fuzzy Inference System, (Darlington, 2014)

Mamdani-type inference was suggested by Mamdani and Assilian (FFL,2014), the input and output membership functions are fuzzy sets and is the most frequently used fuzzy approach and is built using fuzzy set theory.

4.3.1 Analysis steps and the model development

(i) Defining inputs

Development of the DSS was preceded by the design of the fuzzy set for the 5 input variables. Based on subject matter experts' knowledge, the input parameters nominated for the model were defined with three linguistic variables. Since the developed system should be proficient to evaluate all bids irrespective of size, the maximum value for each criterion was used for regularizing the inputs such that the developed fuzzy model had inputs between 0 and 1. The range of the fuzzy values for each linguistic variable for the inputs "quality", "delivery", "after sales services", "experience" and "facilities" is shown below.

Table 6: Linguistic Variables - Fuzzy set parameters for inputs

Criterion (input)	**Linguistic set**	**Fuzzy set parameters**		
Delivery	Bad	0	0	0.45
	Medium	0.4	0.5	0.75
	Good	0.75	1	1
Quality	Bad	0	0	0.5
	medium	0.5	0.5	0.7
	Good	0.65	1	1
Experience	Low	0	0	0.6
	Average	0.5	0.5	0.8
	High	0.75	1	1
After_sales_services	Low	0	0	0.5
	Average	0.5	0.5	0.7
	High	0.6	1	1
Facilities	Few	0	0	0.45
	Average	0.45	0.5	0.7
	Sufficient	0.7	1	1

The system model was then implemented in Matlab R2017® as shown below

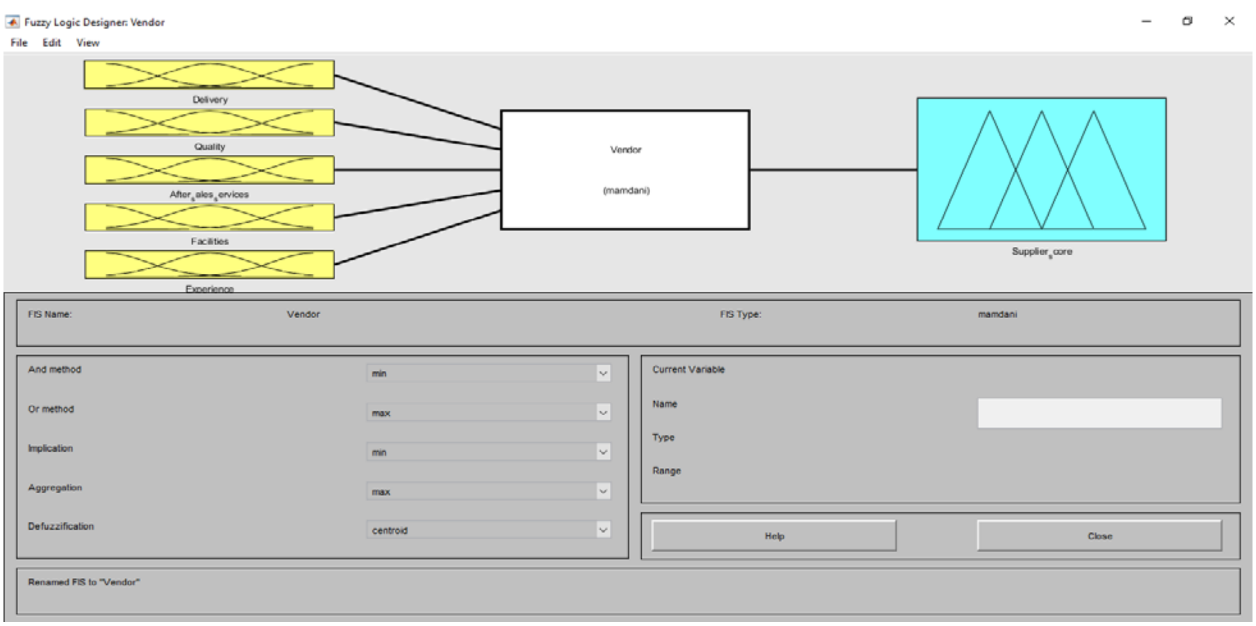

Fig 7: Implementation of the FIS in Matlab R2017

(ii) Outlining input variables membership functions

The membership function for each input was implemented as shown in figures below.

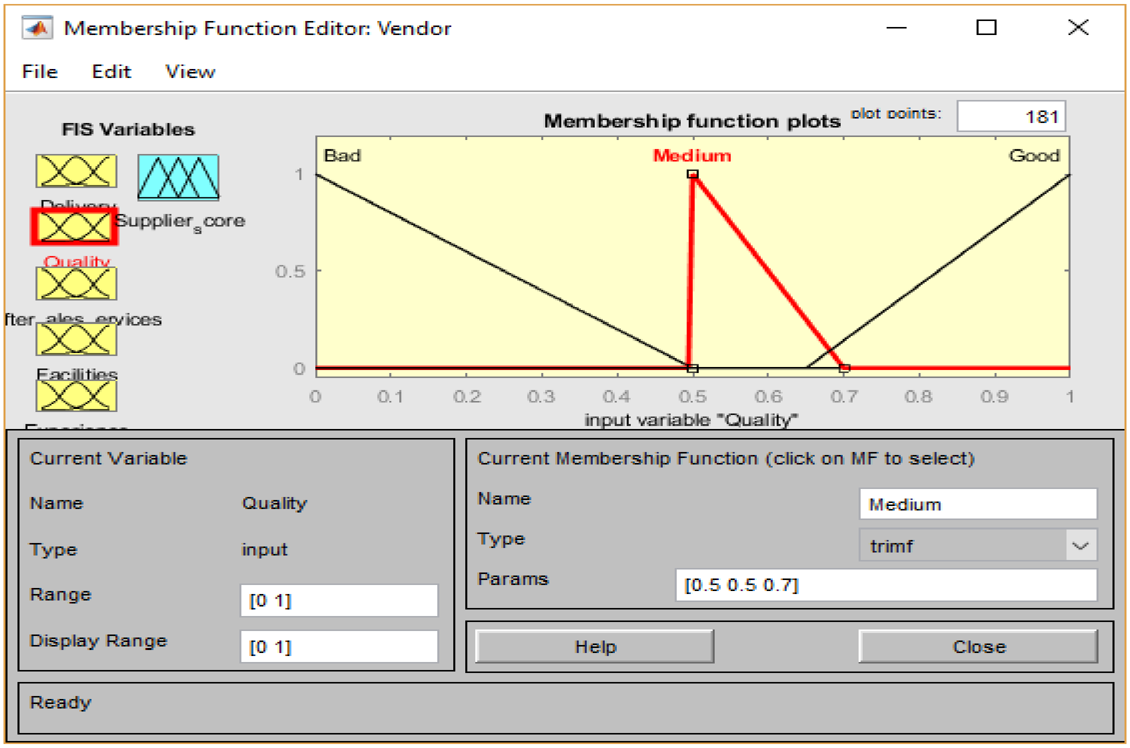

Fig 8: Membership function for "Quality" input

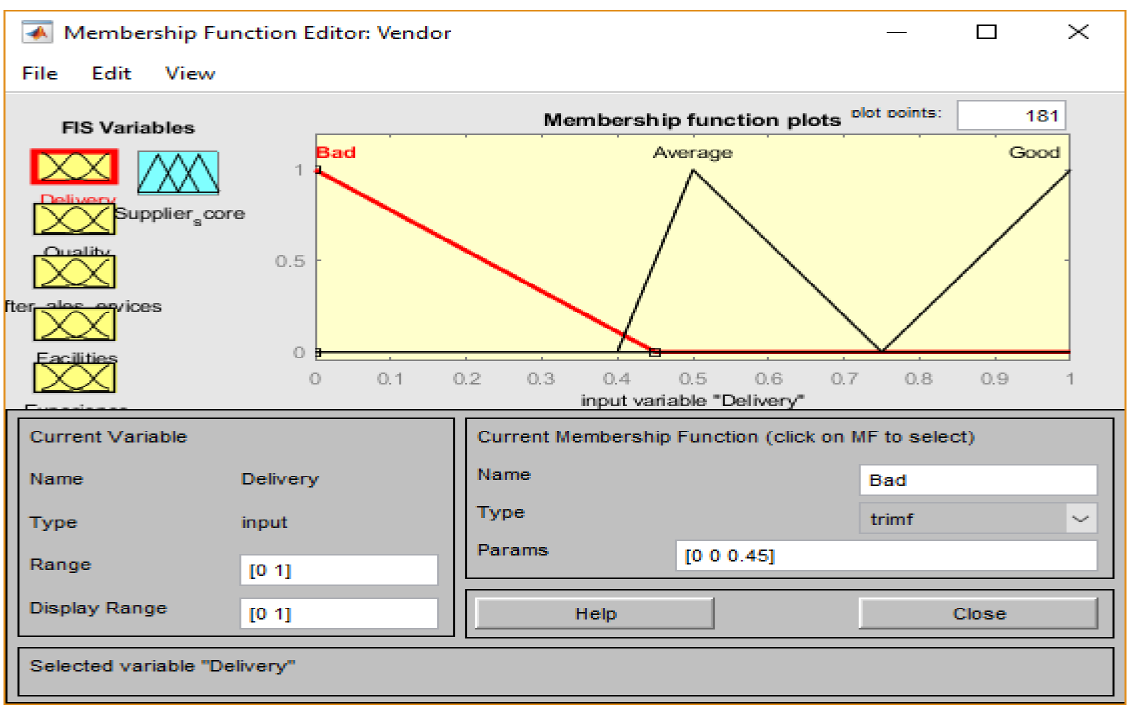

Fig 9: Membership function for "Delivery" input

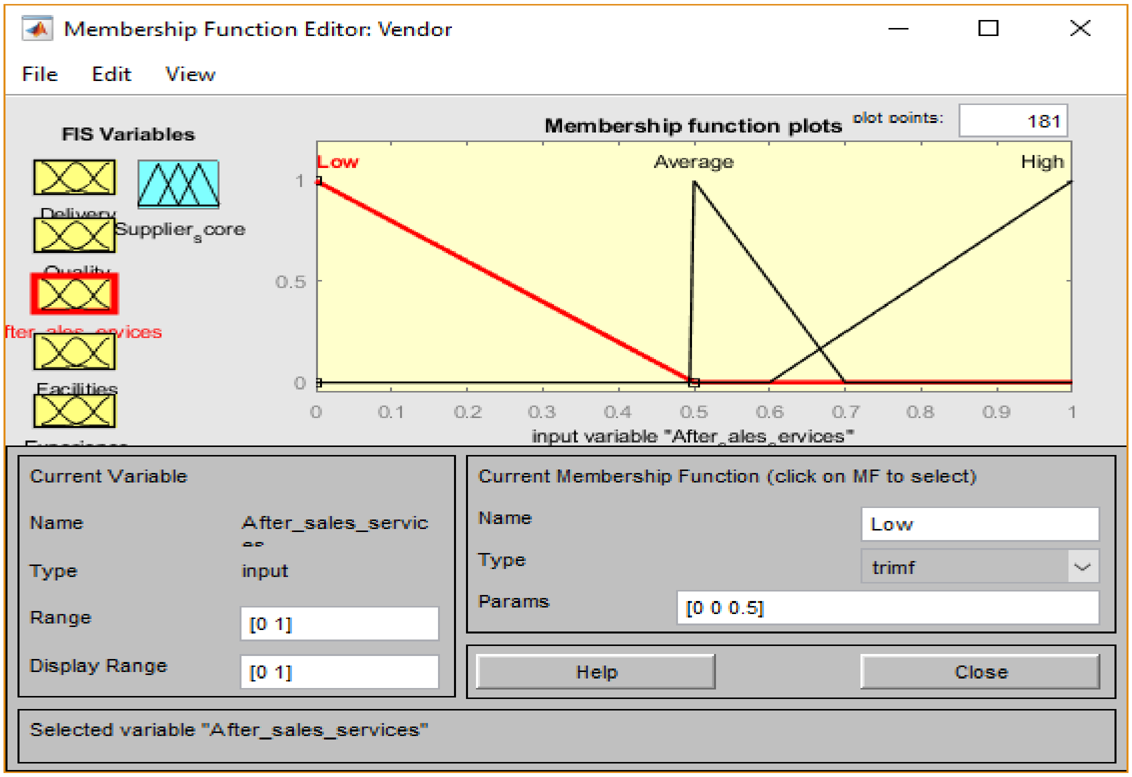

Fig 10: Membership function for "After_sales_services" input

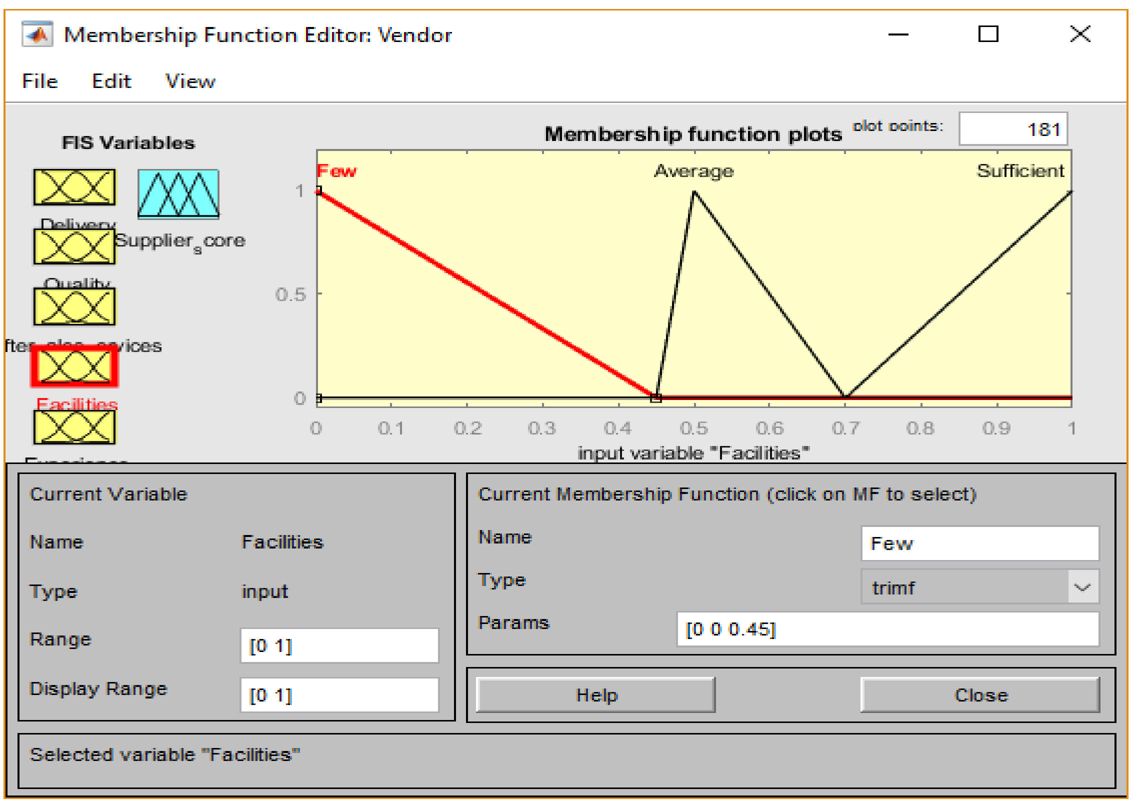

Fig 11: Membership function for "Facilities" input

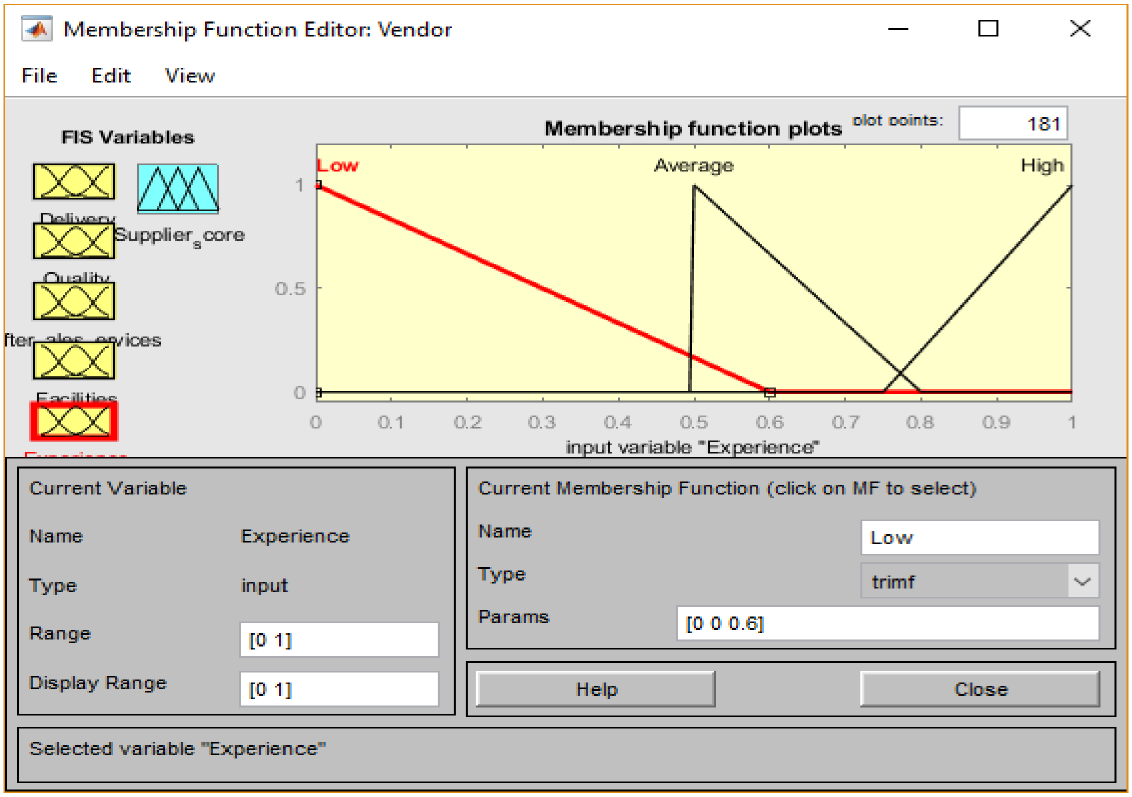

Fig 12: Membership function for "Experience" input

(iii) **Defining rules:** For the fuzzy inference to work, rules to connect input variables to output variables were well-defined. For our model 142 rules were created as per the form of IF-THEN as shown in Figure 13.

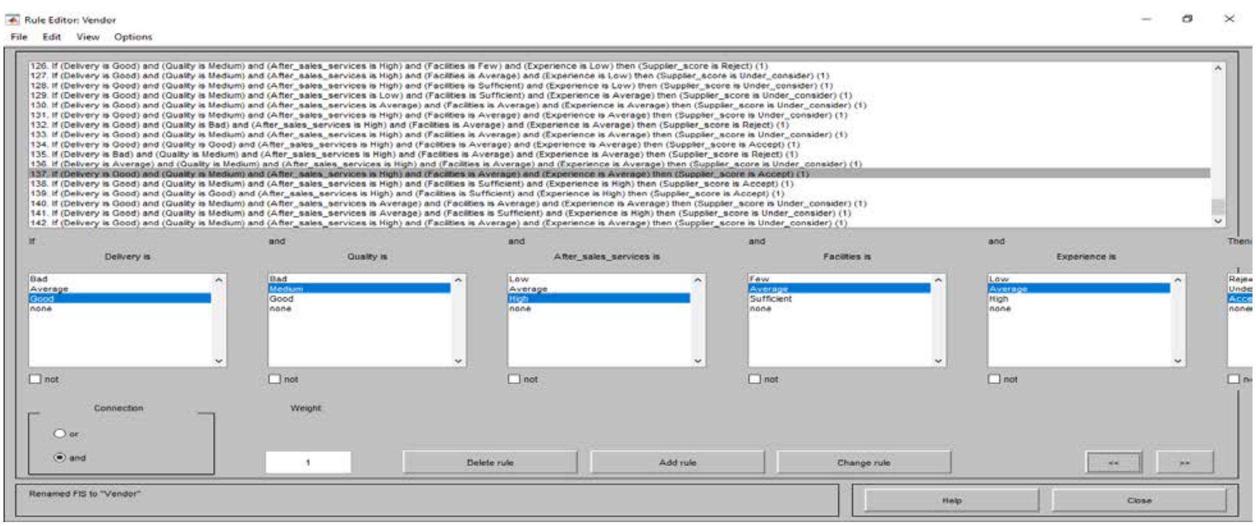

Fig 13: The rule editor

(iii)Defuzzification

In the defuzzification process, the results of the model in the form of fuzzy numbers are converted to particular output numbers. In our study in order to compose the fuzzy rule, the matrix shown in table 7 below was used. It represents the output weight assessment corresponding to the "reject", "under_consider" and "accept" respectively.

Table 7: *Linguistic scale for output assessment*

Linguistic set	Fuzzy set		
reject	0	0	0.5
Under_consider	0.5	0.5	0.7
Accept	0.1	1	1

Below figure shows the membership function implementation of the output in Matlab® FIS

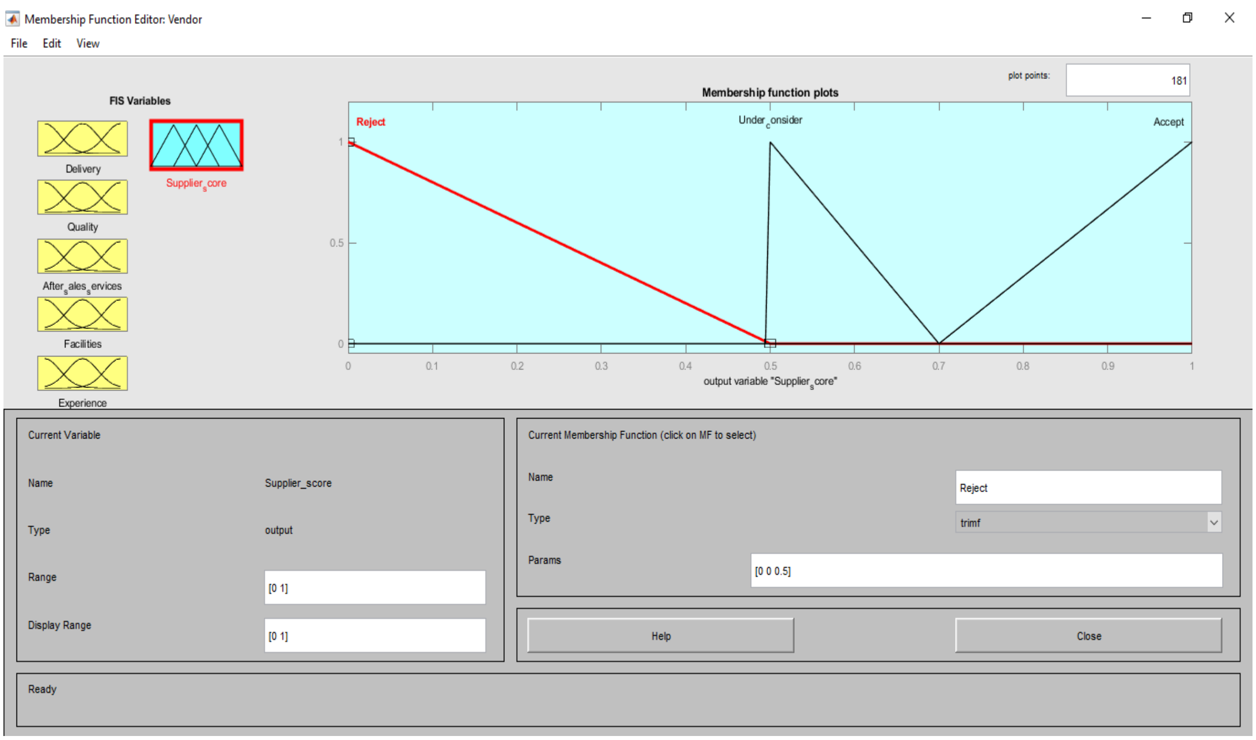

Fig 14: Output membership function

The rules viewer below shows the system values for inputs and output and be used to illustrate the output changes when the inputs are varied.

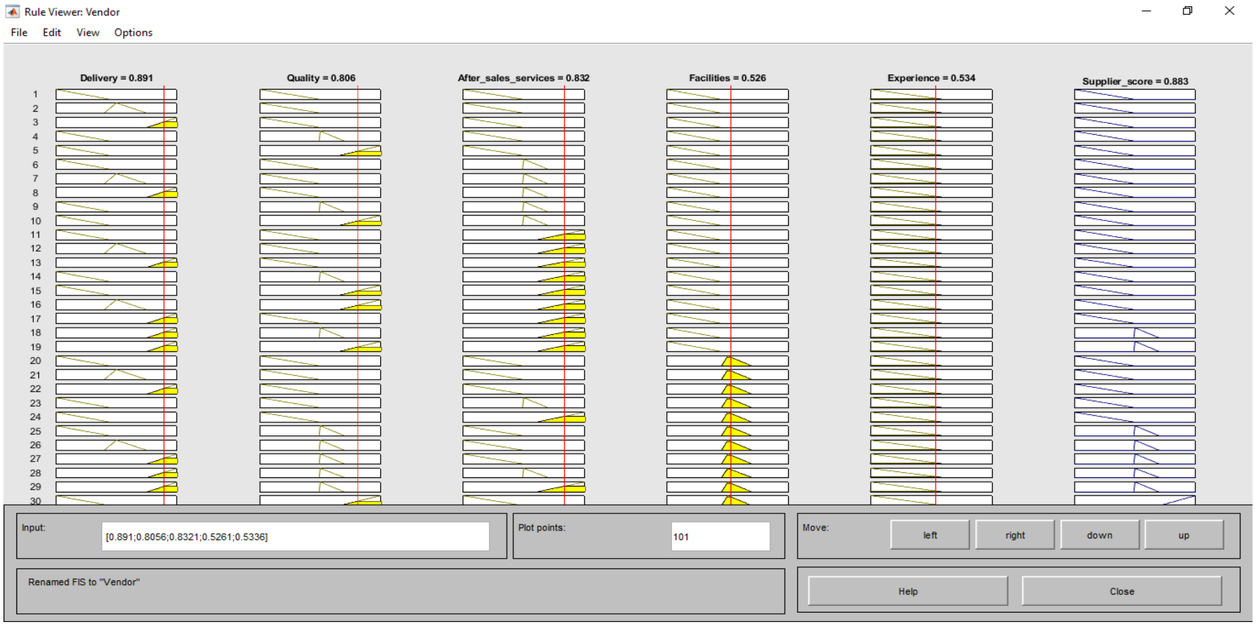

Fig 15: Rule viewer

Finally, the mappings of input to output were attained by electing a view menu and a view surface. Figure 16 below shows Supplier score with respect to quality and facilities inputs. Similarly, Supplier selection for dissimilar mixture of input variables can be obtained. This helps to view the dependence of output to any two of our inputs that are generated and deliver an output surface map of the system.

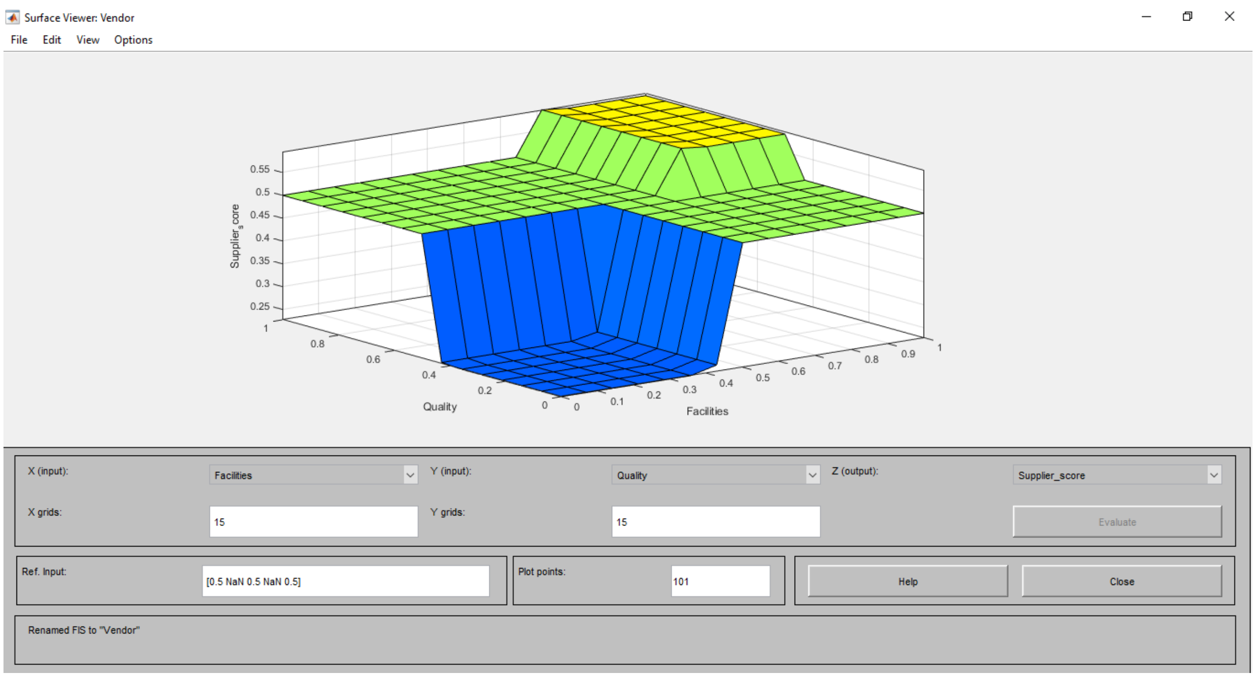

Fig 16: Supplier score vs quality and facilities inputs

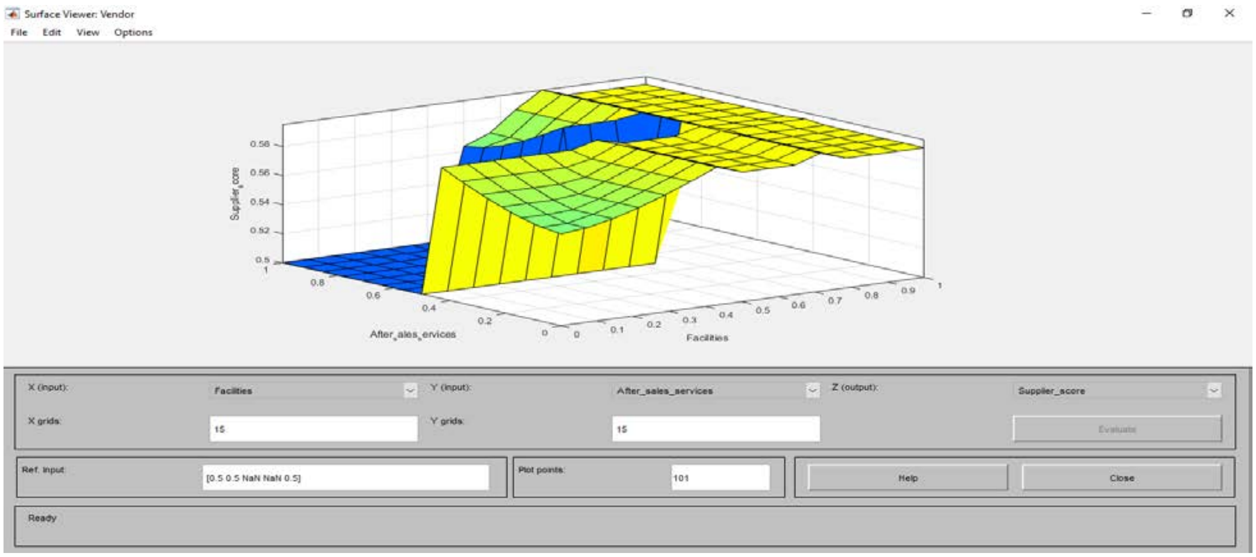

Fig 17: Supplier score vs after_sales_services and facilities inputs

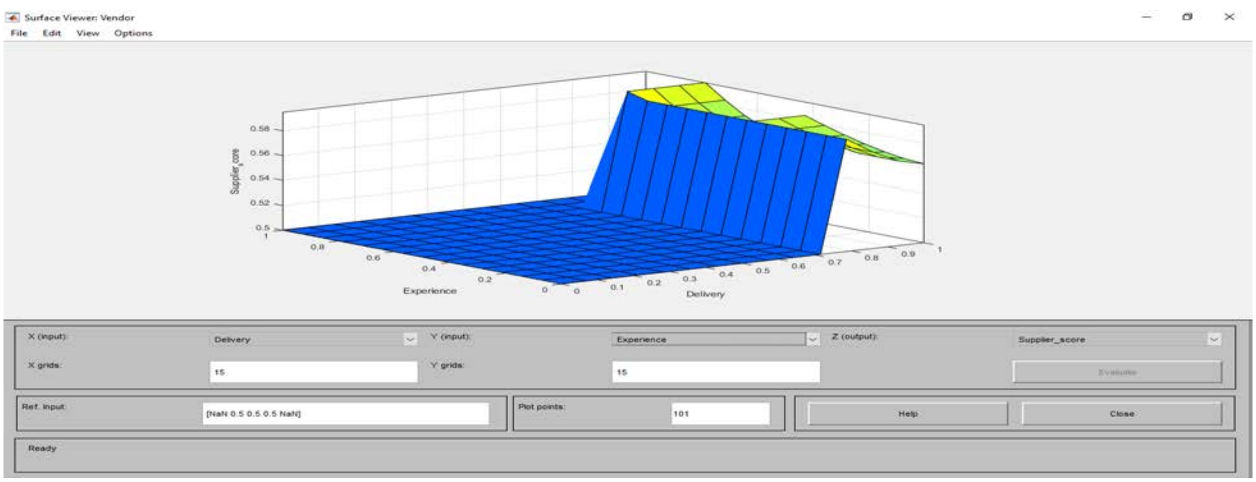

Fig 18: Supplier score vs delivery and experience inputs

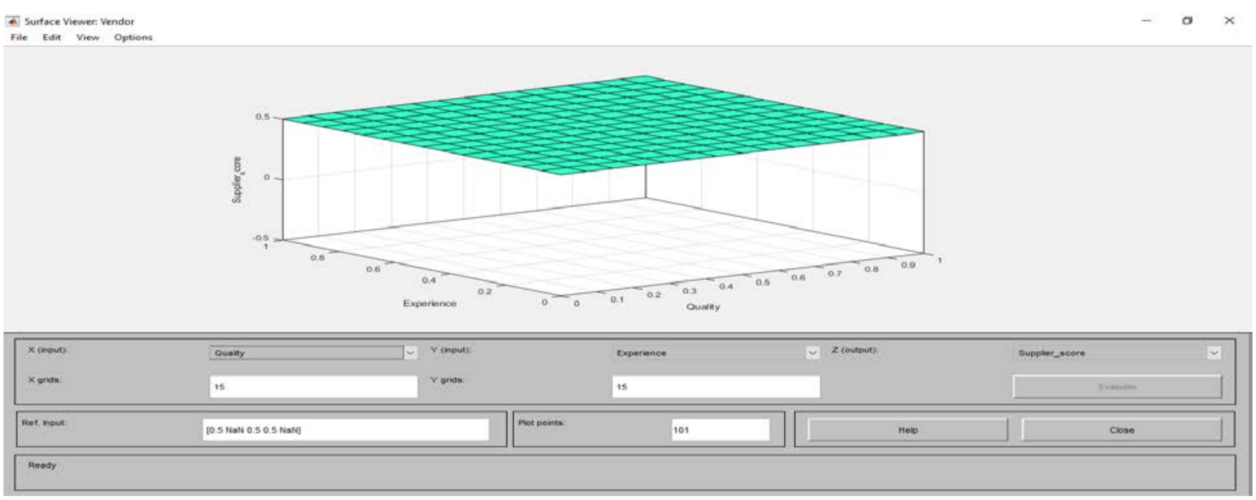

Fig 19: Supplier score vs quality and experience inputs

4.4 Model Validation

Having the model tested using a sample tender; we needed to check the opinion of the supplier selectors about our model. To achieve this, a questionnaire was created and dispersed to seven supplier selectors. Structured interviews were done to them to familiarize the model, explain its key structures and how it could be used. Then, each of them was allowed to try the model themselves and evaluate diverse suppliers in their previous projects and after that rate the model using the questionnaire. The average score given was 3.19 out of 4.0, translating to 79.75 % which can be reflected as an acceptable level that shows the validity of the developed model.

4.5 Discussion

The current method of selecting the right suppliers in construction service industry for governmental organizations is by using technical committees. This method largely does not address the time and human cost elements associated with the process. Moreover the Public procurement act (PPOA) that guides the suppliers' selection advices the use of four factors i.e. price, quality, time and services for valuation and choosing the suppliers in the service industry. Although the criteria on "quality" and "services" are imprecise and fuzzy in nature, fuzzy logic can be used to evaluate them since it takes into consideration the ambiguities and uncertainties in human decisions. With the adoption of e-procurement in supply chain management, there is a need to automate the supplier selection process. We have confidence in that one way to achieve this is through of a decision support system.

This research work generated a tool that will allow organizations to use Fuzzy Logic concepts instead of traditional tender committees when selecting suppliers in supply chain management. It recommends a multiple factor decision model using fuzzy theory to allow the supplier selectors to introduce vagueness, ambiguity and subjectivity into supplier evaluation process where variables are subjective and qualitative in nature and hence difficult to incorporate into quantitative models. Comparing this designed system with the conservative method, the new system is much faster and the model can be used in decision making for supplier selection.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Achievement

5.1.1 Objective 1: To determine the criteria used in supplier selection in construction services.

Through literature review and thorough interviews, it was realized that there are many factors that could affect the selection and evaluation process of the appropriate suppliers in construction service industry. The importance weight of each factor was calculated and indexed based on the statistical analysis and finally, the factors were ranked according to their degree of importance. Factors with high index were considered as the highly crucial factors in selecting suppliers. The analysis of the data showed that only seventeen criteria out of the thirty two criteria identified initially represented the mostly used criteria in selecting suppliers in the construction service industry for government organizations. The seventeen factors were grouped into five major groups and used as inputs to our decision support system.

5.1.2 Objective 2: To design and develop a decision support system for selecting suppliers.

A model for evaluating potential suppliers using a fuzzy based expert decision support system (DSS) was designed and developed using Matlab R2017® software. The model can be used to assist organizations in technical evaluation of suppliers especially where the factors considered are imprecise and vague. Five critical factors which are fuzzy in nature were considered as the input to the system. The designed system evaluates the importance of each factor when selecting a supplier in each bid and the final rating of each supplier was determined. On comparison of this system with the traditional tender team, the developed system was much faster and the need to have the normal tender evaluation meetings for selecting suppliers may be done away with.

5.1.3 Objective 3: To test the suitability of the DSS in suppliers' selection.

The results of the prototype evaluation using a real tender were up-to-per with tender team decision; this validates the view that the system delivered its functions as envisioned. The scoring done by the system was consistence with the tender committee results and users scored the Fuzzy model at 79.75% on its functionality.

5.2 Limitations

The proposed prototype can only be accessed via Matlab® software which is not readily available in many governmental organizations and its usage requires technical skills on the software which may limit number of users. Defining the sets and membership functions for a given fuzzy system can be a subjective task because it is usually done by a collaborative effort of users, process owners and subject matter experts with knowledge in the relevant field. There could be disagreements among the players when formulating the fuzzy sets, inputs, rules and membership functions and this could compromise the degree of match between system offer and actual user's need.

5.3 Implication of the Study

This study contributes on the knowledge of how decision support systems can enhance the process of suppliers' selections using artificial intelligence tools (AI). It investigated the applicability of the fuzzy logic technologies in enhancing the evaluation of suppliers in the construction services industry in Kenya. The automation of supplier selection in service industry using decision support systems in Kenyan governmental organizations may improve the supply chain management and e-procurement efficiency with minimum human intervention. The proposed prototype can act as a blue print or a prototype for the real life implementation as a solution system that could enhance the process of suppliers' selection and provide the data for further analysis and policy formulation.

5.4 Recommendation

Future studies is recommended in this research area to enhance the proposed prototype to be used in supplier selection for more services and products and be integrated to be part of the e-procurement solution using data and specifications from more sources, stakeholders and covering more areas in supply chain management. Also future studies should look at the effect of automating the supplier selection process in supply chain; will it increase efficiency and reduce the rate of improper procurement in governmental organization and will automation of supplier selection contribute to reducing the proliferation of public funds?

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APPENDICES

Appendix 1: Introduction Letter

University of Nairobi, School of Computing and Informatics

Wilson Nguru, P.O Box 9790, Nairobi.

Dear Sir/Madam,

Re: Request To Participate in MSc. Research Questionnaire

I am a M.Sc. Information Systems student at the School of computing and informatics. I am currently doing a project entitled Decision Support System in supplier selection using fuzzy Logic. Today's marketplace is shifting from individual company performance to supply chain performance: the entire chain's ability to meet end-customer needs. Supplier selection metrics have an important role to play in setting objectives, evaluating performance, and determining organization success. PPOA act 2015 provides for four criteria for supplier selection, namely price, time, service and quality for government services suppliers. The Supplier selections criteria can be divided into two major groups qualitative and quantitative. Price and time are quantitative while service and quality are qualitative in nature. In recent years many methodologies have been developed in terms of quantitative measures in suppliers' selection, the qualitative aspect of the supplier selection is still under-explored and remains imprecise. Measuring qualitative factors is not easy because they are not representing numerically and the subjective nature of such measures makes it difficult to incorporate into quantitative models. Fuzzy logic enables a person to model the uncertainty within the subjective formulation of knowledge or opinions. It is therefore important to develop a framework that can be used in measuring the qualitative factors in supplier selection using fuzzy logic. I will be glad if you would assist me to research on this by filling in the questionnaire, which hopefully should take you less than 10 minutes. I wish to particularly obtain your response with regard to experience and some methodologies you have applied in Supplier selection. I will be glad if you will complete and return the questionnaire by 30th November 2017.

Kind feel free to forward any comments that relates to this study. The information obtained will be used purely for academic purpose and treated with utmost confidentiality. Thank you for your time and cooperation

Wilson Nguru-**P56/70352/2007** wnguru@yahoo.com

Appendix 2: Questionnaires

Supplier selection in service industry

1. **Preface;** This questionnaire will help in collecting data on the various criteria used in supplier selection for building service industry in governmental organizations in Kenya and to develop a framework to be used for evaluating the suppliers in the industry using fuzzy logic

2. Introduction

This questionnaire is intended to collect data on qualitative factors used during supplier selection as guided by the PPOA act 2015. This data will be used to write a thesis paper that aims at researching on Supplier selection for building services of governmental organizations in Kenya today. The information collected in this questionnaire will be treated as confidential as possible and would not be used for any other purposes other than intended work in the thesis. I will greatly appreciate if you take 5-6 minutes to fill in the Questionnaire.

This questionnaire is divided into **TWO Sections** each to be filled appropriately.

1. ***General Section***: This section intends to collect general information on respondents and the companies' frameworks for supplier selection by ticking on appropriate options provided.

2. ***Qualitative factors section***: This section intends to collect data specifically on qualitative factors considered during supplier selection. Answer all the questions according to your knowledge, skills and position within your organization.

3. Remark.

As a student undertaking a M.Sc. Program, This questionnaire is NOT to assess people and their work or knowledge. The questionnaire aims only to collect data and assess performance of Supplier selection within governmental organizations. And using the data to write a Thesis for award of M.Sc. Information systems, Feel free to respond to it. In case of clarification or any correspondences you can contact us through email using the following emails address:

Wnguru@yahoo.com

SECTION ONE

General questions

1. Name of your organization: ....

2. How many years has your organization been operating in this business?

    a) Below 5 years, b) 5-10 years, c) 10-15 years, d) 15 and Above

3. Which position do you hold? ....

4. What is your experience in construction industry in years? ....

a. <5, b. 5- 10, c. 10-15, d. 15- 20, e. >20

5. To what extent is computer technology applied in your organization? ....

a. Wide b. Intermediate c. Low

6. How is supplier selection done in your organization done? ....

a. Manual methods, b. Computer software, c. I don’t know

7. If using computer software to (4) above, please give the name of the software? ....

8. How long does it take to undertake supplier evaluation using the current method?

a. Within 4 hour b. Within 1 day c. more than 1 day d. specify other

9. What is the frequency of supplier evaluation (e.g. monthly, weekly, quarterly, yearly)?

10. What are the main challenges that face supplier selection in your company/organization?

11. What kinds of data are used during supplier selection?

12. Who are involved in supplier selection (e.g. supply chain, user departments, management)?

13. To what extent do the following criteria metrics affect your supplier selection? (Tick where appropriate)

Use the following scale:

1-Very Low Extent

2-Low Extent

3- Moderate Extent

4-High Extent

5-Very High Extent

Criteria	**1**	**2**	**3**	**4**	**5**
Financial stability/ Liquidity					
Creditability and discounts					
Banking arrangement & bonding					
Quoted bid price					
Relevant experience					
Built technology capacity					
Research & development ability					
Information technology application					
Innovation					
Management knowledge					
Quality assurance & policy certification					
Licenses and compliance of the contractor					
Organization structure					
Technical expertise					
Labor by trade skills					
Sub-contractor list					
Specialist equipment					
Facilities					
Corporate social responsibilities					
Occupational health & safety administration					
Current work load					
Environmental factors & considerations					
Length of time in business					
Delivery time					
Contractor/ supplier relationship					
Litigation					
Domestic preference					
Contribution to project objectives (price)					
After sales services					
Any other (list below)					

14. Any other comments or suggestion.

Thank you very much for your time.

Evaluation of the proposed prototype

15. Given below as the criteria to be used for supplier evaluation, what will be the score range (between 0-1) for below factors?

Criteria	**Linguistic value**		
	Bad	**Average**	**Good**
Quality			
Facilities			
Experience			
Delivery			
After_sales_services			

16. A Matlab fuzzy logic tool has been designed to capture and assist in supplier selection; Are you able to access the system?

a) Yes b) no

17. Can the system be able to evaluate suppliers?

a) Strongly agree b) Agree c) Not Sure d) Disagree e) Strongly disagree

18 Do you think this could improve the current way of supplier selection?

a) Yes b) not sure c) no

19. In a scale of 1-4 how would you rate the tool tested above?

20. What other features could be included in future to improve the tool?

21. The proposed prototype has been developed using Matlab platform. Is this platform available in your organization and could be used?

22. Any other comments or suggestion.

Appendix 2: Matlab FIS ; Vendor.fis file

[System]

Name='Vendor'

Type='mamdani'

Version=2.0

NumInputs=5

NumOutputs=1

NumRules=96

AndMethod='min'

OrMethod='max'

ImpMethod='min'

AggMethod='max'

DefuzzMethod='centroid'

[Input1]

Name='Delivery'

Range=[0 1]

NumMFs=3

MF1='Bad':'trimf',[0 0 0.45]

MF2='Average':'trimf',[0.4 0.5 0.75]

MF3='Good':'trimf',[0.75 1 1]

[Input2]

Name='Quality'

Range=[0 1]

NumMFs=3

MF1='Bad':'trimf',[0 0 0.5]

MF2='Medium':'trimf',[0.5 0.5 0.7]

MF3='Good':'trimf',[0.65 1 1]

[Input3]

Name='After_sales_services'

Range=[0 1]

NumMFs=3

MF1='Low':'trimf',[0 0 0.5]

MF2='Average':'trimf',[0.5 0.5 0.7]

MF3='High':'trimf',[0.6 1 1]

[Input4]

Name='Facilities'

Range=[0 1]

NumMFs=3

MF1='Few':'trimf',[0 0 0.45]

MF2='Average':'trimf',[0.45 0.5 0.7]

MF3='Sufficient':'trimf',[0.7 1 1]

[Input5]

Name='Experience'

Range=[0 1]

NumMFs=3

MF1='Low':'trimf',[0 0 0.6]

MF2='Average':'trimf',[0.5 0.5 0.8]

MF3='High':'trimf',[0.75 1 1]

[Output1]

Name='Supplier_score'

Range=[0 1]

NumMFs=3

MF1='Reject':'trimf',[0 0 0.5]

MF2='Under_consider':'trimf',[0.5 0.5 0.7]

MF3='Accept':'trimf',[0.7 1 1]

[Rules]

[Input1] [Input2] [Input3] [Input4] [Input5], [Output1] (priority) : weight

1 1 1 1 1, 1 (1) : .. …….. 142 rules

Test case

The table below shows the allocation of weights for inputs as a sample tender that was used to test our system. The values were picked from a real tender for electrical installation works for the proposed construction of hub office for a government organization. Normally the tender documents/bids have a pre-defined score to be used for evaluating suppliers in all projects for governmental organizations as depicted in the figures below.

STAGE 2 - TECHNICAL EVALUATION

A) COMPLIANCE WITH TECHNICAL SPECIFICATIONS

In this section, the bid will be analyzed to determine compliance with General and Particular technical specifications for the works as indicated in the tender document.

The tenderer shall fill in the Technical Schedule as specified in the tender document for Equipment and Items indicating the Country of Origin, Model/Make/Manufacturer of the Item/Equipment they propose to supply.

Where the Equipment proposed by the tenderer differs with the models specified in the tender document, it is mandatory that the brochures/catalogues of the same be submitted with the tender document highlighting the catalogues Numbers of the proposed items. Such brochures/catalogues should indicate comprehensive relevant data of the proposed equipment/items which should include but not limited to the following:

a) Standards of manufacture
b) Performance ratings/characteristics
c) Material of manufacture
d) Electrical power ratings and
e) Any other necessary requirements (Specify)

Following the above analyses, where the proposed equipment are found not to satisfy the specifications, the tender will be deemed Non – Responsive and will not be evaluated further.

B) TECHNICAL EXAMINATION

In this section, the information provided in the Technical Schedule or Brochures attached will be analyzed for bidders who have qualified from **STAGE 2A** above and points awarded as shown below to a maximum of 50 points

Item	Description	Score	Max. score
	Technical schedule/Brochures ○ Relevant Manufacturer Brochures for items in the technical schedule with equipments to be supplied highlighted and meets specification (Where alternative are to supplied-- 50 or ○ Completely filled Technical Schedule indicating Brand, Model/ Country of origin as per specification in the tender----------------- 50 ○ Relevant Manufacturer Brochures for items in the technical schedule with equipments to be supplied not highlighted but within range of those specified and meets specifications --- 40 or ○ Completely filled Technical Schedule indicating items as specified in the tender but with over 75% of items in the technical schedule provided---40 ○ Relevant Manufacturer Brochures for less than 75% of items in the technical schedule with equipments to be supplied highlighted and meets specifications-- 30 or ○ Less than 75% of Technical Schedule filled indicating Brand, Model/Country of origin for the items considered as specified in the tender -------30 ○ No technical data provided, either in form of brochures or filling of Technical Schedule. --- 0		**50**
	TOTAL		50

The Technical score will be carried forward to STAGE 4

Step A: To calculate the share of weights (obtained from the tenders' allocation table) for each criterion, each weight is divided by the sum of all weights. For example for quality it will be: 25/(30+25+25+10+10) = 0.25. Below table shows the share of weights for all criteria for our sample tender.

Table 6: Weights allocation sample for a project

Criterion	Weights	Share of weights
Delivery	10	0.10
Quality	25	0.25
After sales services	10	0.10
Facilities	30	0.30
Experience	25	0.25

Step B: Similarly the weights for each criterion and its sub-criterion were calculated as shown in table below. The value of weights varies from one project and organization to the other but the principle is the same for projects.

Table 8: Score calculation for each criterion and its sub-criteria

Parameter			**Allocated score**				**Normalized weights**			
Criterion	**Sub-criterion**	**Maximum weights**	**supplier 1**	**supplier 2**	**Supplier 3**	**supplier 4**	**Sp 1**	**Sp 2**	**Sp 3**	**Sp 4**
Quality	Product brochures	5	3	5	3	2	0.6	1	0.6	0.4
	Technical specifications	15	10	13	9	8	0.67	0.87	0.6	0.53
	Quality certification	2	2	2	1	0	1	1	0.5	0
	Manufacturers authorization	3	0	3	3	0	0	1	1	0
Total score for Quality		**25**	**15**	**23**	**16**	**10**	**0.6**	**0.92**	**0.64**	**0.4**
Facilities	Equipments and tools	10	6	3	7	5	0.6	0.3	0.7	0.5
	Skilled personnel	5	4	2	3	3	0.8	0.4	0.6	0.6
	Financial resources	15	12	5	10	8	0.8	0.33	0.67	0.53
Total score for Facilities		**30**	**22**	**10**	**20**	**16**	**0.73**	**0.33**	**0.67**	**0.53**
Experience	Current work load	5	3	2	4	2	0.6	0.4	0.8	0.4
	Previous projects	5	2	4	3	3	0.4	0.8	0.6	0.6
	Audited accounts	10	6	4	7	5	0.6	0.4	0.7	0.5
	Litigation	5	4	2	5	5	0.8	0.4	1	1
Total score for Experience		**25**	**15**	**12**	**19**	**15**	**0.6**	**0.48**	**0.76**	**0.6**
After_sales_services	Warranties	2	2	1	2	2	1	0.5	1	1
	Support and maintenance	5	4	3	3	5	0.8	0.6	0.6	1
	Spares availability	3	2	3	3	2	0.67	1	1	0.67
Total score after_sales_services		**10**	**8**	**7**	**8**	**9**	**0.8**	**0.7**	**0.8**	**0.9**
Delivery	Delivery speed	3	3	2	2	3	1	0.67	0.67	1
	Health & Safety components	4	3	2	2	4	0.75	0.5	0.5	1
	Environmental considerations/policy	3	3	2	1	3	1	0.67	0.33	1
Total score for Delivery		**10**	**9**	**6**	**5**	**10**	**0.9**	**0.6**	**0.5**	**1**

The total score for each supplier for each criterion was then used as the input to our system to generate the output score summarized below.

Criterion	**Normalized Scores**			
	Supplier 1	**Supplier 2**	**Supplier 3**	**Supplier 4**
Quality	0.6	0.92	0.64	0.4
Facilities	0.73	0.33	0.67	0.53
Experience	0.6	0.48	0.76	0.6
After_sales_services	0.8	0.7	0.8	0.9
Delivery	0.9	0.6	0.5	1
Fuzzy score	***0.53***	***0.51***	***0.59***	***0.57***

The result was consistent with the technical committee's decision; supplier 3 had the highest score as shown below.