Development of Fuzzy Multi-Criteria Analysis Method

for Tender Cleaning Service Selection

by

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18095

Dissertation submitted in partial fulfilment of

the requirements for the

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(Electrical and Electronic)

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CERTIFICATION OF APPROVAL

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Approved by,

____

(AP Dr Mahmod bin Othman)

UNIVERSITI TEKNOLOGI PETRONAS

BANDAR SRI ISKANDAR, PERAK

JANUARY 2017

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

NURUL BAZLAA' BT AMINUDIN

ABSTRACT

This paper present a development of fuzzy set theory for tender cleaning service selection. It aims to evaluate the tender based on several criterions and provide the information to Tender Owner for selecting the top bidder. Tender evaluation is an action to determine the potential bidder that provide the most benefits for the Tender Board. The subjective assessment process is model using fuzzy number and linguistic terms. The model is solved using algorithms which integrates the decision maker's decision for assessments on criteria weight with the performance ratings. Next, the concept of degree optimality of each bidder respect to each main criterion is used to convert weighted fuzzy performance matrix into a fuzzy singleton matrix. Top two bidder will be awarded the tender based on the ranking of bidders, respective to the evaluation of the corresponding fuzzy utilities. The application of this paper will not only benefited Universiti Teknologi PETRONAS (UTP), but also benefited private sector, oil and gas industry and government agency.

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Assalamualaikum warahmatullahi wabarakatuh. Bismillahirahmanirrahim.

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CHAPTER 1

INTRODUCTION

This chapter provides a brief review on this project which focuses on the Fuzzy Multi-criteria method. The evaluation of tender cleaning service took place in UTP which currently the method use is only generic one data – based on lowest price. This will lead to many bad consequences, therefore a fuzzy method is proposed to generic many criterions for many bidder. The background study and objectives of the project are included in this chapter.

1.1 Background

Tender evaluation is an action to determine the potential bidder that provide the most benefits for the Tender Board – Universiti Teknologi PETRONAS (UTP). Therefore the potential tender should be emphasize in providing analysis such as financial ability or technical ability. This is because work contract, services or supplies and the contractor's inability to implement the contract are some of the main cause of the failure.

The current method used to select the most suitable tender might facing problems such as human error, for example bias towards friend or family related company. Other than that, the selection associated with lowest cost might lead to poor quality of works and many more bad consequences [1]. Because of the tender owner – UTP, wants the best bidder which has a criterion like financing capabilities, technical capabilities and others, thus, we proposed to use Fuzzy logic method as the most suitable method to be use in tender evaluation.

The proposed method is using a fuzzy multi-criteria analysis (MA) which mainly used to formulate the problems which will be solved by an effective algorithm. The algorithm is a combination of the decision maker's (DM's) preferences on customer's assessment on the criteria weigh. In the project, the fuzzy MA is divided into two phase. The first stage is using triangular norm graph which is used to indicate the decision maker's (DM) assessments of each criterion. While the second stage is to rank the alternatives – bidder, respected to the evaluation of their corresponding fuzzy utilities.

The results later will be compare with the results obtained from other Multi-criteria Decision Making (MCDM) method.

1.2 Problem Statement

The main problem with the typical method is based on the multi-criteria which is very tedious process and given the limitations of human ability, thus making it difficult to be handle. Other than that, the problems face are:

i. The difficulty in determining the measurement scale for human traits. The measurement scale usually has a limited selection preference, for example if the evaluator desires giving in 2/3 of "8", decision makers will become frustrated to be settle on mark "9".
ii. Most evaluation methods are not generic and can only be evaluate one type of data.
iii. The evaluation conducted may be influenced by economic and environmental constraints.
iv. The uncertainty of information got from the contractors.

1.3 Objectives and Scope of Study

The main objective of the project is to select the preferred cleaning service tender using the proposed fuzzy MA method. Besides, the specific objectives of the research are:

i. To rank the cleaning service bidders with each criterion by using the ranking index that has been calculated;
ii. To provide information of selected tender to Tender Owner based on the rank.
iii. To compare the results from proposed method and other MCDM method.

CHAPTER 2

LITERATURE REVIEW

This chapter provides a brief review on the overview of tender evaluation. It is then followed by the brief explanation about the Fuzzy theory and type of MA method. Lastly, the explanation about the Analytic Hierarchy Process (AHP) and combination of MA and AHP.

Tender evaluation is an important relation between owner and customer as bidding strategy formulation. Tender evaluation is a procedure of selecting the most suitable and preferred contractor or tenderer from a number of bidder [2], by given the owner and customer the specialization or criterion for a specific project. Currently, rational and analytical approach are used to formulate the bidding. Therefore, tender selection remain as subjective judgement. Other than quantitative criteria, qualitative and intangible criteria are also needed to be considered during tender evaluation process.

In many cases, economy and environment constraint may exist during tender selection. The decision making procedure involve a wide range of criteria which may provide imprecise and subjective information of the bidder. Uncertainty of the information is totally not suitable for analysis of probabilities of selecting the most suitable tender. In real decision making problems, selection techniques always faced with fuzziness, subjectivity and imprecise information [3]. Moreover, evaluation made by multiple numbers of alternatives are normally resulting confliction and making the evaluation more complicated [4]. Thus, the Fuzzy MA method is proposed to solve the problem.

Fuzzy sets concept is created by L. A. Zadeh during the year 1965 [5]. The concept involves capture, represent and working with linguistic notions which is objects with unclear boundaries. Any objects that have same general property are consider as a set [2]. Therefore the fuzzy sets can be defined as a set of numbers that having a continuum of grades of membership.

Fuzzy set theory provides a way for presenting linguistic models such as ‘many’, ‘good’ and ‘important’. Generally, the theory delivers an inference structure that more appropriate with human capabilities. There is no wrong or right in fuzzy set concept, but relatively a matter of degree [6].

The proposed fuzzy set theory includes combination of MA and Analytic Hierarchy Process (AHP). AHP is a common method that applied to solve MA problems [7]. The applications of fuzzy set theory in MA provides an effective way in solving any decision making problems especially in fuzzy environment where the information is imprecise and subjective [8].

MA is a tool to solving problems that are characterized as a choice among alternatives and this tool can be apply to many complex decisions. Main feature of MA is it has limited number of pre-determined alternatives [4]. The final decision is made based on the attributes or criterions. The MA approaches provide a systematics way to evaluate and choose the most preferred and satisfactory alternatives under certain situation [9].

While AHP used to rank the alternatives in a systematic way. AHP is represented in hierarchy and then synthesizes to determine the ranking of alternative [10]. In AHP, a pairwise comparison process is deployed in order to form a reciprocal decision matrix into which will transform qualitative data to crisp ratios. And this process will make it easier and simpler to handle which enable AHP to be implement in various decision making problems [11]. However, this process is often criticized because of its inconsistency outcomes, inappropriate presentation of the ratio and also tedious comparison when there are many criterion involved [12].

CHAPTER 3

METHODOLOGY

This chapter discussed about the methodology of project work which divided into two sections. First, data collection where four types of data are collected from UTP Tender Unit and the User. Second, from the data gathered, analysis is took placed to calculate the most preferred bidder based on main criterions and its sub-criterion. All mentioned steps will be explained and addressed in this chapter.

3.1 Data Collection

The preliminary research started with data collection from UTP Tender Unit and the User which is the Building Services of Maintenance Department UTP. UTP Tender Unit is responsible on awarding the tender to preferred bidder that have been selected by the User.

Both departments are given a good cooperation on providing the information needed. The data that are collected from both departments are listed as:

i. List of criterion used in awarding the tender;
ii. Assessment of bidder based on criterion;
iii. Number of bidder for the tender;
iv. Number of selected tender that needed by the User.

Mentioned that the tender is selected based on two areas: technical term and commercial term. Technical term is more on documentation while commercial term is related to the price quotation. Therefore, the author has come out with the variable needed for the proposed criterion and sub-criterion that will be use in solving fuzzy MA method.

The main criterions is divided into five sections which are Financial Soundness, Technical Value, Working Methodology, References of Tenderer and lastly Team Qualification. Each main criterion is then expanded into several sub-criterion. The criterion and sub-criterion are listed in hierarchy as shown in Figure 3.3.

3.2 Data Analysis

There are two categories in data analysis which firstly to formulate the problem into matric form using the linguistic fuzzy assessment and next to apply the proposed fuzzy MA method to rank the bidder's performances according to main criterions and also the sub-criterions.

i. Problem Formulation

This tender selection involves six alternatives or cleaning Services Company (B1, B2, B3, B4, B5 and B6). These companies are then calculated based on a set of main criterion of Gj (j=1,2,3…), which are independent to each other. Each criteria is then broke down into sub-criterion of Gjk (k=1,2,3…). Subjective assessment are given in linguistic term in order to determine two things which are:

- The degree to which each alternative satisfies each criteria and sub-criteria
- How important each criteria or sub-criteria

The default fuzzy membership function that used in the project is triangular fuzzy numbers as shown in Figure 3.1. The linguistic term

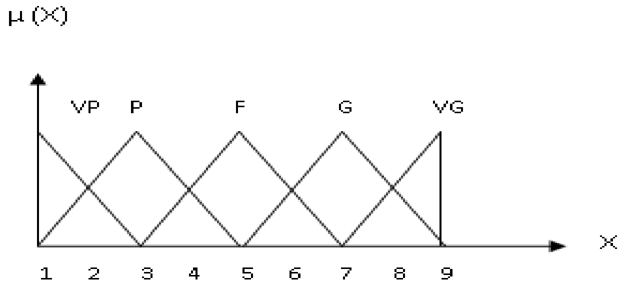

Figure 3.1: Triangular Membership Function

that used by the weighting vector is expressed in the Table 3.1 to assist the qualitative assessment in evaluating the bidder's performances [8]. Later the assessment for each sub-criterion is referred to the linguistic terms.

Table 3.1: Linguistic terms used for decision

Linguistic Terms	Very Poor (VP)	Poor (P)	Fair (F)	Good (G)	Very Good (VG)
Membership Function	(1,1,3)	(1,3,5)	(3,5,7)	(5,7,9)	(7,9,9)

Table 3.2: Linguistic terms used for weighting vectors

Linguistic Terms	Equally important	Moderately more important	Strongly more important	Very strong more important	Extremely more important
Membership Function	1	3	5	7	9

The decision matrix of m criterions and n bidders is given as (1) where its represent the linguistic assessment with respect to main criterions. If the main criterions have sub-criterion, then the decision matrix is given as (2) where its represent the linguistic assessment with respect to sub-criterions.

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1m} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & x_{nm} \end{bmatrix} \qquad (1)$$

$$Y = \begin{bmatrix} y_{11} & \cdots & y_{1m} \\ \vdots & \ddots & \vdots \\ y_{n1} & \cdots & y_{nm} \end{bmatrix} \qquad (2)$$

The weighting vector for main criterions and its sub-criterions are obtained using pairwise comparison method of AHP [11]. The linguistic term used are expressed as in Table 3.1 and represented as Equation (3) and Equation (4) where Wj is fuzzy weight for main criterions and Wjp is fuzzy weight for sub-criterions.

Wj = (W1, W2, W3, …, Wj) (3)

Wjp = (Wj1, Wj2, WJ3, …, Wjp) (4)

ii. The Proposed Fuzzy MA Method.

Fuzzy MA approach is effectively develop by taking the value functions of cumulative fuzzy assessment for each alternatives with respect to the sub-criterion for organizing the assessments on their corresponding main criterion.

The concept of degree for transforming the weighted fuzzy decision matrix into the fuzzy singleton matrix is used in order to always achieve an effective ranking outcome. The ranking procedures is based on fuzzy performances matrix which multiply the weighting factor with the decision matrix.

The weighted fuzzy assessment of all companies with respect of each criterion at the highest level is represent in the form of performance matrix. With this transformations process, the method can integrate the decision making attitude into the ranking procedure. If main criterion, Gj consists a number or sub-criterion, Gjk, the decision vector (X1j, X2j… Xnj) for all bidder with respect to main criterion, Gj is determined using:

$$(x_{1j}, x_{2j}, \dots x_{nj}) = \frac{W_j,\ Y_{Cj}}{\sum_{k=1}^{Pj} w_{jk}} \qquad (5)$$

Equation (5) calculated the normalized value for main criterion, Gj which have a multilevel hierarchy. The multiplication of weighting vector, Wj for each sub-criterion, Gjk with their equivalent decision matrix, Ycj specified the value function. Next, all the vectors of the decision matrix for each criterion is then normalized to the highest level comparable.

From the fuzzy vector (WjX1j, WjX2j… WjXnj) of the assessment matrix for main criterion, Gj, a fuzzy minimum (Mmin) and fuzzy maximum (Mmax) can be calculated to represent the best and less fuzzy performance ratings amid the bidder according to their main criterion, Gj. The membership function for Mmax and Mmin can be calculated by Equation (6):

$$\mu_{max}(x) = \begin{cases} \dfrac{D - X^j_{min}}{X^j_{max} - X^j_{min}} , & x^j_{min} \leq x \leq x^j_{max} \\ 0 , & otherwise \end{cases}$$

(6)

$$\mu_{min}(x) = \begin{cases} \dfrac{X^j_{max} - D}{X^j_{max} - X^j_{min}} , & x^j_{min} \leq x \leq x^j_{max} \\ 0 , & otherwise \end{cases}$$

The degree of ranking for which the bidder, Bi is the best bidder with respect to main criterion, Gj can be determined by comparing between the weighted fuzzy performance and Mmax value. μR(i) indicated the highest degree of ranking of bidder, Bi's weighted performance of main criterion, Cj to the Mmax value while the worst bidder according to their main criterion, Gj can be determined by associating the weighted fuzzy performance of bidder, Bi with the Mmin value.

$$\mu_R (i) = \sup (w_j, x_{ij} \cap M^j_{max})$$

(7)

$$\mu_L (i) = 1 - \sup (w_j, x_{ij} \cap M^j_{max})$$

To integrate the optimism index, λ into the fuzzy MA model, the degree of optimality concept is rooted in an alternative where multiple criteria characterize the notion of the best is applied. The decision makers is not necessary to be an optimistic or pessimistic person in the actual situation settings. An optimization index, λ (range between 0 to 1) is used to specify the relative preference between μR(i) and μL(i). In practical use, the value of λ indicates the optimization of DM. In this work, the index of λ is equal to 0.5 which applied for a moderate DM [8]. The degree of optimality of the bidder can be calculated by Equation (8) and then a fuzzy singleton matrix as in (9) is obtained.

$$r_{ij} = \frac{\lambda\, \mu_{Rj}(i) + (1 - \lambda)\, \mu_{Lj}(i)}{2} \qquad (8)$$

$$R = \begin{bmatrix} r_{11} & \cdots & r_{1m} \\ \vdots & \ddots & \vdots \\ r_{n1} & \cdots & r_{nm} \end{bmatrix} \quad (9)$$

The concept of positive and negative ideal solution is used to rank the bidder based on the fuzzy singleton matrix or weighted decision matrix. The positive ideal solution is the best criteria values while the negative ideal solution is the worst criteria values for all the bidder. The preferred bidder will be chosen based on the value of its positive and negative value. The preferred bidder should have the shortest distance from positive ideal solution and also the longest distance from negative ideal solution [8]. The positive ideal solution can be calculated as in Equation (10) while the negative ideal solution can be calculated using Equation (11).

$$S_i^+ = \sum_{j=1}^{m} (r_j^+ - r_{ij}) \quad (10)$$

$$S_i^- = \sum_{j=1}^{m} (r_{ij} - r_j^-) \quad (11)$$

Where,

$$r_j^+ = \sup(r_{1j}, r_{2j}, \dots, r_{nj}) \quad (12)$$

$$r_j^- = \inf(r_{1j}, r_{2j}, \dots, r_{nj}) \quad (13)$$

Lastly, an overall performance index for bidder with respect to main criterions can be calculated by Equation 14.

$$P_i = \frac{s_i^-}{s_i^+ + s_i^-} \quad (14)$$

The steps of the proposed method algorithm are summarized in the Figure 2.

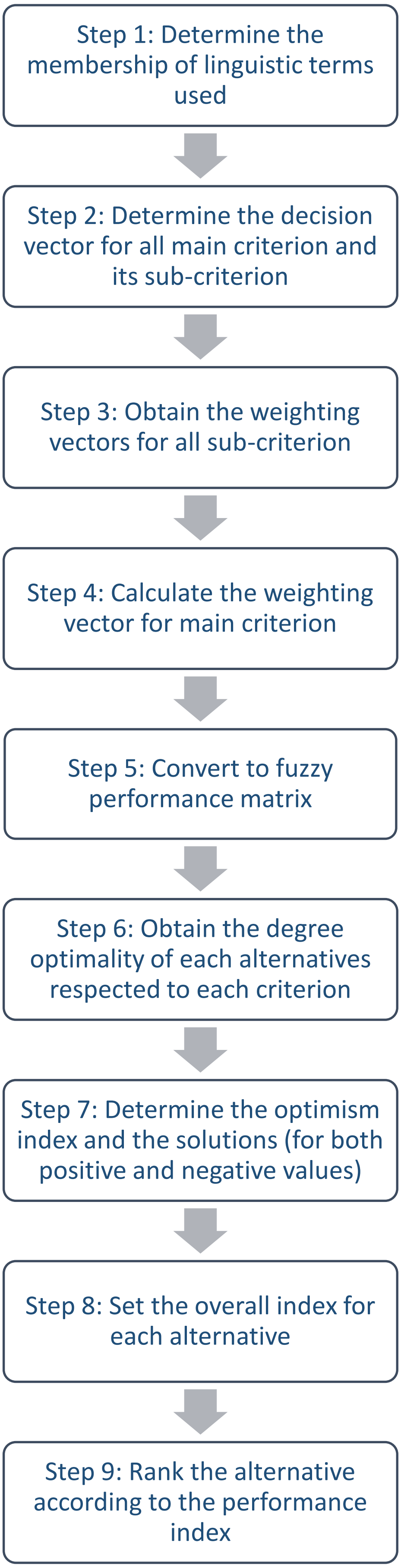

Figure 3.2: Summarize of Overall Steps

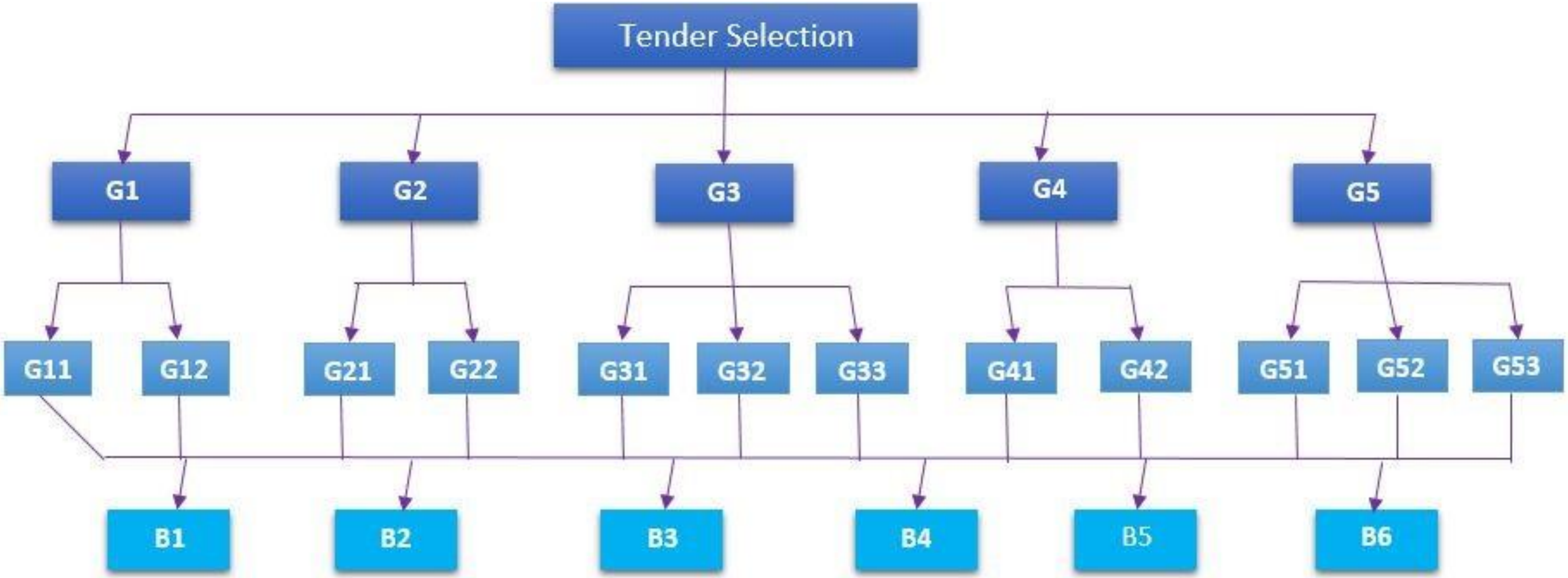

Figure 3.3: Hierarchical structure of Criterion and Sub-criterion for Tender Selection

G1: Financial Soundness G2: Technical Aspect G3: Working Methodology G4: References of Tender G5: Tenderer Qualification

G11: Price offered G12: Financial stability

G21: Specialist materials/equipment used G22: Facilities ability and availability

G31: Tools, technique and working method G32: Planning and conduct of work G33: Proposed quality approach and risk management

G41: Quality of references G42: Amount of references

G51: Aged of workers (<50 years old) G52: Company status (Register with PETRONAS) G53: Experience (>5years)

B1: Bidder 1 B2: Bidder 2 B3: Bidder 3 B4: Bidder 4 B5: Bidder 5 B6: Bidder 6

CHAPTER 4

RESULTS AND DISCUSSION

The main objective of this project is to select the preferred cleaning service tender. All the data obtained was analyzed by using the proposed Fuzzy method in order to get the ranking index. Highest index indicated highest ranking and vice versa. All the results were interpreted in table and supported with relevant theories of study.

The corresponding data for all sub-criterion that constitute each of the five main criterion are discussed below.

i. Financial Soundness (G1)

Financial soundness is referred to two things which are the price offered by the bidder (G11) and also the financial stability of the bidder (G12). The User will provide the requirements such as the number of workers, the working hours and also job descriptions according to place that need to be clean. Based on the information, the bidder will come out with price quotation. Very good criteria for G11 indicate that price offered by the bidder is the lowest among the other bidder while financial stability is determined by bank statement provided from the bidder. Below are the linguistic assessment data for financial soundness:

Table 4.1: Linguistic Assessment Data for Financial Soundness

G1	B1	B2	B3	B4	B5	B6
G11	P (1,3,5)	VG (7,9,9)	G (5,7,9)	F (3,5,7)	F (3,5,7)	VP (1,1,3)
G12	G (5,7,9)	VG (7,9,9)	VG (7,9,9)	VG (7,9,9)	G (5,7,9)	G (5,7,9)

ii. Technical Aspect (G2)

Second main criterion is specify on the equipment and facilities that the bidder has. It then be divided into two sub-criterion which are specialist materials/equipment that the bidder has to be used in cleaning process (G21) and the ability and availability of the equipment (G22). Below are the linguistic assessment data for technical aspect:

Table 4.2: Linguistic Assessment Data for Technical Aspec

G2	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**
G21	F (3,5,7)	G (5,7,9)	G (5,7,9)	P (1,3,5)	P (1,3,5)	VG (7,9,9)
G22	G (5,7,9)	G (5,7,9)	G (5,7,9)	F (3,5,7)	G (5,7,9)	G (5,7,9)

iii. Working Methodology (G3)

The third main criterion is focused more on proposed methodology from the bidder. As the User will provide information on the place or area to be clean, the bidder themselves need to come out with working methodology, planning on working hours for each their workers and provide the Tender Owner with proposed quality approach and risk management paper. A good proposal on health, safety and environment (HSE) indicated a good company's quality. Thus, the working methodology is divided into three sub-criterion which are tools, technique and working method (G31), planning and conduct of work (G32) and proposed quality approach and risk management (G33). Below are the linguistic assessment data for working methodology:

Table 4.3: Linguistic Assessment Data for Working Methodology

G3	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**
G31	F (3,5,7)	G (5,7,9)	G (5,7,9)	F (3,5,7)	G (5,7,9)	G (5,7,9)
G32	F (3,5,7)	VG (7,9,9)	F (3,5,7)	VG (7,9,9)	VP (1,1,3)	P (1,3,5)
G33	VG (7,9,9)	F (3,5,7)	F (3,5,7)	G (5,7,9)	F (3,5,7)	F (3,5,7)

iv. References of Tenderer (G4)

References of tenderer means that the bidder should be able to provide proof regarding the company's experience or past tender and related document on license. This main criterion is divided into two sub-criterion which are quality of references (G41) and the amount of references (G42). Below are the linguistic assessment data for references of tenderer:

Table 4.4: Linguistic Assessment Data for References of Tenderer

G4	B1	B2	B3	B4	B5	B6
G41	G (5,7,9)	G (5,7,9)	G (5,7,9)	F (3,5,7)	F (3,5,7)	F (3,5,7)
G42	G (5,7,9)	VG (7,9,9)	VG (7,9,9)	G (5,7,9)	P (1,3,5)	P (1,3,5)

v. Tenderer Qualification (G5)

There are three sub-criterion for the fifth main criterion which are aged of workers must be less than 50 years old (G51), company status must already register under PETRONAS (G52) and years of experience must be more than 5 years (G53). All this sub-criterion are flat requirement from the User for all the bidder, which means that if the bidder has workers that aged above than 50 years old, or did not register under PETRONAS, or the company experiences is less than 5 years, the bidder will immediately disqualified from the tender and will not even put into the list. Below are the linguistic assessment data for tenderer qualification:

Table 4.5: Linguistic Assessment Data for Tenderer Qualification

G5	B1	B2	B3	B4	B5	B6
G51	VG (7,9,9)	VG (7,9,9)	VG (7,9,9)	VG (7,9,9)	VP (1,1,3)	VP (1,1,3)
G52	VG (7,9,9)	VG (7,9,9)	VG (7,9,9)	VG (7,9,9)	VG (7,9,9)	VG (7,9,9)
G53	G (5,7,9)	VG (7,9,9)	VG (7,9,9)	G (5,7,9)	P (1,3,5)	F (3,5,7)

Table 4.6 shown the list of weight vector for five main criterions and their associated sub-criterion that have been calculated using the pairwise comparison of AHP method, where the assessment data are compared with the linguistic terms in Table 3.2. Based on the relative importance among the criterions, the weighting vector for each criterions and sub-criterions are retrieved [4].

Table 4.6: Weighting vector for main criteria and it's sub-criterion

Weighting vector	Fuzzy criteria weights
W	((0.26), (0.066), (0.034), (0.114), (0.502))
W1	((3.00), (0.25))
W2	((0.25), (3.00))
W3	((0.05), (0.26), (0.32))
W4	(3.00), (0.25)
W5	((0.05), (0.32), (0.26))

Thus, the overall linguistic assessment results for all sub-criterions are listed in table below.

Table 4.7: Linguistic assessment results for Financial Soundness, G1

G1	B1	B2	B3	B4	B5	B6
G11	0.1	0.3	0.23	0.17	0.17	0.03
G12	0.15	0.19	0.19	0.19	0.15	0.15

Table 4.8: Linguistic assessment results for Technical Aspect, G2

G2	B1	B2	B3	B4	B5	B6
G21	0.15	0.21	0.21	0.09	0.09	0.26
G22	0.18	0.18	0.18	0.13	0.18	0.18

Table 4.9: Linguistic assessment results for Working Methodology, G3

G3	B1	B2	B3	B4	B5	B6
G31	0.13	0.18	0.18	0.13	0.18	0.18
G32	0.16	0.28	0.16	0.28	0.03	0.09
G33	0.25	0.14	0.14	0.19	0.14	0.14

Table 4.10: Linguistic assessment results for References of Tenderer, G4

G4	B1	B2	B3	B4	B5	B6
G41	0.19	0.19	0.19	0.14	0.14	0.14
G42	0.18	0.24	0.24	0.18	0.08	0.08

Table 4.11: Linguistic assessment results for Tenderer Qualification, G5

G5	B1	B2	B3	B4	B5	B6
G51	0.24	0.24	0.24	0.24	0.03	0.03
G52	1.00	1.00	1.00	1.00	1.00	1.00
G53	0.18	0.23	0.23	0.18	0.08	0.13

Equation (5) is used to normalize value function for criterions that have multilevel hierarchy. Therefore, the modal of value function can be describe in matrix form, D:

$$D = \begin{bmatrix} 0.34 & 0.95 & 0.74 & 0.56 & 0.55 & 0.13 \\ 0.58 & 0.59 & 0.59 & 0.41 & 0.56 & 0.61 \\ 0.13 & 0.13 & 0.10 & 0.14 & 0.06 & 0.08 \\ 0.62 & 0.63 & 0.63 & 0.47 & 0.44 & 0.44 \\ 0.38 & 0.39 & 0.39 & 0.38 & 0.34 & 0.36 \end{bmatrix}$$

Given the decision vector, D value of fuzzy maximum and fuzzy minimum can be determine on the real line.

Fuzzy maximum, (X_{max}^{j}) = 0.95

Fuzzy minimum, (X_{min}^{j}) = 0.06

Next, by using the fuzzy vector, fuzzy maximum, (X_{max}^{j}) and fuzzy minimum, (X_{min}^{j}) obtained above, the value of $\mu_{max}(x)$ and $\mu_{min}(x)$ can be calculated.

$$\mu_{max}(x) = \frac{D - X_{min}^{j}}{X_{max}^{j} - X_{min}^{j}}$$

$$\mu_{min}(x) = \frac{X_{max}^{j} - D}{X_{max}^{j} - X_{min}^{j}}$$

The calculated value of $\mu_{max}(x)$ and $\mu_{min}(x)$ are represented in matrix below:

$$\mu_{max}(x) = \begin{bmatrix} 0.31 & 1.0 & 0.76 & 0.56 & 0.55 & 0.08 \\ 0.58 & 0.60 & 0.60 & 0.39 & 0.56 & 0.62 \\ 0.08 & 0.08 & 0.04 & 0.09 & 0 & 0.02 \\ 0.63 & 0.64 & 0.64 & 0.46 & 0.43 & 0.43 \\ 0.36 & 0.37 & 0.37 & 0.36 & 0.31 & 0.34 \end{bmatrix}$$

$$\mu_{min}(x) = \begin{bmatrix} 0.69 & 0 & 0.24 & 0.44 & 0.45 & 0.92 \\ 0.42 & 0.40 & 0.40 & 0.61 & 0.44 & 0.38 \\ 0.92 & 0.92 & 0.96 & 0.91 & 1.0 & 0.98 \\ 0.37 & 0.36 & 0.36 & 0.54 & 0.57 & 0.57 \\ 0.64 & 0.63 & 0.63 & 0.64 & 0.69 & 0.66 \end{bmatrix}$$

Matrix $\mu_R(i)$ indicated the highest degree of ranking by comparing matrix $\mu_{max}(x)$ with matrix D. While matrix Sup (min) shown the lowest degree of ranking by comparing matrix $\mu_{min}(x)$ with matrix D which will be used to calculate $\mu_L(i)$ as shown in matrix $\mu_L(i)$.

$$\mu_R(i) = \sup(D \cap \mu_{max}(x))$$

$$\mu_R(i) = \begin{bmatrix} 0.34 & 1.0 & 0.76 & 0.56 & 0.55 & 0.13 \\ 0.58 & 0.60 & 0.60 & 0.41 & 0.56 & 0.62 \\ 0.13 & 0.13 & 0.10 & 0.14 & 0.06 & 0.08 \\ 0.63 & 0.64 & 0.64 & 0.47 & 0.44 & 0.44 \\ 0.38 & 0.39 & 0.39 & 0.38 & 0.34 & 0.36 \end{bmatrix}$$

$$\text{Sup (min)} = D \cap \mu_{min}(x)$$

$$\text{Sup (min)} = \begin{bmatrix} 0.34 & 0 & 0.24 & 0.44 & 0.45 & 0.13 \\ 0.42 & 0.40 & 0.40 & 0.41 & 0.44 & 0.38 \\ 0.13 & 0.13 & 0.10 & 0.14 & 0.06 & 0.08 \\ 0.37 & 0.36 & 0.36 & 0.47 & 0.44 & 0.44 \\ 0.38 & 0.39 & 0.39 & 0.38 & 0.34 & 0.36 \end{bmatrix}$$

$$\mu_L(i) = 1 - \text{Sup (min)}$$

$$\mu_L(i) = \begin{bmatrix} 0.66 & 1.0 & 0.76 & 0.56 & 0.55 & 0.87 \\ 0.58 & 0.60 & 0.60 & 0.59 & 0.56 & 0.62 \\ 0.87 & 0.87 & 0.90 & 0.86 & 0.94 & 0.92 \\ 0.63 & 0.64 & 0.64 & 0.53 & 0.56 & 0.56 \\ 0.62 & 0.61 & 0.61 & 0.62 & 0.6 & 0.64 \end{bmatrix}$$

The degree of optimality of the bidder are calculated as Equation (8). By using λ=0.5, the degree of optimality alternatives can be calculated and shown in matrix R.

	B1	B2	B3	B4	B5	B6
G1	$\frac{0.34\lambda + 0.66\,(1-\lambda)}{2}$	$\frac{1.0\lambda + 1.0\,(1-\lambda)}{2}$	$\frac{0.76\lambda + 0.76\,(1-\lambda)}{2}$	$\frac{0.56\lambda + 0.56\,(1-\lambda)}{2}$	$\frac{0.55\lambda + 0.55\,(1-\lambda)}{2}$	$\frac{0.13\lambda + 0.87\,(1-\lambda)}{2}$
G2	$\frac{0.58\lambda + 0.58\,(1-\lambda)}{2}$	$\frac{0.60\lambda + 0.60\,(1-\lambda)}{2}$	$\frac{0.60\lambda + 0.60\,(1-\lambda)}{2}$	$\frac{0.41\lambda + 0.59\,(1-\lambda)}{2}$	$\frac{0.56\lambda + 0.56\,(1-\lambda)}{2}$	$\frac{0.62\lambda + 0.62\,(1-\lambda)}{2}$
G3	$\frac{0.13\lambda + 0.87\,(1-\lambda)}{2}$	$\frac{0.13\lambda + 0.87\,(1-\lambda)}{2}$	$\frac{0.10\lambda + 0.90\,(1-\lambda)}{2}$	$\frac{0.14\lambda + 0.89\,(1-\lambda)}{2}$	$\frac{0.06\lambda + 0.94\,(1-\lambda)}{2}$	$\frac{0.08\lambda + 0.92\,(1-\lambda)}{2}$
G4	$\frac{0.63\lambda + 0.63\,(1-\lambda)}{2}$	$\frac{0.64\lambda + 0.64\,(1-\lambda)}{2}$	$\frac{0.64\lambda + 0.64\,(1-\lambda)}{2}$	$\frac{0.47\lambda + 0.53\,(1-\lambda)}{2}$	$\frac{0.44\lambda + 0.56\,(1-\lambda)}{2}$	$\frac{0.44\lambda + 0.56\,(1-\lambda)}{2}$
G5	$\frac{0.38\lambda + 0.62\,(1-\lambda)}{2}$	$\frac{0.39\lambda + 0.61\,(1-\lambda)}{2}$	$\frac{0.39\lambda + 0.61\,(1-\lambda)}{2}$	$\frac{0.38\lambda + 0.62\,(1-\lambda)}{2}$	$\frac{0.34\lambda + 0.60\,(1-\lambda)}{2}$	$\frac{0.36\lambda + 0.64\,(1-\lambda)}{2}$

$$R = \begin{bmatrix} 0.25 & 0.50 & 0.38 & 0.28 & 0.275 & 0.25 \\ 0.29 & 0.30 & 0.30 & 0.25 & 0.28 & 0.31 \\ 0.25 & 0.25 & 0.25 & 0.258 & 0.25 & 0.25 \\ 0.315 & 0.32 & 0.32 & 0.25 & 0.25 & 0.25 \\ 0.25 & 0.25 & 0.25 & 0.25 & 0.235 & 0.25 \end{bmatrix}$$

Hamming distance method is used to rank the alternatives based on the R matrix. By using Equation (12) and Equation (13), the results are shown in Table 4.12.

Table 4.12: Positive and Negative ideal solution for Hamming distance

Positive ideal solution, r_j^+		Negative ideal solution, r_j^-	
r_1^+	0.315	r_1^-	0.25
r_2^+	0.50	r_2^-	0.25
r_3^+	0.38	r_3^-	0.25
r_4^+	0.28	r_4^-	0.25
r_5^+	0.28	r_5^-	0.235
r_6^+	0.31	r_6^-	0.25

The positive ideal solution are calculated using Equation (10) as below:

s_1^+ = (0.315-0.25) + (0.315-0.29) + (0.315-0.25) + (0.315-0.315) + (0.315-0.25) = 0.22

s_2^+ =(0.5-0.5) + (0.5-0.3) + (0.5-0.25) + (0.5-0.32) + (0.5-0.25) = 0.88

s_3^+ = (0.38-0.38) + (0.38-0.3) + (0.38-0.25) + (0.38-0.32) + (0.38-0.25) = 0.4

s_4^+ = (0.28-0.28) + (0.28-0.25) + (0.28-0.258) + (0.28-0.25) + (0.28-0.25) = 0.112

s_5^+ = (0.28-0.275) + (0.28-0.28) + (0.28-0.25) + (0.28-0.25) + (0.28-0.235) = 0.11

s_6^+ = (0.31-0.25) + (0.31-0.31) + (0.31-0.25) + (0.31-0.25) + (0.31-0.235) = 0.24

The negative ideal solution calculated one by one using Equation (11) as below:

s_1^- = (0.25-0.25) + (0.29-0.25) + (0.25-0.25) + (0.315-0.25) + (0.25-0.25) = 0.105

s_2^- =(0.5-0.25) + (0.3-0.25) + (0.25-0.25) + (0.32-0.25) + (0.25-0.25) = 0.12

s_3^- = (0.38-0.25) + (0.3-0.25) + (0.25-0.25) + (0.32-0.25) + (0.25-0.25) = 0.25

s_4^- = (0.28-0.25) + (0.25-0.25) + (0.258-0.25) + (0.25-0.25) + (0.25-0.25) = 0.038

s_5^- =(0.275-0.235) + (0.28-0.235) + (0.25-0.235) + (0.25-0.235) + (0.235-0.235)=0.115

s_6^- = (0.31-0.25) + (0.31-0.31) + (0.31-0.25) + (0.31-0.25) + (0.31-0.25) = 0.06

From the positive ideal solution values and negative ideal solution values, the overall performance index for each bidders are calculated using Equation (14) and concluded as Table 4.13.

Table 4.13: Overall performance index and ranking of bidders

Bidder	Index	Ranking
B1	0.32	3
B2	0.12	6
B3	0.38	2
B4	0.25	4
B5	0.51	1
B6	0.20	5

From Table 4.13, it is determined that B5 and B3 will be chosen to be reward the tender. This shown that bidder B5 and bidder B3 have better overall quality from the other bidders. However, the ranking of bidder depending on each main criterion may be vary and this are shown next. The methodology to calculate the values for each criterions are similar with calculation of overall performance.

a. Financial Soundness (G1)

Fuzzy maximum, (X_{max}^{j}) = 0.95

Fuzzy minimum, (X_{min}^{j}) = 0.13

(X_{max}^{j}) - (X_{min}^{j}) = 0.82

$\mu_{max}(x) = [0.26 \quad 1 \quad 0.74 \quad 0.52 \quad 0.51 \quad 0]$

$\mu_{min}(x) = [0.74 \quad 0 \quad 0.26 \quad 0.48 \quad 0.49 \quad 1]$

$\mu_{R}(i) = [0.34 \quad 1 \quad 0.74 \quad 0.56 \quad 0.55 \quad 0.13]$

$\mu_{L}(i) = [0.66 \quad 1 \quad 0.74 \quad 0.52 \quad 0.51 \quad 0.87]$

	B1	B2	B3	B4	B5	B6
G1	$\frac{0.34\lambda + 0.66\,(1-\lambda)}{2}$	$\frac{1.0\lambda + 1.0\,(1-\lambda)}{2}$	$\frac{0.74\lambda + 0.74\,(1-\lambda)}{2}$	$\frac{0.56\lambda + 0.52\,(1-\lambda)}{2}$	$\frac{0.55\lambda + 0.51\,(1-\lambda)}{2}$	$\frac{0.13\lambda + 0.87\,(1-\lambda)}{2}$

R = [0.25 0.5 0.37 0.27 0.27 0.25]

Table 4.14: Performance index and ranking of bidders based on Financial Soundness, G1

Bidder	Index	Ranking
B1	0.25	4
B2	0.5	1
B3	0.37	2
B4	0.27	3
B5	0.27	3
B6	0.25	4

b. Technical Aspect (G2)

Fuzzy maximum, (X^j_{max}) = 0.61

Fuzzy minimum, (X^j_{min}) = 0.41

(X^j_{max}) - (X^j_{min}) = 0.20

$\mu_{max}(x) = [0.85 \quad 0.9 \quad 0.9 \quad 0 \quad 0.75 \quad 1]$

$\mu_{min}(x) = [0.15 \quad 0.1 \quad 0.1 \quad 1 \quad 0.25 \quad 0]$

$\mu_R(i) = [0.85 \quad 0.9 \quad 0.9 \quad 0.41 \quad 0.75 \quad 1]$

$\mu_L(i) = [0.85 \quad 0.9 \quad 0.9 \quad 0.59 \quad 0.75 \quad 1]$

	B1	B2	B3	B4	B5	B6
G1	$\frac{0.85\lambda + 0.85\,(1 - \lambda)}{2}$	$\frac{0.9\lambda + 0.9\,(1 - \lambda)}{2}$	$\frac{0.9\lambda + 0.9\,(1 - \lambda)}{2}$	$\frac{0.41\lambda + 0.59\,(1 - \lambda)}{2}$	$\frac{0.75\lambda + 0.75\,(1 - \lambda)}{2}$	$\frac{1.0\lambda + 1.0\,(1 - \lambda)}{2}$

R = [0.43 0.45 0.45 0.25 0.38 0.5]

Table 4.15: Performance index and ranking of bidders based on Technical Aspect, G2

Bidder	**Index**	**Ranking**
B1	0.43	3
B2	0.45	2
B3	0.45	2
B4	0.25	5
B5	0.38	4
B6	0.50	1

c. Working Methodology (G3)

Fuzzy maximum, (X^j_{max}) = 0.14

Fuzzy minimum, (X^j_{min}) = 0.06

(X^j_{max}) - (X^j_{min}) = 0.08

$\mu_{max}(x)$ = [0.88 0.88 0.5 1 0 0.25]

$\mu_{min}(x)$ = [0.13 0.13 0.5 0 1 0.75]

$\mu_R(i)$ = [0.88 0.88 0.5 1 0.06 0.25]

$\mu_L(i)$ = [0.87 0.87 0.9 1 0.94 0.92]

	B1	B2	B3	B4	B5	B6
G1	$\frac{0.88\lambda + 0.87\,(1-\lambda)}{2}$	$\frac{0.88\lambda + 0.87\,(1-\lambda)}{2}$	$\frac{0.5\lambda + 0.9\,(1-\lambda)}{2}$	$\frac{1.0\lambda + 1.0\,(1-\lambda)}{2}$	$\frac{0.06\lambda + 0.94\,(1-\lambda)}{2}$	$\frac{0.25\lambda + 0.92\,(1-\lambda)}{2}$

R = [0.44 0.44 0.23 0.5 0.25 0.29]

Table 4.16: Performance index and ranking of bidders based on Working Methodology, G3

Bidder	Index	Ranking
B1	0.44	2
B2	0.44	2
B3	0.23	5
B4	0.50	1
B5	0.25	4
B6	0.29	3

d. References of Tenderer (G4)

Fuzzy maximum, (X^{j}_{max}) = 0.63

Fuzzy minimum, (X^{j}_{min}) = 0.44

(X^{j}_{max}) - (X^{j}_{min}) = 0.19

$\mu_{max}(x)$ = [0.95 1 1 0.16 0 0]

$\mu_{min}(x)$ = [0.05 0 0 0.84 1 1]

$\mu_{R}(i)$ = [0.95 1 1 0.47 0.44 0.44]

$\mu_{L}(i)$ = [0.95 1 1 0.53 0.56 0.56]

	B1	B2	B3	B4	B5	B6
G1	$\frac{0.95\lambda + 0.95\,(1-\lambda)}{2}$	$\frac{1.0\lambda + 1.0\,(1-\lambda)}{2}$	$\frac{1.0\lambda + 1.0\,(1-\lambda)}{2}$	$\frac{0.47\lambda + 0.53\,(1-\lambda)}{2}$	$\frac{0.44\lambda + 0.56\,(1-\lambda)}{2}$	$\frac{0.44\lambda + 0.56\,(1-\lambda)}{2}$

R = [0.48 0.5 0.5 0.25 0.25 0.25]

Table 4.17: Performance index and ranking of bidders based on References of Tenderer, G4

Bidder	Index	Ranking
B1	0.48	2
B2	0.50	1
B3	0.50	1
B4	0.25	3
B5	0.25	3
B6	0.25	3

e. Tenderer Qualification (G5)

Fuzzy maximum, (X^j_{max}) = 0.39

Fuzzy minimum, (X^j_{min}) = 0.34

(X^j_{max}) - (X^j_{min}) = 0.05

$\mu_{max}(x) = [0.8 \quad 1 \quad 1 \quad 0.8 \quad 0 \quad 0.4]$

$\mu_{min}(x) = [0.2 \quad 0 \quad 0 \quad 0.2 \quad 1 \quad 1]$

$\mu_R(i) = [0.8 \quad 1 \quad 1 \quad 0.8 \quad 0.34 \quad 0.4]$

$\mu_L(i) = [0.8 \quad 1 \quad 1 \quad 0.8 \quad 0.66 \quad 0.64]$

	B1	B2	B3	B4	B5	B6
G1	$\frac{0.8\lambda + 0.8\,(1-\lambda)}{2}$	$\frac{1.0\lambda + 1.0\,(1-\lambda)}{2}$	$\frac{1.0\lambda + 1.0\,(1-\lambda)}{2}$	$\frac{0.8\lambda + 0.8\,(1-\lambda)}{2}$	$\frac{0.34\lambda + 0.66\,(1-\lambda)}{2}$	$\frac{0.4\lambda + 0.64\,(1-\lambda)}{2}$

R = $[0.4 \quad 0.5 \quad 0.5 \quad 0.4 \quad 0.25 \quad 0.26]$

Table 4.18: Performance index and ranking of bidders based on Tenderer Qualification, G5

Bidder	Index	Ranking
B1	0.40	2
B2	0.50	1
B3	0.50	1
B4	0.40	2
B5	0.25	4
B6	0.26	3

The overall performance index and ranking according to each main criterion shown in Table 4.19.

Table 4.19: Overall performance index and ranking of bidders according to main criterions

Bidder	Criteria Weight									
	G1		G2		G3		G4		G5	
	Index	Ranking	Index	Ranking	Index	Ranking	Index	Ranking	Index	Ranking
B1	0.25	4	0.43	3	0.44	2	0.48	2	0.40	2
B2	0.5	1	0.45	2	0.44	2	0.50	1	0.50	1
B3	0.37	2	0.45	2	0.23	5	0.50	1	0.50	1
B4	0.27	3	0.25	5	0.50	1	0.25	3	0.40	2
B5	0.27	3	0.38	4	0.25	4	0.25	3	0.25	4
B6	0.25	4	0.50	1	0.29	3	0.25	3	0.26	3

The result indicated that the best ranking for Financial Soundness, G1 is B2 while for Technical Aspect, G2 is B6. The best ranking for Working Methodology, G3 is B4. While for both G4 and G5, there are two best bidders which are B2 and B3. This shows that each bidder has their own weakness and strength with respect to the main criterion.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

This chapter concludes all the findings in the project as well as provides recommendations of future works that can be done using the proposed Fuzzy MA method.

On a final note, the objectives of the project is accomplished. The main focus of using Fuzzy method in tender selection is because the subjective and imprecise process of selecting tender which is the nature of fuzzy logic. Using linguistic terms in fuzzy assessment are the most effective and intuitive way that DM normally use in the selection process [8]. Discussed in Chapter 1, the lack of current method and the proposed Fuzzy MA method that can overcome the problem faced during tender selection.

Relevant background information pertaining the tender evaluation and fuzzy methods was summarized in Chapter 2. The importance of fuzzy rule in subjective evaluation and its advantage was discussed. Chapter 3 described the data representation into two parts – Data Collection and Data Analysis. Chapter 4 discussed the results of evaluation using fuzzy MA and fuzzy AHP. The data gathered are generated by rule proposed method was demonstrated.

Thus, in this study, the use of effective fuzzy MA method approach is proposed in order to select the most suitable bidder. This is because the method not only evaluate based on the criterion, but it also will provides crisp ranking outcomes for the selection problem. By using the ranking calculated, the Tender Owner will receive information on which companies/bidder that will be selected.

For the future works of this project, it is proposed that a software computer can be develop to implement the proposed method and compare the results with other MCDM method. This is because computer software can help decision makers to apply this proposed method fast and precisely [9].

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APPENDIX

Table 6.1: Gantt chart and Key Milestones for FYP1

Details/Week	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***
Project Title Selection														
Preliminary Research Work														
• Fundamental understanding														
• Proposal writing														
Extended Proposal Submission														
Proposal Defense (PD) presentation														
• Slide Preparation														
• Presentation														
Continuation of project work														
• Conduct related survey														
• Report writing														
Interim Draft Report Submission														
Interim Report Submission														

Process

Suggested key milestones

Table 6.2: Gantt chart and Key Milestones for FYP2

Details/Week	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***
Continuation of project work														
• Results of MA method														
• Report writing														
Progress Report Submission														
Continuation of project work														
• Comparing results														
• Report writing continues														
Pre-SEDEX presentation														
• Poster preparation														
• Presentation														
Draft Final Report Submission														
Dissertation (soft bound) Submission														
Technical Paper Submission														
Viva presentation														
• Slide preparation														
• Presentation														
Project Dissertation (hard bound) Submission														

Process

Suggested key milestones