INCORPORATION OF DECISION ENGINE IN ELECTRONIC PROCUREMENT MODEL USING FUZZY MCDM

by

Md. Ashek-Al-Aziz

A Project work submitted in partial fulfillment of the requirements for the degree of Master of Engineering in Advanced Engineering Management

Department of Industrial and Production Engineering

Bangladesh University of Engineering and Technology

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CERTIFICATE OF APPROVAL

The Project work titled 'INCORPORATION OF DECISION ENGINE IN ELECTRONIC PROCUREMENT MODEL USING FUZZY MCDM' submitted by Md. Ashek-Al-Aziz, Roll No.- 040808-104P, Session- April, 2008 has been accepted as satisfactory in partial fulfillment of the degree of Master of Engineering in Advanced Engineering Management on December 17, 2012

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Department of Industrial and Production Engineering
Bangladesh University of Engineering and Technology

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CANDIDATE'S DECLARATION

It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

Md. Ashek-Al-Aziz

This book is dedicated to the people who have fought against corruption since the birth of Peoples’ Republic of Bangladesh.

ACKNOWLEDGEMENT

I wish to acknowledge Foriborz Jolai that he did a valuable work on fuzzy MCDM method for bidder selection useful for procurement process on which I could have tried to implicate and fit it into our local e-GP access model. The government of Bangladesh has done a great deal on forming an e-GP model which can be an umbrella for electronic procurement system in Bangladesh. I wish some of my friends who have guided me to think properly to solve the problem. Finally, my supervisor Prof. Dr. Abdullahil Azeem helped to select the background and state of the art perfectly and guided to formulate the outcomes of this complete thesis work.

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LIST OF ABBREVIATIONS

A2I: Access to Information

AGP: Advanced Goal Programming

B2B: Business to Business

B2C: Business to Customer

B2G: Business to Government

DE: Decision Engine

DM: Decision Maker

e-GP: Electronic Government Procurement

EM: Electronic Marketplace

GOB: Government of Bangladesh

GPPC: Government Procurement Process Cycle

LP: Linear Programming

MCDM: Multi Criteria Decision Making

MOMILP: Multiple Object Mixed Integer Linear Progamming

PPA: Public Procurement Act

PMM: Procurement Maturity Model

PPR: Public Procurement Rule

RTI: Right to Information

ABSTRACT

In order to fulfill the right to information of Bangladeshi people, government has initiated A2I program promoting automation, informationization and transformationization which all are required for successful electronic procurement practice. Central Procurement Technical Unit (CPTU) has adopted the e-GP Access Model consists of the domain like General Public, Development Partners, Tendering Community, Evaluation Committee, Procuring Agencies, Payment Service Providers, Operations & Maintenance Partners, e-GP Administrator. This buyer centric model has been modified to e-Marketplace model also incorporating Decision Engine consists of few subsystems of Procurement Risk Identifier, Bidder Selector, Procurement Maturity Level Identifier and Anti Spyware which were absent in e-GP Access Model. Procurement Risk Identifier is developed based on Raymond J Madacy's software procurement model where the attributes for procurement project risk are taken with some revision and fuzzy MCDM is applied for those risk attributes to determine the risk level. A risk mitigation algorithm is presented to mitigate the risk found. Beside, the Bidder Selector is outlined with revision of Foriborz Jolai's model incorporating Price Break Model for considering quantity discount offer which was not found in Jolai model. Procurement maturity is another aspect for professional attitude for organizational and administrative practices. Measurement method for professional maturity in procurement practice is discussed with the application of fuzzy MCDM on the criteria derived by Stephen Guth and grading method is discussed with combining both Stephen Guth and Wilco Van Duinkerken scale of procurement maturity. Finally fuzzy MCDM results have been compared with normal AHP result for the same choice of preference used in the illustrations.

CHAPTER 1

INTRODUCTION

1.1 Background

Procurement is a mandatory practice as a requirement for running operations in both Public and Private sectors. Procurement for huge variety of commodities, equipments and services are found in this practice. We would not be concerned about this practice with high emphasis if it would be limited to purchase the required items from market simply. The scenario becomes so important where the purchase involves the minimization of cost in a business, effective for people and society even maximizing the benefit of the target people. Such requirement of optimization has caught our attention into the method of practice of procurement. In our local context, the scenario is more disastrous where no transparency is found in public sector.

Government of Peoples' Republic of Bangladesh tried to establish a foundation for fulfilling the right to know the information for her people first and then the way to avoid the rough practice of biasing in public procurement process by muscle power and being biased for personal interest that produce corruption and malpractices which are not unknown in our society. Bangladesh took the first initiative in the year of 2009 through the act of Right to Information (RTI). For implementation of this act, Government took a project named Access to Information (A2I). The responsibility of A2I is to promote e-Governance by means of automation, informationization and transformation which all are also required for successful e-procurement practice [1]. This was a great event but there exist a long journey behind it.

The practice of corruption is the major challenge in the smooth operation in the administration including procurement. Administrative and legislative reforms required a great deal of interest. Public procurement is such a part of operational practice where huge amount of money are spent. Unfortunately money is not spent through corruption free process. Shakeel Ahmed Ibn Mahmood [2] wrote in his paper that unexpected delay of procurement process found in a survey of 148 procurement cases which causes serious corruption. Usually a tender is declared to mass media usually print media for advertisement, then interested bidders purchases the bidding documents, prepare technical and financial proposals, submit it to tender box within the dateline, after that the proposals are opened in front of bidders only. Next the process of evaluation comes which is totally closed to bidders and all others. There is no scope to observe the process of evaluation how it is done by the respective authority. In some cases, procurement committee is formed consists of members from procuring organization usually called procuring entity, from other organization and relevant expertise from outside but the process of evaluation is still in the dark. When the selection is finalized the award goes to the selected bidder. If the whole process takes too long period, it does adopt some corrupted practice behind the scene which makes significant lack of utilizing money in procurement expense that can ultimately affect the operational activities. Such unexpected delay means unacceptable inefficiency.

The underdeveloped countries like Bangladesh suffer this type of fever of corruption where procurement is vital part of administrative and operational activities for development. World Bank has been observed this fever over time and tried to minimize the potentialities of corruption scopes in procurement. Because World Bank is one of the world's popular and large development partner and she has been investing in various under developed countries for development through bilateral relationships. Obviously it is expected that the fund sanctioned by World Bank is spent properly by the respective governments and projects become successful so that the financial institution gets its investment back in time with required interest. Procurement is a vital factor for bringing success in any project. World Bank introduced a model involving many entities which in discussed by both Hasan Murad[1] and Shakeel Ahmed Ibn Mahmood[2]. The model was accepted by Central Procurement Technical Unit (CPTU) of Government of Peoples' Republic of Bangladesh which is a sandwich model of Public Administration and Information & Communication Technology (ICT). This model is known as e-GP Access Model depicted in Figure 1.1.

The e-GP Access Model adopted by CPTU consists of several domain like General Public, Development Parnters, Tendering Community, Evaluation Committee, Procuring agencies, Payment Service Providers, Operations & Maintenance Partners, e-GP administrator. Such involvement of these representative enhances the procurement process from the dark to clarity. But we think that there is still missing of the procedure and relevant code of coduct for the evaluation committee. If the evaluation committee takes too long time to decide about a selection in a tender, there would be opportunity for the adversary to incorporate corruption in implementation of this model. That is why we feel for incorporation of a Decision Engine that will enable the evaluator to follow a systematic approach for evaluation of bidders in all tendering process.

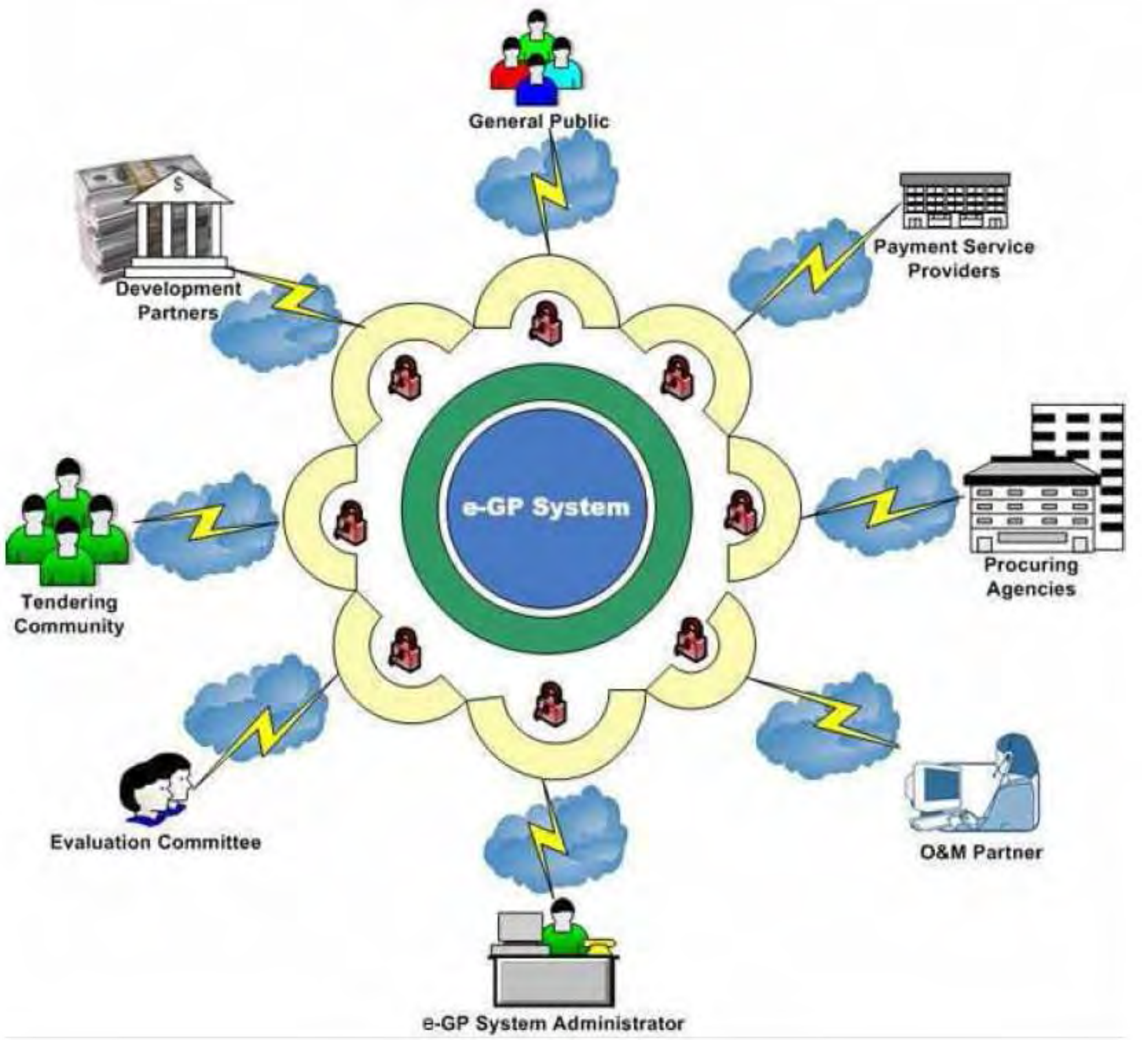

Figure 1.1: Diagram of e-GP Access Model

1.2 Decision Engine for Electronic Procurement Model

In this thesis work, we have tried to incorporate a Decision Engine that consists of four subsystems called Risk Identifier, Bidder Selector, Procurement Maturity Identifier and Anti Spam Wire & Security engine. Every project has some risk associated with it whether the project will be successful fully or partly or not. The Risk Identifier can provide the information in a scientific way to all the entities about risk found by the evaluator in particular cases. That will help the procuring entity to revise the procurement project or necessary actions can be taken into consideration to mitigate the risk or care can be taken for the risk factors suggested by the Decision Engine's Risk Identifier. The most important module is the Bidder Selector which receives the ratings of weight factors and bidders by the members of Evaluation Committee who are known as decision makers. The Bidder Selector will process the ratings using linguistics given by the evaluators or decision makers through some mathematical model and produce the final ratings of the bidders for selection and contract awarding. This will provide unbiased consensus decision for the procurement cases which is mandatory requirement for corruption free practice and computerized processing of evaluation will result the fast contract awarding practice. Another important module is the Procurement Maturity Identifier which will indicate how much professionalism is found in the procurement practice. This will also be rated some group of evaluators other than the members in Evaluation Committee for bidders' assessment involved in particular procurement case. Moreover, an Anti Spamming engine will provide more security for electronic procurement model though accessing the system using some private keys by the entities are seen in Figure 1.1. The revised e-GP Access Model is depicted in Figure 1.2.

Risk Identifier as a subsystem of Decision Engine is a critical part in our proposal which is designed to assess risk presence for various risk factors implemented usign Fuzzy Multi Criteria Decisin Making system. A software based risk mitigation system has been presented by Raymond J. Ramchy that generates decision from a knowledge base getting weightage factors' values through it's interface. The model was developed based on COCOMO which is known as software cost estimation model[4]. Though the technique used in the software preferable for automated procurement decision with risk considerations, it is customized for software procurment only. A general purpose procurement risk identification and risk mitigation is essentially considered in this thesis work.

Beside this, the implementation of fuzzy TOPSIS with Multiple Criteria Decision Making(MCDM) through goal programming is exampled with good sensitivity analysis in the work of Foriborz Jolai, Seyed Ahmed Yazdian, Kamran Shahanagi and Mohammad Azari Khojasteh[5]. Though this technique is good for order distribution among multiple bidders but it is unable to select successful bidder in case of quantity discount offers with full-fuzzy technique. We have tried to revise this model with the addition of Price Break Model [16] for considering quantity discount offers. The revised model of Jolai, Yazdian, Shahanagi &

Khojasteh [5] is to be incorporated into the Decision Engine as a subsystem for secure selection of bidders in procurement cases implementing the electronic procurement model.

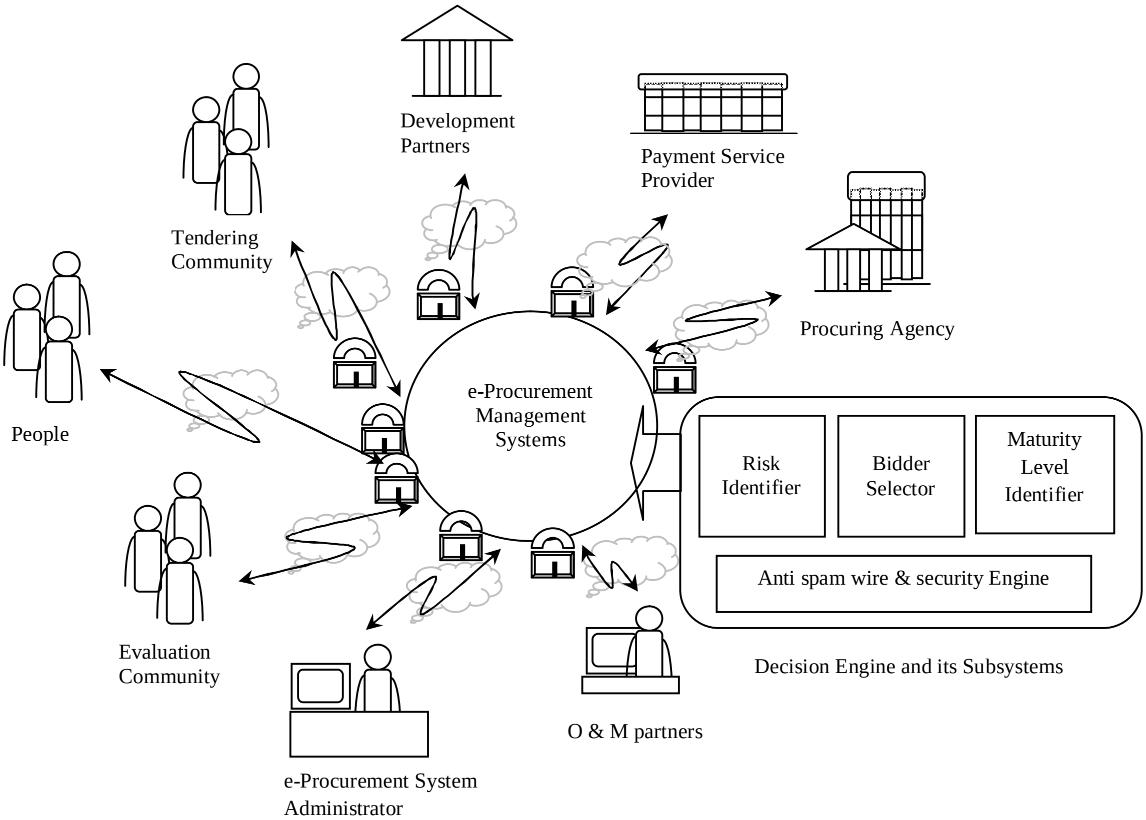

Figure 1.2: e-Procurement Access Model with Decision Engine incorporated

Quality assessment is acheived through benchmarking in procurement. An important aspect of benchmarking is acheived through the development of Procurement Maturity Model(PMM) by making procurement a separate professional practice. Procurement as a separate department in organizations and that consist of separate professionals known as procurement professionals make procurement practice efficient. How much professionalism is obtained in procurement is measured using Procurement Maturity Model [13]. Stephen Guth showed that 60 best practices were found which were set as quality benchmark and each case of procurement is measured using gap analysis between the benchmark level and test case level determined. It was difficult for us to study sufficient procurement cases to find several best practice cases to obtain the benchmark level. So that we decided to use fuzzy MCDM technique for assessment of procurement test cases by some assessors and find the level of professional maturity of procurement using the same measuring attributes and scale showed by Stephen Guth [13].

The Procurement Maturity Model was further studied by Wheele and Reitveld to facilitate the uplift of organization's maturity from transaction level to commercial level in e-Procurement Maturity Model which includes the levels up to value chain integration [14]. This is closely related to Capability Maturity Model (CMM) which practiced in software engineering profession. We have tried to relate the Stephen Guth's scale with Duinkerken, Batenburg & Versendaal [14] scale.

1.3 Security of Electronic Procurement System and Anti spam wire

All the models discussed here in this book deals with nothing but data and information which requires security. The project of INNO-UTILITIES showed the implementation of securityware through the subsystems of Information Management, Information Transaction and Information Repository in electronic places very successfully introducing Innovation Friendly Procurement Model. Such security model came from the experience of electronic revolt by overwhelming network system intentionally uploading SMSs [15]. For this reason we have suggested an Anti spam wire and security engine for continuous monitoring that can prohibit such massacre.

Usually tendering process requires a tender committee consists of few members who play the role of consensus decision making. After them other participants including people are also become part of observation in such model of e-Procurement. Various kinds of participants in a single model demands special public key cryptographic system with customized encryption and decryption process. We suggest RSA algorithm for public and private key encryption and decryption for information transaction security.

As per the experience described in INNO-UTILITES, the electronic revolt creating information system overwhelming collapsed the system of electronic procurement protesting unfair practices is an example in this era. This event puts emphasis to deploy unbiased decision engine as well as a function of continuous monitoring against spamming process tried by hackers and crackers to make free the system from such kind of disruption is a mandatory requirements.

A demonstration of security engine composed of Information Transfer Subsystem, Information Management Subsystem and Information Repository Subsystem each communicating with separate security module is suggested to include in this part of the proposed model [15]. These features are subjected to be located in a dedicated Security Engine.

1.4 e-Marketplace System for e-GP Access Model

The e-GP Access model is basically buyer centric model. It is subjected to be revised to enhance the model to e-marketplace model [17] [18]. e-Marketpalce model is a third party based system where neither the procuring organization nor the bidder have the authenticity to dominate the practice. A third party is the woner of the place where the facility is available, both procuring entity and bidders get their entrance into there and take part in the process of procurement evaluation. The evaluation committee is composed of some closely relevant procurement professional society who process the evaluation of bidders for selection for awarding the contract. There are huge scope to observe the process by other entities like general public, donor agencies, development partners etc, etc.

There is no conflict with the PPR for incorporating Decision Engine into e-GP Access Model. For converting it into a third party based e-Marketplace model, a list of policies should be adopted and legitimated for practice to ensure the services and quality such as:

(a) The entrepreneur should have minimum eligibility to establish a virtual place i.e. electronic marketplace or web site which will be a hub for both procuring entity, bidders, observers and all other related entities to procurement process.

(b) The entrepreneur shall collect a license from authority (Government in this case) for establishing a virtual marketplace for procurement practice.

(c) The system administrative tasks shall be carried out by a group of registered professionals of Information Technology who shall be bound to follow some code of ethics (defined by Government and professional body as well).

(d) The evaluators of all tenders shall be registered to e-Marketplace who shall come from a professional society of procurement with relevant qualification set by the respective professional body.

(e) The evaluator(s) shall evaluate the information made available by the procuring entity and their consultant(s), the evaluator(s) shall evaluate the bidders, and the evaluator(s) shall evaluate the professional maturity in the procurement practice for each case.

(f) The procurement professionals as evaluators shall have to be given status of skills and experience in the field of procurement by the respective professional body and they shall have to be guided by the professional ethics set the body.

(g) All possible information related to procurement should be disclosed to the observers (People, Donor agencies, Procurement partners etc.) supported by the Right to Information Act.

(h) All information related to contract awarding and contract delivery by the successful bidder should be available to the e-Marketplace.

The society or nation who wish to have following policies in procurement can only will go with the proposed model describe in this book. The policies are:

(i) Third party based procurement where buyers and sellers are all participating in the e-marketplace with same status of power exercise opportunity
(ii) No biasing on the decision makers
(iii) Criteria based decision where criteria are weighted by relevant expertise in the domain of e-procurement model
(iv) Proper use of preference but no traditional malpractices like corruption can be found
(v) Secure data transaction which is not possible in classical pen-paper method
(vi) Open consideration of tender selection with opportunity to work with various attributes of variability

Therefore, e-procurement model discussed in this book must satisfy the criteria to hold similar policies mentioned above by a nation where procurement is no more an act of purchasing by the request of potential suppliers or service providers or a cost oriented purchasing administered by procuring agency. Thus the proposed e-procurement model is neither is Transactional Oriented nor Commercial Oriented which both are of initial levels of Wilco Van's maturity framework.

1.5 Scope of e-GP Access and Proposed Model

The revised model of e-GP Access proposed in this book will not be suitable for defense purchase. Because defense department should not procure military equipments through third party based e-Marketplace model where evaluators should be core professionals of military departments and there should not be wide access to procurement judgment and contract awarding. There may some political preference by the government and the department itself in both local and international aspects. There is no need for presence of any donor agencies in the procurement model as partner or observer or process monitor because defense purchase is always discouraged by the development partners or donor agencies. It is advised to keep a customized B2G model for defense purchase. But similar evaluation methods can be applied in that case.

1.6 Methodology

A revised model is introduced on the basis of e-GP Access Model which consists of a Decision Engine that will provide unbiased procurement decision and selection of multiple bidders with quanity discount offers. The decision engine's Risk Identifier is an implication of Madchy Model[4] with fuzzy MCDM. We have suggested methods available for anti spamming and encryption-decryption mechanism for information security available. Lot of research has been done over the past decade in data cryptography and Internet security. Our revised e-GP Access Model can easily be facilitated by latest updated methods and security mechanisms. Here in this book, we discussed risk assessment using fuzzy MCDM with risk mitigation algorithm for procurment in Chapter 3. A revised model of Jolai, Yazdian, Shahanagi & Khojasteh [5] discussed in Chapter 4 which is to be in Bidder Selector module, another core part of Decision Engine and Procurement Maturity Model is illustrated with fuzzy MCDM in Chapter 5. In chapter 6, we have tried to compare the fuzzy MCDM method with AHP method.

CHAPTER 2

LITERATURE REVIEW

2.1 Procurement malpractices and initiatives

The process of procurement in Bangladesh especially in public sector is always questioned about its clarity, efficiency and transparency. Interestingly Government of Bangladesh has also adapted an act for Right to Information (RTI) in 2009 for her people to let them have legal scope to get the information about operational, functional and development activities running in the government and public administration and to come out from deep corruption with nontransparent and unaccountable practices in management. Among many challenges, mind-set is a big issue for officers and employees who ought to disseminate all relevant information to public. Consequently government needs to acquire strategy like e-governance that can make the workforce and work processes transparent, efficient and service oriented. The system of e-governance is nothing but a sandwich of public administration and Information & Communication Technologies (ICT) focusing on World Wide Web and Internet through which all governmental information goes to people, providing citizens with participation opportunity in decision making process even mobilizing the delivery of governmental services to them. ICT can promote e-governance by means of Automation, Informationization and Transformation. For ensuring easy access to government information, Bangladesh has a separate ongoing project named A2I to proceed toward successful implementation of RTI. Network connectivity is also a major part to establish easy and good communication among different departments of government. This requires a proper Information Sharing Management system maintained by the entities involved in such electronic connectivity. Any e-Government application should be designed to meet RTI to empower common citizens of the country [1]. An application has been developed and implemented in Bangladesh which is now receiving tender proposals electronically through the web portal [3].

Administrative and legislative reforms are high priority for a country like Bangladesh with immature democracy. Corruption is the main challenge for smooth operation of administration and development work. Public Procurement is a part of operational practice where huge amount of money are spent for public procurement which are not free from biasness and corruption though public procurement is one of the most important key factor for proper growth in public sector and development. In a survey of 148 procurement cases, 29% awarding the contracts were found after 240 days of tender submitted by bidder where allowed duration is 150 days. Another 28% were found to be awarded the contract or supply or work order after 360 days and the rest were found after 500 days. The huge delay in procurement process implies huge presence of biased and corrupted practices in procurement in Bangladesh. Some of the reasons identified for such malpractices – (i) Poor advertisement (ii) A short bidding period (iii) Poor specifications (iv) Poor advertisement (v) Poor specifications (vi) Nondisclosure of selection criteria (vii) Award of contract by lottery (viii) One-sided contract documents (ix) Negotiation with all bidders (x) Rebidding without adequate grounds (xi) Other miscellaneous irregularities (xii) Corruption and outside influence. Lack of information open to all like bidder, procurement partners, development agencies etc is a major leakage of efficiency in public procurement. To improve the efficiency in public procurement, World Bank suggested a model of Electronic General Procurement Access Model or e-GP Access Model to Government of Bangladesh. As long as the project of Digital Bangladesh is initiated by Government of Bangladesh (GoB), it took the e-GP Access Model for electronic public procurement in year of 2009 in consequence of Public Procurement Rule (PPR) proposed in 2008. e-GP Access Model is basically a Business to Government (B2G) model provides online facility for purchasing goods and services from organizations. Publishing, processing and exchanging of all related information to all related bodies are achieved in this model. In e-GP model, donors are also considered as role player in procurement process to achieve greater accountability and transparency. Though rules and legislative framework is also a mandatory requirement for efficient procurement, e-GP Access Model can provide openness to procurement practices and can obtain better result in selection of bidder through operational clarity [2].

2.2 Risk Identification for software procurement

COCOMO is a powerful tool for software development project costing. It has been implicated to ADA COCOMO, COCOMO II and Win-Win COCOMO. Usually software projects are cost estimated based on the required efforts and schedule of design, coding and development. The required efforts are sometimes biased by capability. That is why capability becomes another constraint to measure the risk for a new software development project whereas schedule is a vital issue for optimizing the project cost. Software was developed by Toth (1994) that was supported by knowledge-based risk technology advisor system but it only focused on technical product risk whereas COCOMO focused on cost and schedule. In quantification of project risk, an initial benchmark was taken like 0-15: low risk, 15-50: medium risk and 50-350: high risk. The value comes out from the summation of the products of effort multiplier products multiplied by risk level (1: moderate, 2: high, 4: very high) where the effort multiplier products are the products of cost drivers' quantified values chosen by users arbitrarily on the given scale (very low-low-nominal-high-very high-extra high). If any cost driver is replaced by schedule driver then effort multiplier product becomes the product of schedule effort multiplier divided by relative schedule whole multiplied by the product of rest of the cost drivers. Its graphical interpretation is visualized on a 2-D plane where the risk of one attribute is shown against another attribute like production complexity versus analyst capability and is discretized into a tabular format. In this way, Toth's software generates a rule base (like knowledge base) which 77 rules has devised yet among which 52 are directly incorporated with project risk assessment [4].

2.3 Supplier Selection Methods

2.3.1 Jolai Method

Every procuring organization needs to evaluate and select supplier among more than one bidder. Sometimes procuring organization purchases same items from multiple suppliers or multiple products from multiple suppliers or providers. This kind of practice provides competitive environment in procurement. The most important business process in this case is obtaining the suppliers with assignment of appropriate order quantity to each of them who have the satisfactory level of performance expected. To ensure a proper selection of such suppliers and avoid the vagueness, procurement is suggested to be conducted in three phases. Phase 0 is an initial stage of screening who have primary eligibility to participate in particular supply. The immediate next in Phase 1, the decision criteria for selection are weighted and calculated using Fuzzy AHP method succeeding the final calculation of rating from importance weighted criteria using modified Fuzzy TOPSIS. This leads to obtaining the overall scoring of the alternative suppliers using a fuzzy Multiple Criteria Decision Making (MCDM) approach. In the Phase 3, using the goal programming (GP) technique, a multi-objective mixed integer linear programming (MOMILP) model is constructed in which two goals of total value of purchasing (TVP) and meeting the total budget of purchasing in each period are taken into consideration. Suppliers' ratings calculated in Phase2 of the approach are used as the parameters of the first goal of the GP model. In this model, quality constraint is considered critically of the defect rate. Good consistency of this model is observed in a sensitivity analysis for different level of periodic budgets and Total Value of Procurement[5].

2.3.2 Toloie Method

Assessment of any service in terms of qualitative measures for the intangible specifications is very difficult job. The taste is different from person to person for qualitative measure for the same specification. To measure the quality of insurance services, use of statistical methods has been seen using the five point Likart scale. Currently the linguistics and its preference values used in fuzzy set theory have got preference in relevant judgments. Parasuraman identified five categories of 22 criteria list for assessing quality of insurance service which is shown in Table 2.1.

In a mathematical illustration, the weight factors of five major categories of specifications have been calculated using Analytical Hierarchy Process (AHP) as 0.251, 0.229, 0.172, 0.187, 0.161 for Tangible cases, Confidence, Responsiveness, Reliability and Harmony respectively. Later three insurance companies have been rated using triangular fuzzy number for each of 22 indexes which is then normalized using fuzzy method. From the fuzzy TOPSIS, each insurance company gets its value relatively nearer to the ideal answer which is given rank i.e. the nearness values are 0.41, 0.83, 0.52 of company A, B and C respective for which company B is given highest rank and company A is the lowest. Part of this work is done using AHP and rest through fuzzy MCDM [6].

2.3.3 Ghorbani Method

In a strategic planning, SWOT analysis is an important tool widely used. SWOT stands for Strength, Weakness, Opportunities and Threats are the factors for determining organization’s internal and external position and exact strategy to move forward. TOWS matrix is the form of SWOT analysis with slight variation with factors paired which is also applicable. Yuksel and Dagdeviren [7] identified the factors as tabularized in Table 2.2.

Table 2.1: Quality assessment criteria of insurance service [6]

Category	Rules/Index
Tangible cases	-Trimness of staff -Friendly environment for customers -Signboards to guide customers -Easy access to branches for customers -Readability and easy understanding of forms
Confidence	-Offering appropriate services by staff -Conducting services at due times -Eagerness of staff in responsiveness and correcting faults -Capability of staff to remove problems of customers
Responsiveness	-Proper dealing with customers on rush hours -Offering necessary information on current and new services to customers -Offering guidance and suggestions to customers proportional to their needs -Establishing easy links between customers and division directors -Proper speed of responding to customers
Reliability	-Trustworthy, confidant and honest staff -Understandable and clear answers of staff to customers -Technical knowledge to answer questions of customers
Harmony	-Individual attention of staff toward customers -Grasping special needs of customers by staff -Offering services at due place and date -Offering services on holidays -Staff want best interests for customers

Table 2.2: TOWS matrix for SWOT analysis [7]

<table>
<tr><td rowspan="6"></td><td colspan="2">Internal factors</td></tr>
<tr><td>Strengths (S)</td><td>Weakness (W)</td></tr>
<tr><td>Intellectual Capital (S1)</td><td>Weak Image of the local products (W1)</td></tr>
<tr><td>Expert management staff (S2)</td><td>Energy Cost (W2)</td></tr>
<tr><td>Technically Qualified Workforce (S3)</td><td>Distance to Market (W3)</td></tr>
<tr><td>Quality of the Product (S4)</td><td></td></tr>
<tr><td>External factors</td><td colspan="2"></td></tr>
<tr><td>Opportunities (O)</td><td rowspan="4">SO strategy

Working with strong suppliers</td><td rowspan="4">WO strategy

Making joint investment with EU suppliers</td></tr>
<tr><td>Liberalization of the country (O1)</td></tr>
<tr><td>New foreign Markets (O2)</td></tr>
<tr><td>Investment Incentives (O3)</td></tr>
<tr><td>Threats (T)</td><td rowspan="5">ST strategy

Investing in former east-bloc countries</td><td rowspan="5">WT strategy

Subcontracting</td></tr>
<tr><td>Threat of other country’s product (T1)</td></tr>
<tr><td>Too High value of YTL (T2)</td></tr>
<tr><td>Economic and Political uncertainty within the country (T3)</td></tr>
<tr><td>Current and Possible Problems in the Continent (T4)</td></tr>
</table>

All the criteria of S1, S2, S3, S4, O1, O2, O3, W1, W2, W3, T1, T2, T3, T4 are paired with the major group of strategies SO, ST, WO, WT in a matrix with different values of Very Low(VL), Low(L), Medium Low(ML), Medium High(MH), High(H), Very High(VH) with numerical equivalents of 0, 1, 3, 5, 7, 9, 10 respectively. Through normalization, the importance weights are found for S1 to T4 which is then closeness co-efficient for each strategies of SO, ST, WO, WT are determined as 0.489, 0.552, 0.368, 0.595 respective and ranked as WO with highest priority and WT is the lowest. In this paper, SWOT is linked with fuzzy TOPSIS method shown that SWOT is used in a better way using this approach [7].

2.3.4 Benyoucef-Canbolat Analysis

The process of procurement is able to be improved using electronic means purchasing goods and services through Internet. It can reduce cost and time for purchasing and lower the inventory expense that builds good collaborative partnership with suppliers. Evaluation and selection of suppliers is a vital issue in procurement both for single sourcing and multiple sourcing. Analytical Hierarchy Processing (AHP) is a useful tool for selection of supplier and integrating with Fuzzy becomes a more powerful tool efficient for the same purposes especially when evaluation is done on the basis of multiple criteria. In AHP modeling, all defined measures are paired for comparisons to determine their relative importance and then weights of each criterion are generated. For finding a feasible solution, doing maximization (e.g. profit) or minimization (e.g. risk) meeting all objectives, the methods like linear or non-linear programming is used with the weights of criteria and objective functions available. The evaluation phases are: (i) Generate pair-wise matrices (ii) Generate the weights of the measures; (iii) Normalize weights to get the consistency among measures and (iv) Calculate the overall ratings of suppliers. While integrating fuzzy with AHP, fuzzy based pair wise comparisons are performed using any approach among Fuzzy Logarithmic Least Square Method, Fuzzy Geometric Mean Method, Interval Arithmetic, Synthetic Extent Analysis, Fuzzy Least Squares Priority Method, Fuzzy Linear and Non linear Programming Method. We know that there two types of numbers are found in set operations like fuzzy numbers and crisp numbers. And there are also two types of fuzzy numbers like triangular fuzzy numbers and trapezoidal fuzzy numbers. Here, fuzzy linear and non linear programming method uses crisp and triangular fuzzy numbers. Fuzzy Logarithmic Least Square Method, Interval Arithmetic, Synthetic Extent Analysis Fuzzy Least Squares Priority Method all uses fuzzy triangular numbers and fuzzy geometric mean method uses trapezoidal fuzzy numbers respectively.

In an extensive study, data were collected on a seven point scale for judging against few criteria like Quality, Delivery, Price and Service which was mean rated as 6.51, 5.88, 5.63, 4.64 respectively. After normalization, mean ratings ($\bar{x}$) became 0.29, 0.26, 025, 0.20 for Quality, Delivery, Price and Service and their standard deviations (σ) are 0.77, 1.07, 1.12, 1.45 respectively. Using the formula, [max(0, $\bar{x}$ -σ), {max(0, $\bar{x}$ -σ) + min(7, $\bar{x}$ +σ)}/2, min(7, $\bar{x}$+σ)] triangular value is determined and compared with following scale with its linguistics and membership function [8].

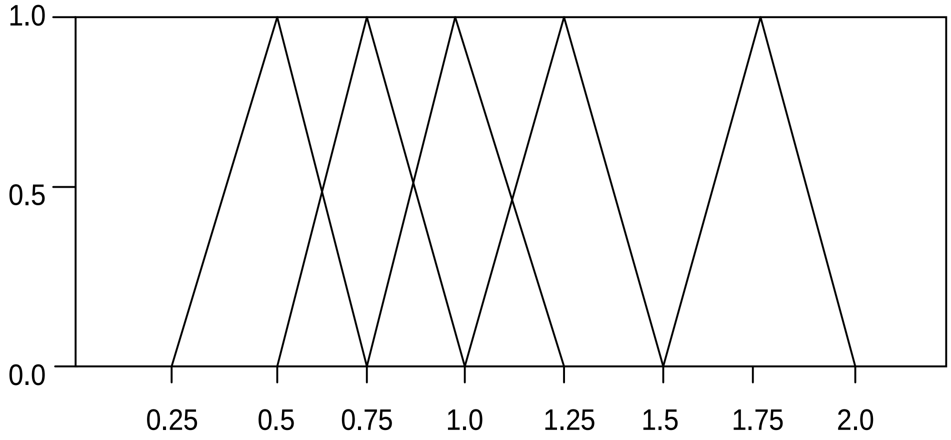

Figure 2.1: Triangular value scale for supplier evaluation

Table 2.3: Linguistic variables and membership function

Linguistics	Lower	Mid	Upper
Extremely Strong	1.50	1.75	2.00
Strong	1.00	1.25	1.50
Same	0.75	1.00	1.25
Weak	0.50	0.75	1.00
Extremely Weak	0.25	0.50	0.75

For example, Quality is a determination criteria which is rated by assessors, its mean rating is 0.29 and standard deviation is 0.77. Using the formula mentioned above, [max(0,| 0.29-0.77|), {max(7,| 0.29-0.77|) + min(0, 0.29+0.77)}/2, min(0, 0.29+0.77)] implies that [max(0,0.48), {max(0,0.48)+min(7,1.06)}/2, min(7,1.06)] i.e. (0.48, 0.77 , 1.06). We see a Weak position in above scale of Quality determinant with the given rating.

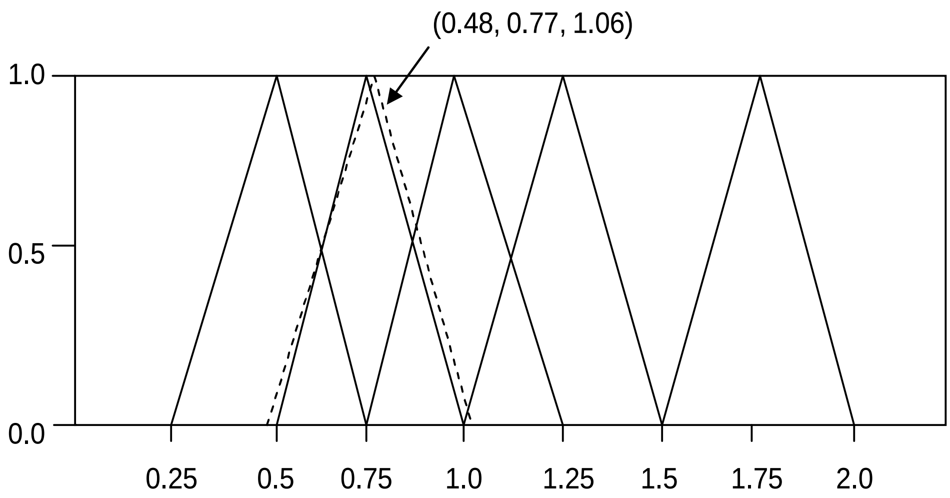

Figure 2.2: Result of supplier evaluation in triangular value scale

Hence we've got the incorporation of fuzzy approach into AHP. The reason behind the expertise switched over Fuzzy AHP through AHP is clearly mentioned in this paper - "If the buyer had to perform pair-wise comparisons using normal AHP in order to build a comparison matrix, then he/she would have to choose a score from 0 to 9 to show how one supplier compares to another in terms of service performance. Although the comparison scales provide flexibility for a decision maker to set scores, in some conditions this flexibility does not guarantee a satisfactory decision. A fuzzy approach, on the other hand, captures the un-certainty in the decision maker's mind." How the uncertainty is attained in the fuzzy method is discussed in other literature review.

2.3.5 Classification Method for vendor selection

In this paper, selection of vendor is done by pattern classification problem. Interestingly fuzzy linear programming is a suggested approach for pattern classification problem because lack of huge data points may cause difficulty in classification. A novel classification technique is discussed in this paper with Multi Criteria Decision Making for better classification.

A decision maker gives his response using a scale defined by the linguistics like 'Equal Importance', 'Moderate Importance', 'Strong Importance', 'Very Strong Importance', ‘Extreme Importance’ with all its fuzzy quantifier (1,1,3), (1,3,5), (3,5,7), (5,7,9) and (7, 9, 9) respectively. This response in fed into AHP method to check its consistency. How to check data consistency in discussed in Hamdy Taha, Operations Research: An Introduction [16]. Then weights of individual criteria is determined using own model of Arpan Kar and Ashish Pani which is then converted from fuzzy values to crisp values which is treated by them as decision vector $(x_1, x_2, x_3 \dots \dots \dots x_n)$ with the condition of $\sum_{i=1}^{n} x_i = 1$.

Let, there are n vendors and r attributes, the vendors are assessed against the attributes, A_{ij} be the values of i-th vendor for j-th attribute. Also let that S_S is the value of response of assessor using above scale. The values of A_{ij} are determined through normalization using equation 2.1,

$$A_{ij} = \frac{(S_S - S_{min})}{(S_{max} - S_{min})} \qquad \dots 2.1$$

The values of A_{ij} are the numerical values for fuzziness of each vendor for each criteria. These values can be plotted in a two dimensional plot of membership values versus criteria vector. For all vendors, the plotted points can exhibit individual fuzzy sets.

Here is a problem of overlapping sets. There are points those lie among both sets. This will lead to imperfect classification of vendors. The remedy is to compute the ‘b’ value which is also called the boundary value of two classes of suitable and unsuitable vendors. The ‘b’ value is computed for two separate models of Minimized Sum of Distances (MSD) and Maximized Minimum Distances (MMD). The ‘b’ value is restricted to 0 to 1. In case, ‘b’ value exceeds the error limit defined by classification error ‘e’, then sufficiency of data points should be rechecked and if size of data points is not increasable then ‘e’ value is readjusted to repeat the process. The ‘e’ value is computed using equation 2.2.

$$e = \frac{\begin{gathered}[(Wrongly\ Classified\ as\ unsuitable\ but\ actually\ suitable\ vendor\ count) \\ +(Wrongly\ classified\ as\ suitable\ but\ actually\ suitable\ vendor\ count)]\end{gathered}}{(Total\ number\ of\ data\ points)} \qquad \dots 2.2$$

‘b’ value is computed using linear programming method. The method is described as Soft classification of vendors [9].

2.4 Fuzzy Logic and Fuzzy Set

Fuzzy logic is a tool used to control various processes ranging from medical diagnosis to engineering process control. This tool is used as mode of reasoning underlying approximate not exact. Fuzzy logic is a mode of reasoning that deals with approximate not precise. Let's say, 'Usually snow is white'. Here 'usually' is a fuzzy proportion of how many times snow is seen white and how many times not- neither all the time nor too few times to say. This 'usually' refers such a mid position that can graphically be depicted as in Figure 2.3 [10].

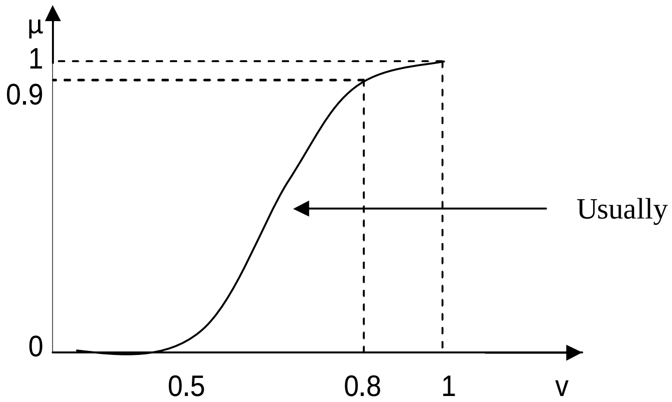

Figure 2.3: Graphical interpretation of fuzzy proportion

There are differences between fuzzy logic and other traditional logical system. In a traditional logic, say for two valued logical system, a predicate is either true or false i.e. 1 or 0. In case of a multi valued logical system, there may be a set of values for which membership is 'True' for that particular set. In fuzzy logic, fuzzy subset can be applied that a member can be 'Very True', 'True', 'Partially True' or 'Slightly True' which in turn is treated as linguistic variables. This is the imprecise characterization of numerical truth values. This is the main difference. In two valued logical system, a predicate must be crisp. But interestingly in fuzzy system, a predicate can be crisp though imprecise characterization is done with numerical values for fuzzyfication e.g. 'Chittagong port is large' is a crisp predicate of the crisp set of large ports {Mongla, Chittagong} but 'how much large' can be quantified by completely partial assumption. This is a power of fuzzy logic. On the other hand, in two valued or multi valued logical system, the predicates are found with the quantifiers like 'There exist', 'All' or 'Some'. These are limited to express the presence of the set elements only. But fuzzy system adds some more quantifiers like 'most', 'many', 'few', 'much of', 'frequently', 'occasionally', 'usually'. One more interesting nature of fuzzy logic is to apply the imprecise characterization of a predicate e.g. 'Shahid is tall' is a predicate but how much tall he is that can be expressed in a fuzzy reasoning. At the same time, ‘Shahid is tall’ can be assessed as ‘(Shahid is tall) is merely true’ as he is found with height 5’3” by some assessor. Similarly it can also be expressed in functional form like ‘Height(Shahid) is TALL’.

2.5 Fuzzy MCDM and Fuzzy Set operation

The system of fuzzy decision making is discussed. Decision is made by one person and sometimes decision is made by more than one person. Decision can be made on the basis of one criterion or decision can be made by multiple criteria. Thus, various classes of decision making is obtained i.e. decision on the basis of one criteria by one decision maker, multiple criteria by one decision maker, multiple criteria by one decision maker and multiple criteria by multiple decision maker [11].

In an illustrative example here, a decision is made by one decision maker on the basis of multiple criteria. An individual needed to decide a job selection among four jobs $\{a_1, a_2, a_3, a_4\}$ using the selection criteria of {High salary, Interesting work, Close driving distance}.

Job a_1 with salary of $40,000, job a_2 with $45,000, job a_3 with $50,000 and job a_4 with $60,000 is offered. At the same time, job a_1 needs to be driven 27 miles regularly whereas job a_2, a_3, a_4 are located 7.5, 12 and 2.5 miles distant apart from his location respectively. The individual rated all jobs as per attraction of job nature i.e. how much interesting the job is. The rating is as follows:

$$c_1 = 0.4|_{a_1} + 0.6|_{a_2} + 0.2|_{a_3} + 0.2|_{a_4}$$

Here c_1 is the criteria of Job Interestingness, c_2 is the criteria of Driving distance and G is the set of Salary preferences. The ratings are as follows:

$$G = 0.11|_{a_1} + 0.3|_{a_2} + 0.48|_{a_3} + 0.8|_{a_4}$$

and

$$C_2 = 0.1|_{a_1} + 0.9|_{a_2} + 0.7|_{a_3} + 1|_{a_4}$$

Now the decision is to be obtained which job is to be selected as per the preferences given above.

According to Zimmermann, H. J. Fuzzy Sets, Decision Making and Expert Systems, Kluwer, Boston (1987), a decision situation is composed of (i) a set A of possible actions, (ii) a set of goals $G_i(i \in \mathbb{N}_n)$, each of which is expressed in terms of a fuzzy set defined on A and (iii) a set of constraints $C_j(j \in \mathbb{N}_m)$, each of which is also expressed by a fuzzy set defined on A. Goals and Constraints are expressed as $G_i(a) = G_i^/(g(a))$ and $C_i(a) = C_i^/(c(a))$ where Decision is determined by $D(a) = \min\,[inf_{i\in\mathbb{N}_n} G_i(a), inf_{i\in\mathbb{N}_m} C_j(a)]$ where $a \in A$. Using this formula, the decision in above cases is determined as:

$$D = 0.1|_{a_1} + 0.3|_{a_2} + 0.2|_{a_3} + 0.2|_{a_4}$$

Which represents the desirable job is a_2 among four jobs by the individual. This type of set operation gives interesting phenomena of obtaining optimal solution which is depicted in Figure 2.4.

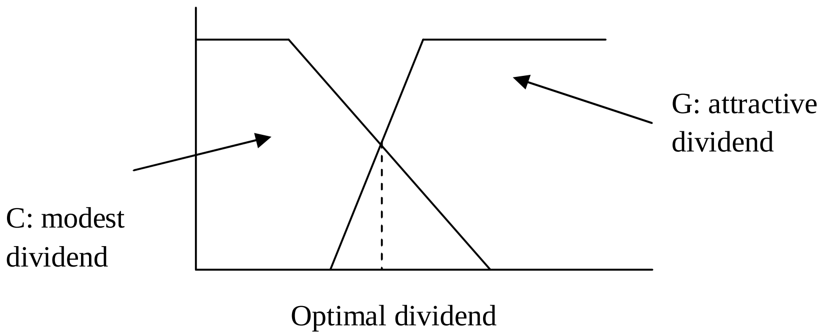

Figure 2.4: Optimal solution among fuzzy sets [11]

In another example of this chapter, a group of people involved in decision making is illustrated. They need to decide which car is to buy for a business process among some brands available like {Acclaim, Accord, Camry, Cutlass, Sable}. They used a scale for grading the attractiveness of the cars as 1, 3, 5, 7, 9 for Little attractive, Moderately attractive, Strongly attractive, Very strongly attractive, Extremely attractive respectively and 2, 4, 6, 8 are for Intermediate values of attractiveness between above levels.

Table 2.4: Attractiveness grades given by decision makers

$F(x_i, x_j)$	Acclaim	Accord	Camry	Cutlass	Sable
Acclaim	1	7	9	3	8
Accord	3	1	3	2	4
Camry	1	1	1	3	5
Cutlass	2	7	7	1	7
Sable	2	6	8	3	1

This above matrix in Table 2.4 of preferences is now being normalized using equation 2.3 formula [11] and the normalized matrix is shown in Table 2.5.

$$F\left(x_i, x_j\right) = \frac{f(x_i,x_j)}{\max\left[f(x_i,x_j),f(x_j,x_i)\right]} = \min\left[1, f(x_i, x_j) / f(x_j, x_i)\right] \qquad \ldots 2.3$$

Table 2.5: Relative preference grades obtained normalizing Table 2.4 using equation 2.3

$F(x_i, x_j)$	Acclaim	Accord	Camry	Cutlass	Sable
Acclaim	1	0.43	0.11	0.67	0.25
Accord	1	1.00	0.33	1.00	1.00
Camry	1	1.00	1.00	1.00	1.00
Cutlass	1	0.29	0.43	1.00	0.43
Sable	1	0.66	0.625	1.00	1.00

Using the formula, $p(x_i) = min_{x_j \in X} F(x_i, x_j)$, following preference values are obtained shown in Table 2.6. The car with the highest preference value can be selected to be bought by the decision maker i.e. Camry is in this case is the selection in this multi person decision making. Here is a discrepancy of using one decision maker’s data in this example where all members of the group should put their choice of preferences in the matrix and forming an aggregated matrix would lead to actual result of decision using the min-max optimization.

Table 2.6: Result of relative preference grades

$F(x_i, x_j)$	$p(x_i)$
Acclaim	0.11
Accord	0.33
Camry	1.00
Cutlass	0.29
Sable	0.63

The methodology is further discussed for multi criteria decision making. Assuming that $X = \{x_1 x_2, \dots \dots, x_n\}$ and $C = \{c_1 c_2, \dots \dots, c_n\}$ be a set of alternatives and a set of criteria respectively for a decision situation. The basic information involved is multi criteria decision making is expressed by the following matrix [11].

$$R = \begin{bmatrix} r_{11} & \cdots & r_{1n} \\ \vdots & \ddots & \vdots \\ r_{m1} & \cdots & r_{mn} \end{bmatrix} \qquad \dots 2.4$$

The matrix R is then normalized using the equation 2.5 to obtain $R^{/} = [r_{ij}^{/}]$.

$$r_{i,j} = \frac{r_{ij}^{/} - min_{j \in N_n} r_{ij}^{/}}{max_{j \in N_n} r_{ij}^{/} - min_{j \in N_n} r_{ij}^{/}} \qquad \dots 2.5$$

Fuzzy logic is introduced by Lofti A Zadeh in 1965 in a seminal paper. Fuzzy logic deals with fuzzy sets. Fuzziness is something like vagueness. This is a useful mathematical tool to solve problems with uncertainty arisen due to vagueness. A query is exampled here - ‘Is water colorless?’ The answer is ‘Yes’. Another query is – ‘Are you a freshman?’ , obviously the answer is either ‘Yes’ if you are a student of first year of university undergraduate program or ‘No’ if you are a school student, sophomore, junior, senior or graduate. Here the results are binary type i.e. set of answers is {Yes, No} or {1, 0}. Such sets are known as crisp set. Let’s consider another query – ‘Is Zia honest man?’ .The answer may be ‘extremely honest’, ‘very honest’, ‘honest at times’ or ‘extremely dishonest’. These are the degree of honesty expressed by different person from their different view. Here the answer is not bounded to Yes or No. This is the fuzziness. The fuzziness is expressed with numerical values e.g. ‘extremely honest (1.0)’, ‘very honest (0.8)’, ‘honest at times (0.4)’ or ‘extremely dishonest (0)' using a scale 1~0 for representing the degrees with the linguistics. All the set operations for the crisp set are quite similar for the set operation for the fuzzy sets. An example is shown here.

Two sets of people who are Young and Middle age. Mohan, Sohan, John and Abdul are four person with their ages 18, 21, 25 and 26 years. They all are members of Young set of people. Another set of Middle age people are Zia, Anwar and Mosharraf with their ages 35, 45 and 50. These people ore of different age though they grouped into two sets. Here Sohan is younger than all others in the same set as well as Mosharraf is the oldest person among all other is Middle age group sets. They all can be associated with degree of youngness or oldness with fuzzy values. This is illustrated in Figure 2.5.

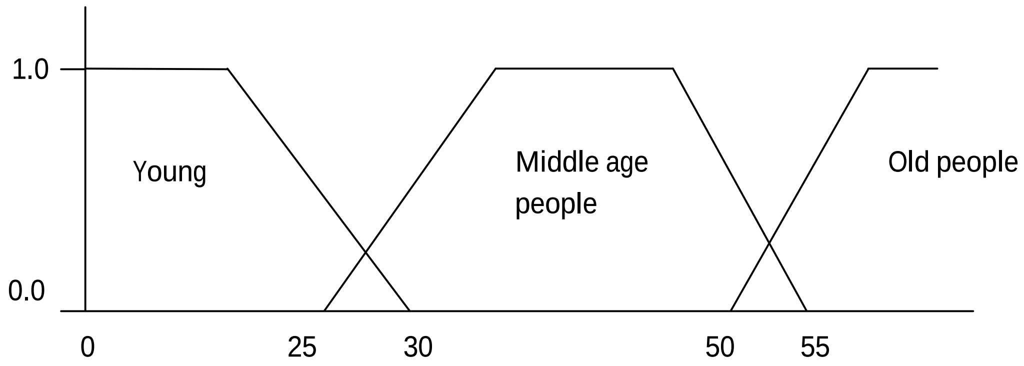

Figure 2.5: Graphical interpretation of sets for three different age group people

Now we can say that Mohan, Sohan and John is completely young with the degree of youngness 1.0 but Abdul is little bit older than them as 26 years old with little less of degree but in the set of Young people. Now the set can be expressed as {Mohan(1.0), Sohan(1.0), John(1.0), Abdul(0.25)} which is a fuzzy set. Similarly the set of middle age people can be fuzzyfied and fuzzy set expressed as {Zia(1.0), Anwar(0.89), Mosharraf(0.45)}. If we now think to find the people who belonged to both the set of young and middle age people, we need to follow a set operation as

{Mohan(1.0), Sohan(1.0), John(1.0), Abdul(0.25)} ∩ {Zia(1.0), Anwar(0.89), Mosharraf(0.45)} = {Abdul(0.25)}

Similarly for finding a set of people who are either in the set of young people or in the set of middle age group we can easily determine as

{Mohan(1.0), Sohan(1.0), John(1.0), Abdul(0.25)} ∩ {Zia(1.0), Anwar(0.89), Mosharraf(0.45)} =
{Mohan(1.0), Sohan(1.0), John(1.0), Abdul(0.25), Zia(1.0), Anwar(0.89), Mosharraf(0.45)}

Similarly all other operations for crisp sets can be performed over fuzzy sets [12].

2.6 Procurement Maturity

Procurement became a profession in World War II. Since then it is known as a separate carrier field and professionals are certified to maintain the standard, Certified Professionals in Supply Chain got the priority to achieve the quality goals in Procurement Organizations. As a separate entity of Procurement organization, it is affected by several external factors - customers, policy, staff, processes, vendors, tools and organization. The performance of procurement is measured in terms of value of cost savings, enhanced vendor performances and mitigated legal and operational risks where the traditional performance measures involve customer satisfaction surveys, vendor surveys, employee feedback, achievement of internal performance matrix and achievement of business goals. Through the comparison with other best procurement performances, few benchmark is obtained that are suggested to be followed by Stephen Guth, a procurement specialist, that are like Procurement Organization Involved in 95+% of Spend, Purchase Orders Generated (Electronically) for 80+% of Spend, 75+% of Spend Flows Through Approved Vendors, Annual Rfx – "Spend Plans" Identify Expiring / Terminating Contracts, Re-bids, and New Purchases, Industry-relevant Certification Required for Procurement Staff, Procurement Staff Receive 24+ Hours of Procurement Training Annually, Use of an Automated Contract Management System (Not Excel-based), 80+% of Contract Documents are Executed Using Customer Contract Templates, 80+% of Contracts Executed Within 30 Calendar Days; 95+% within 60 Calendar Days. Where the cases contribute value a too little or zero, procurement performance gets loser obtaining the adoption cost and lead towards strategic planning to implement e-Rfx system for the provision of automated Rfx procurement process, implement a contract risk level tracking system and maintenance of vendor portal for vendor certification qualification monitoring and administration. Procurement Maturity Model (PMM) has the benchmarking with easy assessment options for users to compare a particular case of practice to a best practice case. PMM consists of five worksheets – Instructions, Assumptions, PMM Rating Input and Scores, Graphed Measurement Area Scores, Graphical PMM Comparison. This PMM model was initially adopted by large non-profit organizations later identified versatility for counting best practice, current practice and a spread sheet model. PMM model of Input and Output Scoring Worksheet may consists of some sections like “Measurement Area” that identifies the broad elements of Customers, Organization, Policy, Processes, Staff, Tools, Value, Vendors; “Measurement Element” that further categorizes each Measurement Area into topical classifications; “Current Practice” that represents a choice of current practices; the number corresponding to each current practice represents a numerical rating and not the order of the Current Practice; “Your Rating” that the user selects the number of the Current Practice that most closely approximates the user’s practice for the Measurement Area / Measurement Element; “Your Calculated Score” that represents a calculation of Your Rating, weighted by a predetermined level of Measurement Area / Measurement Element importance; “Best Practice” that describes the associated procurement best practice; “Best Practice Score” that represents the score value of the indicated best practice; “Significance of Gap” based on the difference between Your Calculated Score and the Best Practice Score. By analyzing the actionable gap with the help of some graphical interpretation like plotting curve for the scores of the criteria Inhibiting, Performing (minimum acceptability), Enabling, Optimizing, Best in class and World class, the case in current practice case is judged with its maturity level. This whole system of approach is known as Procurement Maturity Model [13].

As the consequence of work of Wheele and Rietveld, the Procurement Maturity Model (PMM) is further studied and six stages of procurement maturity level is defined to identify the relationship between IT enabled procurement process with IT enabled interaction between buyer and seller specifically B2B business communication. If there is no procurement strategy maintained and it is done just acting on purchasing requests from rest of the organization, then Duinkerken, BatenburgVersendaal [14] says organizations maturity at Transactional Orientation level whereas specially cost oriented purchasing is done a little bit higher of Commercial Orientation level. An organization goes to Purchasing Co-ordination level if a dedicated procurement department is allocated to optimize the basic sourcing and purchasing. This level of practice makes an organization goes little higher maturity gain through gaining in business transactions and solvency towards Internal Integration of the procurement department as a major strategic part with all other part of whole organization. The immediate next level of maturity is achieved if the organization thinks its suppliers are also stakeholders and consider them to integrate with its’ own existence as valuable external resource. This particular level practice makes the organization reaching at the highest level of procurement maturity when it can contribute to the effectiveness of the entire consumer supply chain. Interestingly, these six levels of procurement maturity were influenced at development stage by Capability Maturity Model (CMM) which is usually practiced by software development firms [14].

2.7 Revolt in Electronic Procurement

The work of Innovation-friendly procurement model was initiated in the year of 2003 finished by 2005 to implement an enhanced procurement system in EU countries which was later exampled by UNICEF as good procurement model of practiced as they have to work with various government bodies, local and international agencies and own partners in this field of procurement to ensure good quality services to the children of global village. After the massacres in telecommunications network stuck by several millions of SMS intentionally uploaded to do an electronic revolt against some public decision, the issue of security became the vital part of INNO-UTILITIES development project for Innovation-friendly procurement model. Such model became consists of three subsystems – Information Transfer Subsystem, Information Management Subsystem and Information repository each supported by individual security module. This INNO-UTILITIES model is not only a robust procurement system having proper security ware but also free from legal implications as the project was carried out by some recommendations and non-technical component development part. Hence the model became a real model to information society [15].

2.8 Decision Analysis and AHP Method

Decision analysis is a major tool used in problem solving area in various business, operational and production process. A manager needs to make decision when he has some options available like investing in a project A considering criteria c1 and c2 or investing in project B with consideration of same criteria. The manager may have options to decide with possible return r1 and r2 in project A and B respectively with weight values of the criteria of c1 and c2 are w1 and w2 respectively. Such a case can be resolved making a decision tree. If there is options available to project A and B of return possibilities rA and rB respectively with the condition to the investment variation in sub sectors of sA and sB then the decision for maximizing the project return considering the objective criteria can be achieved using Linear Programming. All these are deterministic. Another important method is found suitable for dealing with probabilistic condition under certainty known as Analytical Hierarchy Process (AHP). With this method, probabilistic choice of preferences are substituted in a matrix for the criteria available which is then normalized using a particular mathematics to form a row or column matrix of decision weight which can further be feed into the Linear programming or Goal programming method to obtain optimized decision [16]. A simple case is discussed below:

A job seeker needs to select a job among three jobs J1, J2 and J3 considering two criteria. He likes to join in a firm who will provide higher salary for him (C1) also he expects to have his job location not far from his house (C2). Let's say the job seeker prefers job J2 more 50% than job J1 for higher salary whereas 20% of the job J3 for the same criteria. Similarly, he prefers job J3 five times than job J1 for same criteria. Such choices of preferences are summarized in the following matrix for two different criteria.

$$M_{C1} = \begin{pmatrix} 1 & \frac{1}{2} & \frac{1}{5} \\ 2 & 1 & \frac{1}{2} \\ 5 & 2 & 1 \end{pmatrix}$$

and

$$M_{C2} = \begin{pmatrix} 1 & 2 & 3 \\ \frac{1}{2} & 1 & \frac{3}{2} \\ \frac{1}{3} & \frac{2}{3} & 1 \end{pmatrix}$$

Summing the columns, we get M_{C1}-column sum = (8, 3.5, 1.7) and M_{C2}-column sum = (1.83, 3.67, 5.5). Now dividing all elements of both matrix above by respective column sum, both above matrix is normalized as below:

$$M_{C1} = \begin{pmatrix} 0.125 & 0.143 & 0.118 \\ 0.250 & 0.286 & 0.294 \\ 0.625 & 0.571 & 0.588 \end{pmatrix} \text{ and } M_{C2} = \begin{pmatrix} 0.545 & 0.545 & 0.545 \\ 0.273 & 0.273 & 0.273 \\ 0.182 & 0.182 & 0.182 \end{pmatrix}$$

By taking average of each row, we get the following matrices.

The values $(W_{J1C1}, W_{J2C1}, W_{J3C1}) = (0.129, 0.277, 0.594)$ provide the respective weights for higher salary and $(W_{J1C2}, W_{J2C2}, W_{J3C2}) = (0.545, 0.273, 0.182)$ for job location. Now we can get, $(W_{J1}, W_{J2}, W_{J3}) = (0.129, 0.277, 0.594)$. Next the parameter value of n_{max} is calculate as follows:

$$M_{C1} \times W_j = \begin{pmatrix} 1 & \frac{1}{2} & \frac{1}{5} \\ 2 & 1 & \frac{1}{2} \\ 5 & 2 & 1 \end{pmatrix} \begin{pmatrix} 0.129 \\ 0.277 \\ 0.594 \end{pmatrix} = \begin{pmatrix} 0.3863 \\ 0.8320 \\ 1.7930 \end{pmatrix}$$

Therefore we get, n_{max}= 0.3863+0.8320+1.7930 = 3.0113. Since n=3, Consistency Index $CI = \frac{n_{max} - n}{n-1} = \frac{3.0113-3}{3-1} = 0.00565$ and Random Consistency Index $RI = \frac{1.98(n-2)}{n} = \frac{1.98\times 1}{3} = 0.66$. Now the Consistency Ratio (CR) = CI/RI = 0.00565/0.66 = 0.00856 which is less than 0.1. Thus the level of consistency is accepted in this case. The method is generally expressed in the Chapter 13 of this book.

2.9 AHP, Fuzzy AHP and ANP: Behavioral Similarities

All IT companies involve in various project works time to time. Sometimes these organizations need to have additional human resource by outsourcing method specially when more technically skilled people are needed for dedicated assignments, they do outsource some consultants. Outsourcing is now a popular method of hiring skilled people as organization doesn’t need to appoint permanently. Any IT project may have very distinct nature and in such case more skillful people are needed for the organizations for the success of such projects. The criteria along with few sub criteria for each for selecting the most suitable consultant have been defined by Vayvay, Ozcan & Cruz-Cunha (2012). These are (i) Cost - (a) Transportation Cost, (b) Consultancy Cost, (ii) Work Experience – (a) Companies Employed, (b) Project Completed, (c) References, (iii) Education Level – (a) Department Graduate, (b) Occupational Seminars, (iv) Communication Ability – (a) Awareness of Responsibility, (b) Ability to Persuade. While selecting consultant in a practical case, AHP, fuzzy AHP and ANP - all three methods have been applied and checked the results before finalizing the selection of most suitable person. All three methods are known as Multi-criteria Decision Making tools or MCDM in short. The assessment ratings have been substituted in the pair wise comparison matrix for AHP, fuzzy AHP and ANP method also the hierarchies are derived for AHP and ANP method implementation. Finally the results are obtained and ranking of the nominees are done for selecting the highest rank consultant. Interestingly very little difference is observed among the results of the three different methods even the ranking of the three consultants have been determined same for all three methods [19].

2.10 e-Marketplace and its features

We know that marketplace is defined as a place where buyer(s) purchas(es) his/her/their desired product and seller sells his/her/their commodities or services. Classically this takes place in some marketplace but marketplace is completely a logical existence for buying and selling. For example a freelancer consultant serves his clients over the buyer's place. Here the models are differentiated like Customer goes to Business entities (C2B), Business goes to Consumers (B2C), sometimes Business organization goes to other Business entities for services or products (B2B), Business entities go to Government agencies (B2G) etc. All these are either buyer centric or seller centric and either of the party have the role plays in the process. But e-Marketplace model can easily be differentiated from these models. e-Marketplace model provides opportunities for disclosing of information related to product or services, requirement as well as negotiation between both the parties in a common place. e-Marketplace model is a hub where both buyers and sellers join in procurement process where an intermediary plays the role of coordinator. Few advantages are clearly described here – (i) Matching buyers and sellers to negotiate prices on a dynamic and real-time basis, (ii) Ensuring trust among participants by maintaining a neutral position, (iii) Facilitating market operations by supporting certain transaction phases, and (iv) Aggregating together a large number of buyers and sellers. The extensive characteristics have been defined in this paper – (i) An e-marketplace system can reduce customers' costs for obtaining information about the prices and product offers of alternative suppliers as well as suppliers' costs for communicating information about their prices and product characteristics to additional customers. (ii) The benefits by individual participants in an e-marketplace increase as more organizations join the system. (iii) The e-marketplace can impose significant switching costs on its participants. (iv) The e-marketplace typically requires large capital investments and offers substantial economies of scale and scope. (v) Potential participants on the e-marketplace face substantial uncertainty with regard to the actual benefits of joining such a system. Occasionally, this uncertainty remains even after an organization joins the system. Some factors have been identified for successful entrance into the e-Marketplace system for an organization. These are – (i) Top management support to new IT and ways of business (ii) Formulated e-commerce strategy (iii) Trained employees with information technology and knowledge (iv) Modern IT infrastructure (v) Readiness of business processes to connect with business partners (vi) IT department support in the organization (vii) Use of an enterprise resource planning system that enables them to connect with business partners (viii) Defined position of an electronic commerce executive in the organization (ix) Availability of an electronic catalogue of products and services (x) Experiences with electronic commerce. Therefore an organization when deciding for entering into e-Marketplace model should make a strategic plan first as per the criteria and characteristics described in this section [17].

e-Marketplace is basically an industrial network where communication is enhanced, transaction is automationized, brokerage is coordinated and process is integrated [18]. This model is facilitated by EM functions and technologies that enhance the content provision and communication such as public storefront, browsing suppliers and products or services, Request for product quotation (RFQ), classified advertisements, discussion forums, industry newsletters, events calendar, bulletin board, scrolling ticker etc. Storage of vast communication data become an excellent source for development of procurement knowledge. EM integrates various enterprises in the back end with the marketplaces. EM itself generates some revenues through different fees like subscription fee, advertising fee, transaction fee etc. EM consists of some role based models like Communicator Model, Transaction Facilitator Model, Value Chain Coordinator Model, and Collaboration Enabler Model. Communicator Model enhances the communication between the participants in the EM by providing support of content management which releases information with some approval from relevant authority making available to industrial network and public storefronts. Moreover it can process information as necessary. We find many different kinds of products in big departmental stores but for sophisticated products and services we find segregated marketplace e.g. if we like to purchase technological products we should go to cell phone shops or customer care, PC and Laptop shops and service center or PC hardware accessories seller. If we think for bigger objects like Power Substation, we should definitely knock some particular manufacturer or vendor. The Transaction Facilitator Model of EM provides spot trading and one stop shop of every kind of products and service. It can enrich informationization through participants' links with other EM's participants. The Value Chain Coordination Model enhances the process of supply chain by speeding up the information processing and making more available of information. Finally the Collaboration Enabler

Model enhances the relationship of buyers and sellers. The main strength of Collaboration Enabler Model is sharing the knowledge and skills among participants and flexible strategies [18]. Each model discussed above is each step for generating revenues for EM itself proportionate to increase with network cooperation.

CHAPTER 3

RISK IDENTIFIER & RISK MITIGATION ALGORITHM

3.1 Procurement Risk Identifier

Risk assessment and cost estimation is the primary tool to predict the chance of success and failure of any project. This is a usual practice to assess the risk at initial stage of a project subject to minimize the failure chance mitigating the problem factors to maximize success potentiality. In this paper, a new approach of fuzzy based risk derivation through proper quantification and mathematical foundation is introduced in this section. In the model discussed by Raymond Madachy [4], two major categories of factors are considered - (i) Linear Factors and (ii) Exponential Factors. Exponential Factors are further classified by (i) Product Attributes, (ii) Customer Attributes (iii) Personnel Attributes and (iv) Project Attributes whereas each attribute class like Product Attributes consist of (i) Required software reliability (ii) Database size (iii) Product complexity, Customer Attributes consist of (i) Execution time constraint (ii) Main storage constraint (iii) Virtual machine volatility (iv) Computer turnaround time, Personnel Attributes consist of (i) Analyst capability (ii) Applications experience (iii) Programmer capability (iv) Virtual machine experience (v) Programming language experience, Project Attribute consist of (i) Use of modern programming practices (ii) Use of software tools (iii) Required development schedule and finally Exponential Factors include as Additional Process Attributes consist of (i) Process experience (ii) PDR design thoroughness (iii) Risks eliminated by PDR and (iv) Requirements volatility. All these above factors are only suitable for software project risk mitigation and not suitable to implement for generalized purpose for procurement project. All these attributes are necessary to revise to fit for procurement project risk assessment generalized attributes. Proposed list of attributes are mentioned in Table 3.1 and a rule base or knowledge base is prepared in APPENDIX which comes from fuzzy pair wise comparison matrix of Table 3.2.

Table 3.1: Ramond Madachy's Cost drivers Vs. General purpose procurement projects

Raymond Madachy Cost Drivers	**Generalized e-Procurement Risk Attributes (Proposed)**
Linear Factors Product Attributes - Required software reliability (RELY) - Database size (DATA) - Product complexity (CPLX) Customer Attributes - Execution time constraint (TIME) - Main storage constraint (STOR) - Virtual machine volatility (VIRT) - Computer turnaround time (TURN) Personnel Attributes - Analyst capability (ACAP) - Applications experience (AEXP) - Programmer capability (PCAP) - Virtual machine experience (VEXP) - Programming language experience (LEXP) Project Attributes - Use of modern programming practices (MODP) - Use of software tools (TOOL) - Required development schedule (SCED)	Product or Service Attributes - Required product or service reliability (RELY) - Required product volume or service duration (DURN) - Product or service complexity (CPLX) Customer Attributes - Product complementary infrastructure (CPIS) - Customer skills, knowhow and adaptability (CADP) Personnel Attributes - Service Providers or consultants or bidders capability (SCAP) - Workforce size (WSZE) - Workforce skills (WSKL) - Service experience (SEXP) Project Attributes - Use of modern technologies (UMTG) - Required supply or service schedule (SCED) Process Attributes - Process experience (PMEX) - Process documentation thoroughness (PDTH) - Risk to be eliminated by rules and regulations or process (RISK) - Requirements volatility (RVOL)
Exponential Factors Ads Process Attributes - Process experience (PMEX) - PDR design thoroughness (PDRT) - Risks eliminated by PDR (RISK) - Requirements volatility (RVOL)	

3.2 Mathematical Modeling for Procurement Risk Identification

Fuzzy risk values are assigned by respective persons as per their choice of levels from Table 3.3 for pair wise comparison which gives a matrix for normalization using equation 3.1. Fuzzy MPDM (Multi person decision making) or more specifically MPPC (Multi person preference criteria) technique is implemented here with the risk criteria for pair wise comparisons.

Table 3.3: Suggested numbers for risk grading [11]

$f(x_i, x_j)$	**Risk weight x_i of with respect to x_j**
1	Low risk
3	Moderate risk
5	High risk
7	Very high risk
9	Extra high risk
2,4,6,8	Intermediate values between levels

Following formula will do first normalization of fuzzy variable input as evaluator's ratings for generalized risk attributes of procurement. The formula is adapted from George J Klir and Bo Yuan [11].

$$f(x_i, x_j) = \frac{f(x_i, x_j)}{\max[f(x_i, x_j), f(x_j, x_i)]} = \min[1, f(x_i, x_j) / f(x_j, x_i)] \quad \ldots 3.1$$

After getting the normalized ratings of fuzzy values applying the formula shown in equation 3.1, individual risk/cost attribute will have the fuzzy risk rating for individual attributes using equation 3.2,

$f^{/}(X_k) = min(X_i)$ where k= 1 to 15 and X=generalized risk/cost attributes … 3.2

The total risk value of risk indicator can now be calculated using equation 3.3,

$$Rv = max\,[f^{/}(X_k)] \quad \ldots 3.3$$

The value of Rv is positioned into the scale mentioned in Table 3.4 and determined the risk level of the test case of procurement project.

All the risk attributes are rated by individual decision makers for different level of risk as Low risk, Moderate Risk, High Risk, Very High Risk, Extra High Risk etc. For quantification using Fuzzy system, reference grading is done over the attributes available, the individual risk attributes in this case. The numerical values are substituted in the fuzzy matrix for the assessment using such linguistics and then normalized using equation 3.1. After that least risk is obtained for each criteria is found using equation 3.2 and aggregated risk level is determined using equation 3.3. The suggestion generator will display the suggestion messages from the knowledge base selected through risk mitigation algorithm mentioned in section 3.3.

3.3 Algorithmic approach for risk mitigation

Following is a risk mitigation algorithm – a five step algorithm to helpful to locate risk areas of procurement and give flexibility to procurement professionals to resolve the issues.

$$STEP\ 1: If\ f^{/}(X_k)\ has\ more\ than\ zero\ row\ then\ select: Attribute\ (\max[f^{/}(X_k)])\ else\ goto\ STEP\ 5$$

$$STEP\ 2: If\ (\max[f^{/}(X_k)]) > 0.1\ then\ goto\ STEP\ 3\ else\ goto\ STEP\ 5$$

$$STEP\ 3: Risk\ Message \leftarrow Description\ (Knowledge\ base): (Attribut - X_j)\quad where\ X_j = All\ other\ attributes\ except\ the\ selected\ attribute$$

$$STEP\ 4: Resolve\ the\ descrepencies, remove\ row\ from\ f^{/}(X_k), goto\ STEP\ 1$$

$$STEP\ 5: Risk\ mitigated/Insufficient\ Risk$$

Dry Run of above algorithm is shown in Table 3.8, the algorithm is iterated for 15 times and at the 16th iteration the algorithm is terminated. Table 3.7 shows the generated messages for risk identification for first iteration.

3.4 Illustrative example

Table 3.4: Fuzzy risk grading for a test case

$f(x_i, x_j)$	RELY	DURN	CPLX	CPIS	CADP	SCAP	WSZE	WSKL	SEXP	UMTG	SCED	PMEX	PDTH	RISK	RVOL
RELY	1	3	7	9	7	9	3	5	5	5	3	1	3	9	5
DURN	5	1	3	5	5	3	7	5	3	5	9	3	3	3	9
CPLX	9	5	1	9	9	9	7	9	5	7	5	7	3	9	5
CPIS	3	3	5	1	1	3	3	5	3	1	3	5	3	7	1
CADP	9	1	1	1	1	1	3	3	5	5	3	3	1	7	1
SCAP	5	7	5	3	1	1	7	7	3	1	5	7	1	9	1
WSZE	1	9	7	1	1	3	1	9	3	3	5	1	1	3	1
WSKL	7	7	5	5	1	5	3	1	5	3	7	1	1	9	3
SEXP	1	1	3	1	1	5	3	7	1	1	1	3	1	3	1
UMTG	7	5	5	3	3	9	3	7	3	1	3	5	3	9	7
SCED	1	5	7	1	1	5	9	9	3	5	1	1	5	7	3
PMEX	3	1	1	3	1	7	3	5	7	5	3	1	7	1	1
PDTH	1	1	7	3	1	5	3	5	1	1	1	3	1	1	1
RISK	5	7	9	7	3	7	3	9	5	9	3	3	3	1	5
RVOL	5	1	3	1	7	3	1	1	5	1	5	3	5	7	1

Calculation samples:

$$f(x_1, x_1) = \frac{f(x_1, x_1)}{\max\,[f(x_1, x_1), f(x_1, x_1)]} = \frac{1}{\max\,[1,1]} = \frac{1}{1} = 1$$

$$f(x_1, x_3) = \frac{f(x_1, x_3)}{\max\,[f(x_1, x_3), f(x_3, x_1)]} = \frac{9}{\max\,[9,7]} = \frac{9}{9} = 1$$

$$f(x_2, x_1) = \frac{f(x_2, x_1)}{\max\,[f(x_2, x_1), f(x_1, x_2)]} = \frac{3}{\max\,[3,5]} = \frac{3}{5} = 0.6$$

$$f(x_2, x_3) = \frac{f(x_2, x_3)}{\max\,[f(x_2, x_3), f(x_3, x_2)]} = \frac{5}{\max\,[5,3]} = \frac{5}{5} = 1$$

$$f(x_2, x_4) = \frac{f(x_2, x_4)}{\max\,[f(x_2, x_4), f(x_4, x_2)]} = \frac{3}{\max\,[3,5]} = \frac{3}{5} = 0.6$$

$$f(x_2, x_5) = \frac{f(x_2, x_5)}{\max\,[f(x_2, x_5), f(x_5, x_2)]} = \frac{1}{\max\,[1,5]} = \frac{1}{5} = 0.2$$

$$f(x_2, x_{11}) = \frac{f(x_2, x_{11})}{\max\,[f(x_2, x_{11}), f(x_{11}, x_2)]} = \frac{5}{\max\,[5,9]} = \frac{5}{9} = 0.55$$

$$f(x_2, x_{12}) = \frac{f(x_2, x_{12})}{\max\,[f(x_2, x_{12}), f(x_{12}, x_2)]} = \frac{1}{\max\,[1,3]} = \frac{1}{3} = 0.33$$

$$f(x_2, x_{13}) = \frac{f(x_2, x_{13})}{\max\,[f(x_2, x_{13}), f(x_{13}, x_2)]} = \frac{1}{\max\,[1,3]} = \frac{1}{3} = 0.33$$

$$f(x_2, x_{14}) = \frac{f(x_2, x_{14})}{\max\,[f(x_2, x_{14}), f(x_{14}, x_2)]} = \frac{7}{\max\,[7,3]} = \frac{7}{7} = 1$$

$$f(x_2, x_{15}) = \frac{f(x_2, x_{15})}{\max\,[f(x_2, x_{15}), f(x_{15}, x_2)]} = \frac{1}{\max\,[1,9]} = \frac{1}{9} = 0.11$$

Table 3.5: Normalized matrix using equation 3.1 from Table 3.4

$f(x_i, x_j)$	RELY	DURN	CPLX	CPIS	CADP	SCAP	WSZE	WSKL	SEXP	UMTG	SCED	PMEX	PDTH	RISK	RVOL
RELY	1	0.6	0.78	1	0.78	1	1	0.714	1	0.714	1	0.33	1	1	1
DURN	1	1	0.6	1	1	0.429	0.78	0.714	1	1	0.6	1	1	0.429	1
CPLX	1	1	1	1	1	1	1	1	1	1	1	1	0.429	1	1
CPIS	0.33	0.6	0.56	1	1	1	1	1	1	0.33	1	1	1	1	1
CADP	1	0.2	0.11	1	1	1	1	1	1	1	1	1	1	1	0.143
SCAP	0.56	1	0.56	1	1	1	1	1	0.6	0.11	1	1	0.2	1	0.33
WSZE	0.33	1	1	0.33	0.33	0.429	1	1	1	1	0.11	0.33	0.33	1	1
WSKL	1	1	0.56	1	0.33	0.714	0.33	1	0.714	0.429	0.11	0.2	0.2	1	1
SEXP	0.2	0.33	0.6	0.33	0.2	1	1	1	1	0.33	1	0.429	1	0.6	0.2
UMTG	1	1	0.714	1	0.6	1	1	1	1	1	1	1	1	1	1
SCED	0.33	0.55	1	0.33	0.33	1	1	1	1	1	1	0.33	1	1	0.6
PMEX	1	0.33	0.143	0.6	0.33	1	1	1	1	1	1	1	1	0.33	0.33
PDTH	0.33	0.33	1	1	1	1	1	1	1	0.33	0.6	0.429	1	0.33	0.2
RISK	0.56	1	1	1	0.429	0.78	1	1	1	1	0.429	1	1	1	0.714
RVOL	0.2	0.11	0.6	1	1	1	1	1	1	0.143	1	1	1	1	1

Table 3.6: Deriving the values of $f^{/}(X_k)$ using equation 3.2

$f(x_i, x_j)$	**RELY**	**DURN**	**CPLX**	**CPIS**	**CADP**	**SCAP**	**WSZE**	**WSKL**	**SEXP**	**UMTG**	**SCED**	**PMEX**	**PDTH**	**RISK**	**RVOL**	$f^{/}(X_k)$
RELY	1	0.6	0.78	1	0.78	1	1	0.714	1	0.714	1	0.33	1	1	1	0.33
DURN	1	1	0.6	1	1	0.429	0.78	0.714	1	1	0.6	1	1	0.429	1	0.429
CPLX	0.33	1	1	1	1	1	1	1	1	1	1	1	0.429	1	1	0.33
CPIS	1	0.6	0.56	1	1	1	1	1	1	0.33	1	1	1	1	1	0.33
CADP	1	0.2	0.11	1	1	1	1	1	1	1	1	1	1	1	0.143	0.11
SCAP	0.56	1	0.56	1	1	1	1	1	0.6	0.11	1	1	0.2	1	0.33	0.11
WSZE	0.33	1	1	0.33	0.33	0.429	1	1	1	1	0.11	0.33	0.33	1	1	0.11
WSKL	1	1	0.56	1	0.33	0.714	0.33	1	0.714	0.429	0.11	0.2	0.2	1	1	0.11
SEXP	0.2	0.33	0.6	0.33	0.2	1	1	1	1	0.33	1	0.429	1	0.6	0.2	0.2
UMTG	1	1	0.714	1	0.6	1	1	1	1	1	1	1	1	1	1	0.6
SCED	0.33	0.55	1	0.33	0.33	1	1	1	1	1	1	0.33	1	1	0.6	0.33
PMEX	1	0.33	0.143	0.6	0.33	1	1	1	1	1	1	1	1	0.33	0.33	0.143
PDTH	0.33	0.33	1	1	1	1	1	1	1	0.33	0.6	0.429	1	0.33	0.2	0.2
RISK	0.56	1	1	1	0.429	0.78	1	1	1	1	0.429	1	1	1	0.714	0.429
RVOL	0.2	0.11	0.6	1	1	1	1	1	1	0.143	1	1	1	1	1	0.11

Calculation of Risk Value using equation 3.3:

Rv = {0.33, 0.429, 0.33, 0.33, 0.11, 0.11, 0.11, 0.11, 0.2, 0.6, 0.33, 0.143, 0.2, 0.429, 0.11}
= 0.6

The Risk mitigation algorithms of Section 3.3 will select Attribute UMTG using the condition of *STEP1* and generate a list of suggestions shown in Table 3.8. As per the instruction of *STEP 4* in Risk Mitigation Algorithm, suggested message should be considered by procurement professionals and corrective measures should be done to remove the risk and algorithm is iterated further to find next highest risk attribute. In the second iteration it will generate risk suggestions of DURN-RELY, DURN-CPLX, DURN-CPIS, DURN-CADP, DURN-SCAP, DURN-WSZE, DURN-WSKL, DURN-SEXP, DURN-UMTG, DURN-SCED, DURN-PMEX, DURN-PDTH, DURN-RISK, DURN-RVOL from knowledge base and after removal of these risks, the algorithm will be iterated again and so on. The iterations are summarized in Table 3.9. This is simply the result of Dry Run of Risk Mitigation Algorithm.

3.5 Alternative approach

Here, we have tried to substitute the fuzzy numerical equivalents with triangular fuzzy numbers instead of using single valued crisp number for fuzzyfication. In Table 3.10, same linguistics in Table 3.3 (except the intermediate values between levels) are mentioned with fuzzy triangular equivalents. After normalization, we compute the values of normalized risk ratings for each attribute and get an overall score for *Rv* and positioned into the scale of Table 3.11 and graphically fit into the scale as in Figure 3.1.

Table 3.7: Generated suggestions for particular test case

Attribute Pair with Risk Values	**Messages**
UMTG-RELY**(1.0)**	Bidder’s usage of modern technology is required to have significant reliability
UMTG –DURN**(1.0)**	Bidder’s usage of modern technology is required to have success to finish job within limited duration
UMTG –CPLX**(0.714)**	Bidder’s usage of modern technology is required to be fit for any level of job or product complexity
UMTG –CPIS**(1.0)**	Bidder’s usage of modern technology is required to show coping up any complementary product or service infrastructure available
UMTG –CADP**(0.6)**	Bidder’s usage of modern technology is required to adjust with customer’s adaptability
UMTG –SCAP**(1.0)**	Bidder’s usage of modern technology is required to show uplift their capability
UMTG –WSZE**(1.0)**	Bidder’s usage of modern technology is required to optimize workforce size
UMTG –WSKL**(1.0)**	Bidder’s usage of modern technology is required to show significant workforce skills
UMTG –SEXP**(1.0)**	Bidder’s usage of modern technology is required to show significant service experience
UMTG –SCED**(1.0)**	Bidder’s usage of modern technology is required to show history of successful job completion within tight schedule
UMTG –PMEX**(1.0)**	Bidder’s usage of modern technology is required to be related with relevant process experience
UMTG –PDTH**(1.0)**	Bidder’s usage of modern technology is required to be overcoming the barriers of available thoroughness of process documentations
UMTG –RISK**(1.0)**	Bidder’s usage of modern technology is required to be minimizing risk potentialities
UMTG –RVOL**(1.0)**	Bidder’s usage of modern technology is required to be cope able with any kind of requirement volatility

Table 3.8: Result of each iteration of Algorithm for risk mitigation

Iteration	**Instruction sequence**	**Generated Message with risk values**
1	*STEP 1, STEP 2, STEP 3, STEP 4*	UMTG-RELY**(1.0)**,UMTG –DURN**(1.0)**,UMTG –CPLX**(0.714)**,UMTG –CPIS**(1.0)**,UMTG –CADP**(0.6)**,UMTG –SCAP**(1.0)**,UMTG –WSZE**(1.0)**,UMTG –WSKL**(1.0)**,UMTG –SEXP**(1.0),** UMTG –SCED**(1.0)**,UMTG –PMEX**(1.0)**,UMTG –PDTH**(1.0)**,UMTG –RISK**(1.0)**,UMTG –RVOL**(1.0)**
2	*STEP 1, STEP 2, STEP 3, STEP 4*	DURN-RELY**(1.0)**,DURN-CPLX**(0.6)**,DURN-CPIS**(1.0)**,DURN-CADP**(1.0)**,DURN-SCAP**(0.429)**,DURN-WSZE**(0.78)**,DURN-WSKL**(0.714)**,DURN-SEXP**(1.0)**,DURN-UMTG**(1.0)**,DURN-SCED**(0.6)**,DURN-PMEX**(1.0)**,DURN-PDTH**(1.0)**,DURN RISK**(0.429)**,DURN-RVOL**(1.0)**
3	*STEP 1, STEP 2, STEP 3, STEP 4*	RISK-RELY**(1.0)**,RISK-DURN**(1.0)**,RISK-CPLX**(1.0)**,RISK-CPIS**(1.0)**,RISK-CADP**(0.429)**,RISK-SCAP**(0.78)**,RISK-WSZE**(1.0)**,RISK-WSKL**(1.0)**,RISK-SEXP**(1.0)**,RISK-UMTG**(1.0)**,RISK-SCED**(0.429)**,RISK-PMEX**(1.0)**, RISK-PDTH**(1.0)**, RISK-RVOL**(0.714)**
4	*STEP 1, STEP 2, STEP 3, STEP 4*	RELY-DURN**(0.6)**, RELY-CPLX**(0.78)**, RELY-CPIS**(1.0)**, RELY-CADP**(0.78)**, RELY-SCAP**(1.0)**, RELY-WSZE**(1.0)**, RELY-WSKL**(0.714)**, RELY-SEXP**(1.0)**, RELY-UMTG**(0.714)**, RELY-SCED**(1.0)**, RELY-PMEX**(0.33)**, RELY-PDTH**(1.0)**, RELY-RISK**(1.0)**, RELY-RVOL**(1.0)**
5	*STEP 1, STEP 2, STEP 3, STEP 4*	CPLX-RELY**(1.0)**, CPLX-DURN**(1.0)**, CPLX-CPIS**(1.0)**, CPLX-CADP**(1.0)**, CPLX-SCAP**(1.0)**, CPLX-WSZE**(1.0)**, CPLX-WSKL**(1.0)**, CPLX-SEXP**(1.0)**, CPLX-UMTG**(1.0)**, CPLX-SCED**(1.0)**, CPLX-PMEX**(1.0)**, CPLX-PDTH**(0.429)**, CPLX-RISK**(1.0)**, CPLX-RVOL**(1.0)**
6	*STEP 1, STEP 2, STEP 3, STEP 4*	CPIS-RELY(**1.0**),CPIS-DURN(**0.6**), CPIS-CPLX(**0.56**), CPIS-CADP(**1.0**), CPIS-SCAP(**1.0**), CPIS-WSZE(**1.0**), CPIS-WSKL(**1.0**), CPIS-SEXP(**1.0**), CPIS-UMTG(**0.33**), CPIS-SCED(**1.0**), CPIS-PMEX(**1.0**), CPIS-PDTH(**1.0**), CPIS-RISK(**1.0**), CPIS-RVOL(**1.0**)
7	*STEP 1, STEP 2, STEP 3, STEP 4*	SCED-RELY**(1.0)**,SCED–DURN**(0.55)**,SCED–CPLX**(1.0)**,SCED–CPIS**(0.33)**,SCED–CADP**(0.33)**,SCED–SCAP**(1.0)**,SCED–WSZE**(1.0)**,SCED–WSKL**(1.0)**,SCED–SEXP**(1.0)**,SCED-UMTG**(1.0)**,SCED–PMEX**(0.33)**,SCED–PDTH**(1.0)**,SCED–RISK**(1.0)**,SCED–RVOL**(0.6)**

Iteration	Instruction sequence	Generated Message with risk values
8	*STEP 1, STEP 2, STEP 3, STEP 4*	SEXP-RELY**(1.0)**, SEXP-DURN**(0.33)**,SEXP-CPLX**(0.6)**, SEXP-CPIS**(0.33)**, SEXP-CADP**(0.2)**, SEXP-SCAP**(1.0)**, SEXP-WSZE**(1.0)**, SEXP-WSKL**(1.0)**, SEXP-UMTG**(0.33)**, SEXP-SCED**(1.0)**, SEXP-PMEX**(0.429)**, SEXP-PDTH**(1.0)**, SEXP-RISK**(0.6)**, SEXP-RVOL**(0.2)**
9	*STEP 1, STEP 2, STEP 3, STEP 4*	PDTH-RELY**(1.0)**, PDTH–DURN**(0.33)**, PDTH–CPLX**(1.0)**, PDTH–CPIS**(1.0)**, PDTH–CADP**(1.0)**, PDTH–SCAP**(1.0)**, PDTH–WSZE**(1.0)**, PDTH–WSKL**(1.0)**, PDTH –SEXP**(1.0)**, PDTH –UMTG**(0.33)**, PDTH –SCED**(0.6)**, PDTH–PMEX**(0.429)**, PDTH–RISK**(0.33)**, PDTH–RVOL**(0.2)**
10	*STEP 1, STEP 2, STEP 3, STEP 4*	PMEX-RELY**(1.0)**, PMEX–DURN**(0.33)**, PMEX–CPLX**(0.143)**, PMEX–CPIS**(0.6)**, PMEX–CADP**(0.33)**, PMEX–SCAP**(1.0)**, PMEX–WSZE**(1.0)**, PMEX–WSKL**(1.0)**, PMEX–SEXP**(1.0)**, PMEX–UMTG**(1.0)**, PMEX–SCED**(1.0)**,PMEX–PDTH**(1.0)**,PMEX–RISK**(0.33)**,PMEX –RVOL**(0.33)**
11	*STEP 1, STEP 2, STEP 3, STEP 4*	CADP-RELY**(1.0)**, CADP-DURN**(0.2)**, CADP-CPLX**(0.11)**, CADP-CPIS**(1.0)**, CADP-SCAP**(1.0)**, CADP-WSZE**(1.0)**, CADP-WSKL**(1.0)**, CADP-SEXP**(1.0)**, CADP-UMTG**(1.0)**, CADP-SCED**(1.0)**, CADP-PMEX**(1.0)**, CADP-PDTH**(1.0)**, CADP-RISK**(1.0)**, CADP-RVOL**(0.143)**
12	*STEP 1, STEP 2, STEP 3, STEP 4*	SCAP-RELY**(1.0)**, SCAP-DURN**(1.0)**, SCAP-CPLX**(0.56)**, SCAP-CPIS**(1.0)**, SCAP-CADP**(1.0)**, SCAP-WSZE**(1.0)**, SCAP-WSKL**(1.0)**, SCAP-SEXP**(0.6)**, SCAP-UMTG**(0.11)**, SCAP-SCED**(1.0)**, SCAP-PMEX**(1.0)**, SCAP-PDTH**(0.2)**, SCAP-RISK**(1.0)**, SCAP-RVOL**(0.33)**
13	*STEP 1, STEP 2, STEP 3, STEP 4*	WSZE-RELY**(1.0)**,WSZE-DURN**(1.0)**,WSZE-CPLX**(1.0)**,WSZE-CPIS**(0.33)**,WSZE-CADP**(0.33)**,WSZE-SCAP**(0.429)**,WSZE-WSKL**(1.0)**, WSZE-SEXP**(1.0)**, WSZE-UMTG**(1.0)**, WSZE-SCED**(0.11)**, WSZE-PMEX**(0.33)**,WSZE-PDTH**(0.33)**,WSZE-RISK**(1.0)**,WSZE-RVOL**(1.0)**
14	*STEP 1, STEP 2, STEP 3, STEP 4*	WSKL-RELY**(1.0)**,WSKL-DURN**(1.0)**, WSKL-CPLX**(0.56)**, WSKL-CPIS**(1.0)**, WSKL-CADP**(0.33)**, WSKL-SCAP**(0.714)**, WSKL-WSZE**(0.33)**, WSKL-SEXP**(0.714)**, WSKL-UMTG**(0.429)**, WSKL-SCED**(0.11)**, WSKL-PMEX**(0.2)**, WSKL-PDTH**(0.2)**, WSKL-RISK**(1.0)**, WSKL-RVOL**(1.0)**

Iteration	Instruction sequence	Generated Message with risk values
15	*STEP 1, STEP 2, STEP 3, STEP 4*	RVOL-RELY**(1.0)**, RVOL-DURN**(0.11)**, RVOL-CPLX**(0.6)**, RVOL-CPIS**(1.0)**, RVOL-CADP**(1.0)**, RVOL-SCAP**(1.0)**, RVOL-WSZE**(1.0)**, RVOL-WSKL**(1.0)**, RVOL-SEXP**(1.0)**, RVOL-UMTG**(0.143)**, RVOL-SCED**(1.0)**, RVOL-PMEX**(1.0)**, RVOL-PDTH**(1.0)**, RVOL-RISK**(1.0)**
16	*STEP 1, STEP 5*	No message, Algorithm terminated

Table 3.9: Suggested triangular numbers for risk grading

$\boldsymbol{S(a, b, c)_i}$	**Linguistics**
(1,1,3)	Low risk
(1,3,5)	Moderate risk
(3,5,7)	High risk
(5,7,9)	Very high risk
(7,9,9)	Extra high risk
(2,4,6)	Intermediate values between Low Moderate Risk and High Risk
(4, 6, 8)	Intermediate values between High Risk and Very High Risk

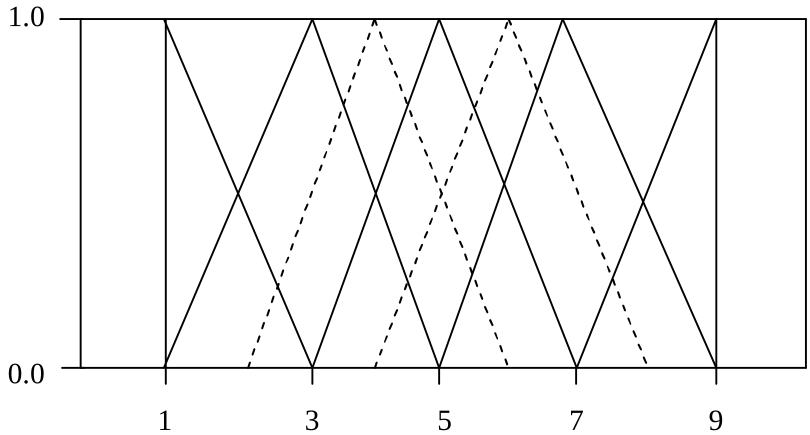

Figure 3.1: Graphical interpretation of triangular fuzzy number for fuzzy linguistics

Table 3.10: Fuzzy Triangular Risk Value and Description

Risk Value *(Rv)*	**Risk Description**
(1, 1, 3)	Very Low Risk
(1,3, 5)	Low Risk
(3, 5, 7)	Moderate Risk
(5, 7, 9)	High Risk
(7, 9, 9)	Very High Risk

The formula of equation 3.4 will do normalization of fuzzy input variable as triangular values for generalized risk attributes of procurement. The formula is taken from Arpan Kaur, Ashish Pani, Bijaya Mangaraj & Supriya De [9].

$$A_{ij} = \frac{f(a,b,c)_{ij}}{max\,[f(a,b,c)_{ij}, f(a,b,c)_{ji}]} \qquad \dots 3.4$$

After getting the calculated weights of fuzzy values, individual risk/cost attribute will have the fuzzy risk rating using formula of equation 3.5,

$$f^{/}(A(a,b,c)_j) = min\,[A(a,b,c)_j] \qquad \dots 3.5$$

where j= 1 to 15 and *A*=generalized risk or cost attributes

The total risk value of risk indicator can now be calculated using equation 3.6,

$$Rv = max[f^{/}(A(a,b,c)_j)] \qquad \dots 3.6$$

All the risk attributes are rated by individual decision makers for different level of risk as VERY LOW, LOW, MODERATE, HIGH, VERY HIGH and EXTRA HIGH. For quantification using Fuzzy system, reference grading is done over the attributes available, the individual risk attributes in this case. The numerical values are substituted in the fuzzy matrix for the assessment using such linguistics in the Table 3.12 and then normalized using equation 3.4 to obtain the matrix in Table 3.13. After that least risk is obtained for each criterion in Table 3.14 is found using equation 3.5 and aggregated risk level is determined using equation 3.6. This alternative approach is exampled next illustration in Illustrative Example 3.2.

Table 3.13: Triangular Risk values of each attribute

Risk attributes	**(a, b, c)**
RELY	(4.87, 4.99, 6.56)
DURN	(2.88, 3.34, 3.52)
CPLX	(5.51, 5.19, 5.79)
CPIS	(3.78, 3.83, 4.06)
CADP	(5.05, 5.19, 6.45)
SCAP	(4.46, 4.95, 4.95)
WSZE	(4.31, 4.13, 4.18)
WSKL	(4.33, 5.93, 6.02)
SEXP	(2.84, 3.11, 3.46)
UMTG	(2.81, 3.77, 4.74)
SCED	(5.99, 6.51, 6.88)
PMEX	(3.73, 5.32, 5.91)
PDTH	(3.68, 3.76, 4.66)
RISK	(5.01, 5.82, 6.1)
RVOL	(3.29, 4.28, 4.97)

The overall risk is obtained as (4.17, 4.67, 5.22) which is depicted in Figure 3.2. It exists in the set of Moderate Risk level.

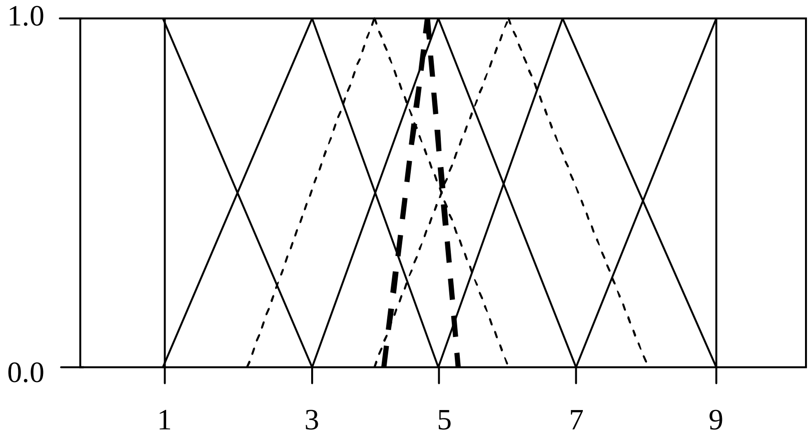

Figure 3.2: Risk level obtained in triangular fuzzy scale

In this illustration, no risk mitigation algorithm is further discussed. It would be quite similar to previous model and illustration and care should be taken to mitigate the risk presence where risk levels obtained greater than Low Risk until all attributes have been reduced to the same level of risk value such as Low Risk level.

Table 3.14: Risk attributes' values generated by Fuzzy MCDM and AHP method

	RELY	DURN	CPLX	CPIS	CADP	SCAP	WSZE	WSKL	SEXP	UMTG	SCED	PMEX	PDTH	RISK	RVOL
AHP data	0.085	0.083	0.114	0.051	0.05	0.069	0.052	0.069	0.034	0.081	0.068	0.057	0.038	0.09	0.058
Fuzzy data	0.33	0.429	0.33	0.33	0.11	0.11	0.11	0.11	0.2	0.6	0.33	0.143	0.2	0.429	0.11

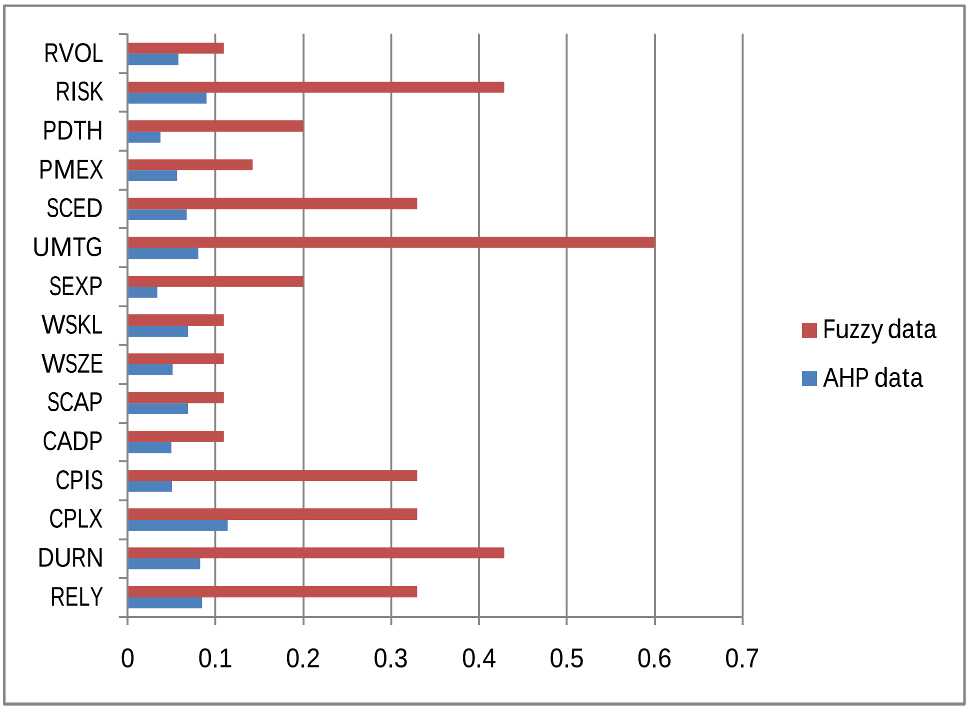

Figure 3.3: Comparison of risk values for Fuzzy MCDM and AHP results

3.7 Discussion

The major disadvantage of Algorithmic approach for procurement risk mitigation discussed in Section 3.3 is to remove all risk issues completely from procurement process is given mandatory which is quite impossible in real cases. Sometimes, procurement process is needed to be executed with some sort of risk. In such case this model will suspend the whole process until risk is totally removed as it is in the loop and termination condition of the algorithm.

The remedy to this problem is nothing but it is to insert another conditional statement whether to leave the risk value to exist in the procurement process or it is really needed to remove risks and make the process totally risk free before the selection process starts. Moreover, we have devised 210 rules for knowledge base or rule base where all the rules have been used as message for risk definition and its risk potentiality. There could be more accurate knowledge base if attribute pairs are paired further and new knowledge description is determined. Raymond Madachy [4] also derived about 210 rules and he separated some of them as suggestions, some as rules and few as useless but we have considered all 210 rules as message to users and risk factor to be mitigated.

Both Fuzzy MCDM and AHP method have been implemented to assess the risk with respective normalization technique and results have been noted and compared. Assessment of risk ratings have been summarized in Table 3.4 using the linguistics in Table 3.3 which is normalized using equation 3.1 and determined risk values for each attribute of risk areas which is later used to determine the optimized risk value of the procurement project. After that AHP normalization processed has been exercised over the dataset of Table 3.4 by dividing each element of the matrix by the column sum of respective column and summing up the results of division. The result of f/(x) of Fuzzy normalization and the result of AHP normalization have been summarized in Table 3.14 and tried to observe the differences.

Here we have found a significant difference in the results between AHP and Fuzzy MCDM method results. We have found that Fuzzy MCDM showed higher values in attribute values of risk associated in test result where AHP produces lower values. The question is which results are to be considered as more acceptable.

AHP determines the selection by selecting highest value from the matrix of the row sums of AHP normalized. AHP method has produced selected risk area CPLX (Product or Service Complexity). According to Fuzzy MCDM we have the selected risk area is UMTG (Usage of Modern Technology Area) which is determined by selecting the maximum value from the minimum values of each attribute pairs' normalized. This is actually an optimized solution determined by Fuzzy MCDM. So, going with AHP result would loss the better optimized values in this case. Moreover, AHP result will provide less opportunity to concentrate for risk mitigation for each area as both CPLX and UMTG have higher risk value generated by Fuzzy method than AHP results.

If we incorporate the risk mitigation algorithm with AHP selection of risk areas, it would be iterated less times and mitigate the risk found by the system execution as AHP method has produced lower values in the results than Fuzzy MCDM which could lower the system efficiency.

Hence, Fuzzy MCDM has been found better suited method than AHP in this risk area selection and risk mitigation.

CHAPTER 4

BIDDER SELECTOR

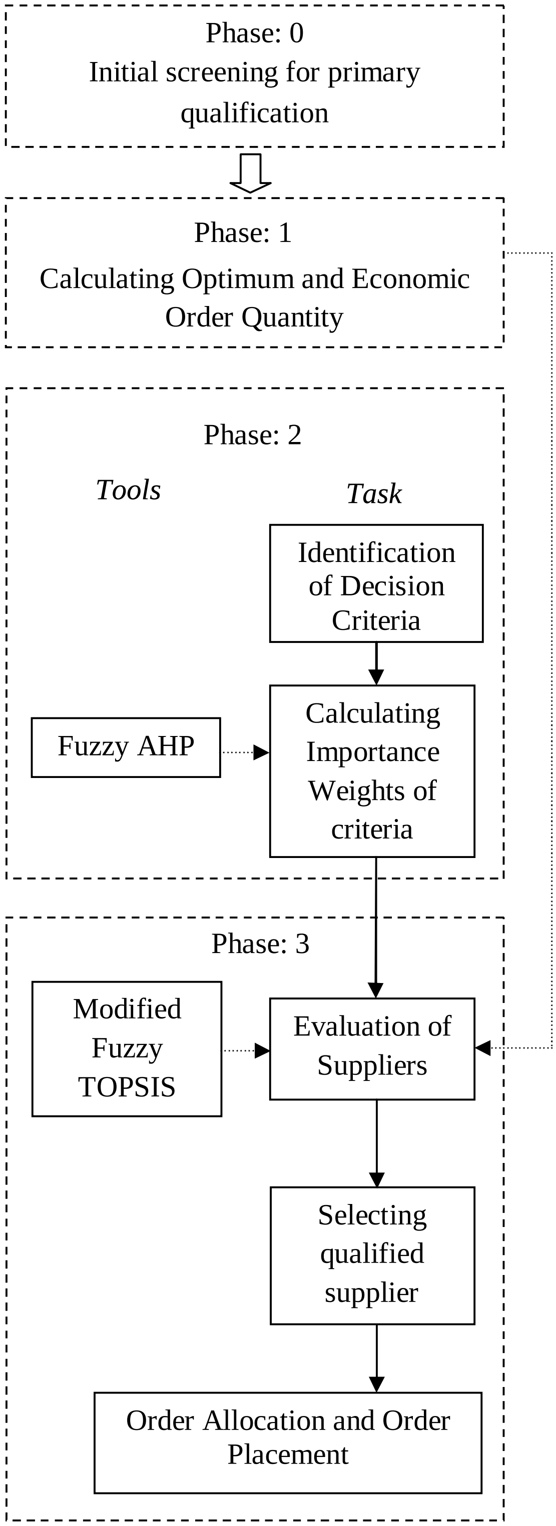

Figure 4.1: Diagram of Supplier Evaluator subsystem of Decision Engine [5]

4.1 Supplier Evaluator and Selector

In the literature of Jolai and Yazdian(2011) [5], a model consists of few phases like Phase 0 (Initial Screening), Phase 1 (Decision Criteria Identification, Calculation of Importance Weights, Evaluation of Suppliers, Selecting Qualified Suppliers – all are with the help of fuzzy TOPSIS) and Phase 2 (Shipment/order allocation to different suppliers using MOMILP). As this model is unable to select bidder with quantity discount offers, we have inserted an extra Phase into it to provide Price Break Model calculation to select some bidder who offers Economic and Optimum order quantity price quotations. The new proposed model is depicted in Figure 4.1.

There is no mathematical formula for Phase 0 evaluation because only relevance can be checked whether the bidder offers the same kind of product or same sort of services they are offering that are required by the procuring agency or the buyer.

4.1.1 Mathematical Modeling for Phase 1

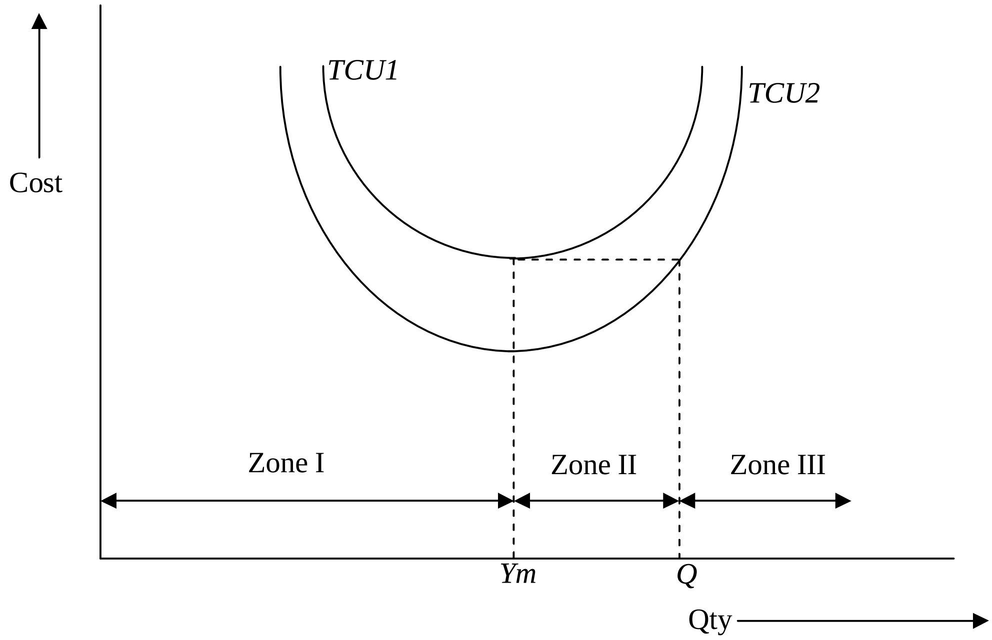

Figure 4.2: Inventory Cost Function with Price Breaks or Quantity Discount Offers [16]

The Price Break Model of inventory management can best be considered for quantity discount offers. We have got this model with mathematical foundation from Hamdy Taha[16].

Economic Order Quantity (EOQ) with Price break for quantity discount offers,

$$c = \begin{Bmatrix} c_1, if\ y \leq q \\ c_2, if y > q \end{Bmatrix}, c_1 > c_2 \quad \ldots 4.1$$

where,
y = size of the order
q = given limit for order quantity
c_1, c_2 = purchasing cost per unit

$$TCU(y) = \begin{cases} TCU_1(y) = Dc_1 + \frac{KD}{y} + \frac{h}{2}y, y \leq q \\ TCU_2(y) = Dc_2 + \frac{KD}{y} + \frac{h}{2}y, y > q \end{cases} \quad \ldots 4.2$$

$TCU_1(y), TCU_2(y)$ = Two different cost functions depicted the cost curves in Figure 4.2

K = Setup cost associated with placement of an order
D =Annual Demand of product quantity
h = holding cost of each quantity per unit time

Y_m= Optimum Order Quantity, $Y_m = \sqrt{\frac{2KD}{h}}$ … 4.3

Conditionally, $TCU_1(Y_m) = TCU_2(Q)$ this has been simplified into,

$$Q^2 + \left(\frac{2(c_2D - TCU_1(Y_m))}{h}\right)Q + \frac{2KD}{h} = 0 \quad \ldots 4.4$$

Where actual order quantity should be equal to q if it is in feasible area of figure in Zone-II

Algorithmic Approach for Order Quantity Calculation:

$STEP\ 1: Determine\ Value\ of\ Y_m$ (eq 4.3)
$STEP\ 2: Determine\ Q(> Y_m) from$ (eq 4.4)
$STEP\ 3: if\ q\ is\ in\ Zone - I, Zone - III, then\ order\ quantity\ is\ Y_m\ else\ if\ q\ is\ in\ Zone - II, then\ order\ quantity\ is\ q$

Table 4.1: Generalized Price offer list with feasibility check

Bidders(B_i)	**Offers (if order quantity ≤ q_i price = $p_i^/$ else order quantity> q_i price=p_i)**	**Feasibility**
Bidder 1	Breaking quantity (Qty) = q1, price=p1	Yes/No
Bidder 2	Breaking quantity (Qty) = q2, price=p2	Yes/No
Bidder 3	Breaking quantity (Qty) = q3, price=p3	Yes/No
…	… … … … … … …	…
Bidder N	Breaking quantity (Qty) = qN, price=pN	Yes/No

4.1.2 Mathematical Modeling of Phase 2

We have got the mathematical modeling from Jolai and Yazdian(2011) [5]. For evaluating suppliers, following decision criteria could be suited for the process of evaluation of bidders. These are:

(i) On-time delivery (C1)
(ii) Closeness of relationship with supplier (C2)
(iii) Supplier product/service quality (C3)
(iv) Supplier operational capability (C4)
(v) Price/cost (C5)

Fuzzy pair wise decision criteria evaluation matrix using all above criteria (C1~C5) are formed in Table 4.2 and generalized in Table 4.3.

Table 4.2: Fuzzy pair wise decision criteria evaluation matrix

	C1	**C2**	**C3**	**C4**	**C5**
C1	W11	W12	W13	W14	W15
C2	W21	W22	W23	W34	W25
C3	W31	W32	W33	W34	W35
C4	W41	W42	W43	W44	W45
C5	W51	W52	W53	W54	W55

Generalized form of above matrix is shown in Table 4.3.

Table 4.3: Fuzzy pair wise decision criteria evaluation matrix for n criteria

	C1	**C2**	**… … …**	**Cn**
C1	W11	W12	… … …	W1n
C2	W21	W22	… … …	W2n
. . .	. .	. .	. .	. .
Cn	Wn1	Wn2	… … …	Wnn

For m number of attributes (A1~Am) and n number of criteria (C1~Cn), fuzzy pair wise decision matrix is as shown in Table 4.4.

Table 4.4: Fuzzy pair wise comparison matrix for m attributes and n criteria for Multi criteria decision making (MCDM)

	C1	**C2**	**… … …**	**Cn**
A1	W11	W12	… … …	W1n
A2	W21	W22	… … …	W2n
. **.** **.**	. . .	. . .	. . .	. . .
Am	Wm1	Wm2	… … …	Wmn

Table 4.5: Linguistic variables for pair wise comparisons of criteria and their triangular fuzzy values [5]

Linguistic Variable	**Three variable fuzzy numbers**
Equal importance	(1,1,3)
Moderately more important	(1,3,5)
Strongly more important	(3,5,7)
Very strongly important	(5,7,9)
Extremely more important	(7,9,9)

For normalization of matrix of Table 4.3, equation 4.5 can be applied to form the normalized matrix after substituting the triangular fuzzy numbers as per ratings by Decision Makers using Linguistics in Table 4.5.

$$a_{jl} = \left(\prod_{k=1}^{K} a_{jl}^{k}\right)^{1/K} \quad , j = 1,2, \dots, n \ , \ l = 1,2, \dots, n \qquad \dots 4.5$$

Where K = number of decision makers, a_{jl} = is the normalized matrix of the matrix of table 11, 12, 13 or 14. The normalized matrix is further simplified into a row matrix using equation 4.6.

$$e_j = (a_{j1}, a_{j2}, \dots, a_{jn})^{1/n} \qquad \dots 4.6$$

Using the fuzzy geometric mean technique, the above row matrix can be transformed into fuzzy weight matrix of W_j.

$$W_j = e_j.(e_1 \oplus e_2 \oplus \dots \oplus e_n)^{-1} = e_j.\frac{1}{n}\sum_{j=1}^{n} e_j \quad \dots 4.7$$

4.1.3 Mathematical Modeling of Phase 3

Since (a, b, c) be a triangular fuzzy number, the graded mean integration method represents

$$P(A) = \frac{a+4b+c}{6} \quad \dots 4.8$$

In this book, the linear scale normalization formulas are used for transformation the various criteria from linguistic variables to equivalent fuzzy numeric values according to scales into normalized values of matrix which is to be used for normalized fuzzy decision making.

Generally speaking, $\mathbb{R} = [r_{ij}]_{m\times n}$

Where $r_{ij} = \left(\frac{a_{ij}}{c_{ij}}, \frac{b_{ij}}{c_{ij}}, \frac{c_{ij}}{c_{ij}}\right) \quad i = 1,2,\dots,m$ and $r_{ij}^{-} = \left(\frac{a_{ij}^{-}}{c_{ij}}, \frac{b_{ij}^{-}}{c_{ij}}, \frac{c_{ij}^{-}}{c_{ij}}\right) \quad i = 1,2,\dots,m \quad \dots 4.9$

which leads to

$r_j^{+} = \max[r_{ij}]$ and $r_j^{-} = \min[r_{ij}]$ where $i = 1,2,\dots,m$ and $j = 1,2,\dots,n$ … 4.10

In this consequence, fuzzy positive ideal solution and fuzzy negative ideal solution implied the formula in equation 4.11.

$$D_i^{+} = \sum_{j=1}^{n} W_j.d(r_{ij}, r_j^{+}), \quad i = 1,2,\dots,m \quad \dots 4.11$$

$$D_i^{-} = \sum_{j=1}^{n} W_j.d(r_{ij}, r_j^{-}), \quad i = 1,2,\dots,m \quad \dots 4.12$$

$$C_i = \frac{D_i^{-}}{D_i^{-}+D_i^{+}} \quad i = 1,2,\dots,m \quad \dots 4.13$$

$$CC_{ii} = \frac{C_{i1}+4C_{i2}+C_{i3}}{6}, \quad i = 1,2,\dots,m \quad \dots 4.14$$

$$R_i = \frac{CC_{ii} - CC_{ii}^{min}}{CC_{ii}^{max} - CC_{ii}^{min}}, \quad i = 1,2,\dots,m \quad \dots 4.15$$

In this stage, evaluation of alternative bidders for different criteria is the major important task which is the core job function of this particular model. Table 4.6 is the tool which describes the linguistic variable and their fuzzy equivalent numeric.

Table 4.6: Linguistic variables for rating of alternatives with respect to each criterion

Linguistic Variable	Three Variable Fuzzy Number
Very Poor (VP)	(0, 0, 1)
Poor (P)	(0, 1, 3)
Medium Poor (MP)	(1, 3, 5)
Fair (F)	(3,5,7)
Medium Good (MG)	(5, 7, 9)
Good (G)	(7, 9, 10)
Very Good (VG)	(9, 10, 10)

4.2 Illustrative example

Phase 1 Calculation

Table 4.7: Quantity discount offers from different bidders or suppliers

Bidders	Offers	
	Price Rate for quantity less than Q	Price Rate for quantity greater than or equal to Q
Bidder 1	Tk=55 for Q≤1250	Tk=52 for Q>1250
Bidder 2	Tk=49 for Q≤1100	Tk=48 for Q>1100
Bidder 3	Tk=56 for Q≤1310	Tk=55 for Q>1310
Bidder 4	Tk=48 for Q≤1750	Tk=47 for Q>1750
Bidder 5	Tk=60 for Q≤1000	Tk=57 for Q>1000
Bidder 6	Tk=43 for Q≤1660	Tk=40 for Q>1660
Bidder 7	Tk=74 for Q≤2000	Tk=72 for Q>2000
Bidder 8	Tk=69 for Q≤1500	Tk=67 for Q>1500

In an industry, some kind of product is to be procured by evaluation of offers proposed by some suppliers. The goods are not perishable and stored in an inventory. Table 4.7 is the summery of immediate next of initial screening that the generated list of bidders or suppliers with the relevant offers and the offers are of quantity discount price quotations. For following considerations, the optimum order quantity is calculated first so that economic order is quantity is obtained and feasibility of each quotation offers for particular prices and inventory capacity available is determined so that another list is obtained that consists of the bidders with their offers whose price quotation for respective quantity offers are feasible. The result is shown in Table 4.9.

Considerations:

Holding Cost: Tk, 12/= per unit per unit time

Setup Cost: Tk, 560/=

Annual Demand: 1480 units

Optimum order quantity (Y_m) $=\sqrt{(2 \times 560 \times 1480)/12} = 371.60$

Table 4.8: Optimum and Economic Order Quantity assessment

Bidders	Offers		Zone of Phase 1 Model of cost functions
	Price Rate for quantity less than Q	**Price Rate for quantity greater than or equal to Q**	
Bidder 1	Tk=55 for Q≤1250	Tk=52 for Q>1250	Zone-II: Feasible
Bidder 2	Tk=49 for Q≤1100	Tk=48 for Q>1100	Zone-III: Non feasible
Bidder 3	Tk=56 for Q≤1310	Tk=55 for Q>1310	Zone-III: Non feasible
Bidder 4	Tk=48 for Q≤750	Tk=47 for Q>750	Zone-II: Feasible
Bidder 5	Tk=60 for Q≤1000	Tk=57 for Q>1000	Zone-II: Feasible
Bidder 6	Tk=43 for Q≤660	Tk=40 for Q>660	Zone-II: Feasible
Bidder 7	Tk=74 for Q≤2000	Tk=72 for Q>2000	Zone-III: Non feasible
Bidder 8	Tk=69 for Q≤1500	Tk=67 for Q>1500	Zone-III: Non feasible

Table 4.9: Selected offers

Bidders	Offers	
	Quantity and Price	**Feasibility**
Bidder 1	Tk=52 for Q>1250	Feasible
Bidder 4	Tk=47 for Q>750	Feasible
Bidder 5	Tk=57 for Q>1000	Feasible
Bidder 6	Tk=40 for Q>660	Feasible

Phase 2 Calculation

A three member team of decision making has selected five criteria (i) On-time delivery (C1) (ii) Closeness of relationship with supplier (C2) (iii) Supplier product/service quality (C3) (iv) Supplier operational capability (C4) (v) Price/cost (C5) mentioned in Section 4.1.2. For these decision criteria, the three decision makers have found the importance weight for each criterion below. The three decision makers Decision Maker 1, Decision Maker 2 and Decision Maker 3 put their choices according to Table 4.6 linguistics and the respective triangular numerical values are shown in following Table 4.10, Table 4.11 and Table 4.12 respectively. These three fuzzy matrixes are then aggregated using above mathematical foundation and importance weight is determined in Table 4.14.

.

Table 4.10: The fuzzy pair wise comparision matrix of cirteria (decisin maker 1)[5]

	c1	c2	c3	c4	c5
c1	(1,1,1)	(5,7,9)	(1/5,1/3,1)	(3,5,7)	(1/3,1,1)
c2	(1/9,1/7,1/5)	(1,1,1)	(1/9,1/9,1/7)	(1/5,1/3,1)	(1/9,1/7,1/5)
c3	(1,3,5)	(7,9,9)	(1,1,1)	(3,5,7)	(1,3,5)
c4	(1/7,1/5,1/3)	(1,3,5)	(1/7,1/5,1/3)	(1,1,1)	(1/7,1/5,1/3)
c5	(1,1,3)	(5,7,9)	(1/5,1/3.1)	(3,5,7)	(1,1,1)

Table 4.11: the fuzzy pair wise comparision matrix of cirteria (decisin maker 2)[5]

	c1	c2	c3	c4	c5
c1	(1,1,1)	(3,5,7)	(1/5,1/3,1)	(5,7,9)	(1/5,1/3,1)
c2	(1/7,1/5,1/3)	(1,1,1)	(1/9,1/7,1/5)	(1,1,3)	(1/9,1/7,1/5)
c3	(1,3,5)	(5,7,9)	(1,1,1)	(5,7,9)	(1/3,1,1)
c4	(1/9,1/7,1/5)	(1/3,1,1)	(1/9,1/7,1/5)	(1,1,1)	(1/7,1/5,1/3)
c5	(1,3,5)	(5,7,9)	(1,1,3)	(3,5,7)	(1,1,1)

Table 4.12: the fuzzy pair wise comparision matrix of cirteria (decisin maker 3)[5]

	c1	c2	c3	c4	c5
c1	(1,1,1)	(5,7,9)	(1/7,1/5,1/3)	(1,3,5)	(1/5,1/3,1)
c2	(1/9,1/7,1/5)	(1,1,1)	(1/9,1/7,1/5)	(1/3,1,1)	(1/9,1/7,1/5)
c3	(3,5,7)	(5,7,9)	(1,1,1)	(3,5,7)	(1,1,3)
c4	(1/5,1/3,1)	(1,1,3)	(1/7,1/5,1/3)	(1,1,1)	(1/9,1/7,1/5)
c5	(1,3,5)	(5,7,9)	(1/3,1,1)	(5,7,9)	(1,1,1)

Table 4.13: Aggregated fuzzy pair wise comparison matrix
of criteria (over all decision makers)

	c1	c2	c3	c4	c5
c1	(1.0,1.0,1.0)	(4.16, 6.14, 8.10)	(0.18, 0.28, 0.70)	(2.44, 4.65, 6.67)	(0.24, 0.48, 1.0)
c2	(0.12, 0.16, 0.24)	(1.0,1.0,1.0)	(0.11, 0.13, 0.18)	(0.41, 0.70, 1.44)	(0.11, 0.15, 0.20)
c3	(1.44, 3.51, 5.50)	(5.50, 7.46, 8.80)	(1.0,1.0,1.0)	(3.51, 5.50, 7.46)	(0.70, 1.44, 2.44)
c4	(0.15, 0.22, 0.41)	(0.70, 1.44, 2.44)	(0.13, 0.18, 0.28)	(1.0,1.0,1.0)	(0.13, 0.18, 0.28)
c5	(1.44, 2.44, 3.51)	(4.92, 6.87, 8.80)	(0.41, 0.70, 1.44)	(3.51, 5.50, 7.46)	(1.0,1.0,1.0)

Table 4.14: e_j values and fuzzy importance weights W_j

Criteria	e_j	W_j
c1	(0.85, 1.31, 2.07)	(0.13, 0.18, 0.20)
c2	(0.23, 0.29,0.42)	(0.03, 0.04, 0.04)
c3	(1.81, 2.91, 3.88)	(0.27, 0.40, 0.38)
c4	(2.28, 0.40, 0.60)	(0.34, 0.06, 0.06)
c5	(1.59, 2.30, 3.19)	(0.24, 0.32, 0.32)

Phase 3 Calculation

In this phase, the decision makers are supposed to put the grading for the selected bidders to determine the ranking value of each bidder to finally select a single bidder or the best among the proposals. The bidders are evaluated as per assessments of decision makers in the same way in fuzzy comparison matrixes. Each bidder's aggregated fuzzy rating is obtained using mathematical formula mentioned above and summarized in Table 4-30 for each criteria C1 ~ C5. After that Table 4-30 is normalized and formed Table 4-31 to determine the values of r_j^+ and r_j^- which will lead to values of D_i^+ and D_i^- that has provided the value for C_i and CC_i. Hence finally the ranking of the bidder have obtained with R_i.

Table 4.15: The rating of four selected bidders by decision makers for criteria C1

Alternative bidders	Decision Makers (DM)		
	DM 1	DM 2	DM 3
Bidder 1	G	VG	VG
Bidder 4	VG	G	F
Bidder 5	F	MG	G
Bidder 6	MG	F	G

Table 4.16: Three variable fuzzy rating for criteria C1

Alternative bidders	Decision Makers (DM)		
	DM 1	DM 2	DM 3
Bidder 1	(7, 9, 10)	(9, 10, 10)	(9, 10, 10)
Bidder 4	(9,10,10)	(7, 9, 10)	(3, 5, 7)
Bidder 5	(3,5,7)	(5, 7, 9)	(7, 9, 10)
Bidder 6	(5, 7, 9)	(3, 5, 7)	(7, 9, 10)

Table 4.17: Three variable fuzzy rating for criteria C1

Alternative bidders	DM ratings aggregated
Bidder 1	(8.10, 9.44, 9.77)
Bidder 4	(5.64, 7.51, 8.69)
Bidder 5	(4.65, 6.67, 8.39)
Bidder 6	(4.65, 6.67, 8.39)

Table 4.18: The rating of four selected bidders by decision makers for criteria C2

Alternative bidders	Decision Makers (DM)		
	DM 1	DM 2	DM 3
Bidder 1	F	VG	F
Bidder 4	VG	MG	VG
Bidder 5	MG	G	VG
Bidder 6	G	MG	F

Table 4.19: Three variable fuzzy rating for criteria C2

Alternative bidders	Decision Makers (DM)		
	DM 1	DM 2	DM 3
Bidder 1	(3, 5, 7)	(9, 10, 10)	(3, 5, 7)
Bidder 4	(9, 10, 10)	(5, 7, 9)	(9, 10, 10)
Bidder 5	(5, 7, 9)	(7, 9, 10)	(9, 10, 10)
Bidder 6	(7, 9, 10)	(5, 7, 9)	(3, 5, 7)

Table 4.20: Three variable fuzzy rating for criteria C2

Alternative bidders	DM ratings aggregated
Bidder 1	(4.26, 6.18, 7.72)
Bidder 4	(7.25, 8.69, 9.44)
Bidder 5	(6.67, 8.39, 9.44)
Bidder 6	(4.65, 6.67, 6.98)

Table 4.21: The rating of four selected bidders by decision makers for criteria C3

Alternative bidders	Decision Makers (DM)		
	DM 1	DM 2	DM 3
Bidder 1	MG	F	VG
Bidder 4	VG	G	MG
Bidder 5	G	G	G
Bidder 6	MG	VG	G

Table 4.22: The rating of four selected bidders by decision makers for criteria C3

Alternative bidders	Decision Makers (DM)		
	DM 1	DM 2	DM 3
Bidder 1	(5, 7, 9)	(3, 5, 7)	(9, 10, 10)
Bidder 4	(9, 10, 10)	(7, 9, 10)	(5, 7, 9)
Bidder 5	(7, 9, 10)	(7, 9, 10)	(7, 9, 10)
Bidder 6	(5, 7, 9)	(9, 10, 10)	(7, 9, 10)

Table 4.23: Three variable fuzzy rating for criteria C3

Alternative bidders	DM ratings aggregated
Bidder 1	(5.05, 6.91, 8.39)
Bidder 4	(6.67, 8.39, 9.44)
Bidder 5	(6.87, 8.80, 9.77)
Bidder 6	(6.67, 8.39, 9.44)

Table 4.24: The rating of four selected bidders by decision makers for criteria C4

Alternative bidders	Decision Makers (DM)		
	DM 1	DM 2	DM 3
Bidder 1	P	F	G
Bidder 4	VG	F	G
Bidder 5	G	G	F
Bidder 6	F	P	P

Table 4.25: The rating of four selected bidders by decision makers for criteria C4

Alternative bidders	Decision Makers (DM)		
	DM 1	DM 2	DM 3
Bidder 1	(0, 1, 3)	(3, 5, 7)	(7, 9, 10)
Bidder 4	(9, 10, 10)	(3, 5, 7)	(7, 9, 10)
Bidder 5	(7, 9, 10)	(7, 9, 10)	(3, 5, 7)
Bidder 6	(3, 5, 7)	(0, 1, 3)	(0, 1, 3)

Table 4.26: Three variable fuzzy rating for criteria C4

Alternative bidders	DM ratings aggregated
Bidder 1	(0.0, 3.51, 5.84)
Bidder 4	(5.64, 7.51, 8.69)
Bidder 5	(5.19, 7.25, 8.69)
Bidder 6	(0.0, 1.70, 3.92)

Table 4.27: The rating of four selected bidders by decision makers for criteria C5

Alternative bidders	Decision Makers (DM)		
	DM 1	DM 2	DM 3
Bidder 1	MG	MG	F
Bidder 4	G	VG	VG
Bidder 5	G	G	MG
Bidder 6	VP	P	F

Table 4.28: The rating of four selected bidders by decision makers for criteria C5

Alternative bidders	Decision Makers (DM)		
	DM 1	DM 2	DM 3
Bidder 1	(5, 7, 9)	(5, 7, 9)	(3, 5, 7)
Bidder 4	(7, 9, 10)	(9, 10, 10)	(9, 10, 10)
Bidder 5	(7, 9, 10)	(7, 9, 10)	(5, 7, 9)
Bidder 6	(0, 0, 1)	(0, 1, 3)	(3, 5, 7)

Table 4.29: Three variable fuzzy rating for criteria C5

Alternative bidders	DM ratings aggregated
Bidder 1	(4.16, 6.14, 8.10)
Bidder 4	(8.10, 9.44, 9.77)
Bidder 5	(5.50, 8.10, 9.44)
Bidder 6	(0.0, 0.0, 2.73)

Table 4.30: Aggregated fuzzy ratings for all criteria of selected bidders for fuzzy evaluation

	C1	C2	C3	C4	C5
Bidder 1	(8.10, 9.44, 9.77)	(4.26, 6.18, 7.72)	(5.05, 6.91, 8.39)	(0.0, 3.51, 5.84)	(4.16, 6.14, 8.10)
Bidder 4	(5.64, 7.51, 8.69)	(7.25, 8.69, 9.44)	(6.67, 8.39, 9.44)	(5.64, 7.51, 8.69)	(8.10, 9.44, 9.77)
Bidder 5	(4.65, 6.67, 8.39)	(6.67, 8.39, 9.44)	(6.87, 8.80, 9.77)	(5.19, 7.25, 8.69)	(5.50, 8.10, 9.44)
Bidder 6	(4.65, 6.67, 8.39)	(4.65, 6.67, 6.98)	(6.67, 8.39, 9.44)	(0.0, 1.70, 3.92)	(0.0, 0.0, 2.73)

Table 4.31: Normalized matrix of fuzzy ratings for all criteria of selected bidders

	C1	C2	C3	C4	C5
Bidder 1	(0.81, 0.94, 0.98)	(0.43, 0.62, 0.77)	(0.51, 0.69, 0.84)	(0.0, 0.35, 0.58)	(0.42, 0.61, 0.81)
Bidder 4	(0.56, 0.75, 0.87)	(0.73, 0.87, 0.94)	(0.67, 0.84, 0.94)	(0.56, 0.75, 0.87)	(0.81, 0.94, 0.98)
Bidder 5	(0.47, 0.67, 0.84)	(0.67, 0.84, 0.94)	(0.69, 0.88, 0.98)	(0.52, 0.73, 0.87)	(0.55, 0.81, 0.94)
Bidder 6	(0.47, 0.67, 0.84)	(0.47, 0.67, 0.70)	(0.67, 0.84, 0.94)	(0.0, 0.17, 0.39)	(0.0, 0.0, 0.27)
W_j	(0.13, 0.18, 0.20)	(0.03, 0.04, 0.04)	(0.27, 0.40, 0.38)	(0.34, 0.06, 0.06)	(0.24, 0.32, 0.32)

Table 4.32: r_{ij} matrix

	C1	C2	C3	C4	C5
Bidder 1	0.83, 0.96, 1.0	0.56, 0.81, 1.0	0.61, 0.82, 1.0	0.0, 0.60, 1.0	0.52, 0.75, 1.0
Bidder 4	0.64, 0.86, 1.0	0.78, 0.93, 1.0	0.71, 0.89, 1.0	0.64, 0.86, 1.0	0.83, 0.96, 1.0
Bidder 5	0.56, 0.80, 1.0	0.27, 0.10, 1.0	0.70, 0.90, 1.0	0.60, 0.84, 1.0	0.59, 0.86, 1.0
Bidder 6	0.56, 0.80, 1.0	0.67, 0.96, 1.0	0.71, 0.89, 1.0	0.0, 0.44, 1.0	0.0, 0.0, 1.0

$$r_j^+ = \max[r_{ij}] = (0.83, 0.96, 1.0)$$
$$r_j^- = \min[r_{ij}] = (0.0, 0.0, 1.0)$$

Table 4.33: r_{ij} and W_j

r_j^+	(0.83, 0.96, 1.0)	(0.78, 0.96, 1.0)	(0.71, 0.90, 1.0)	(0.64, 0.86, 1.0)	(0.83, 0.96, 1.0)
	r_j^+ = (0.83, 0.96, 1.0)				
r_j^-	(0.56, 0.80, 1.0)	(0.27, 0.10, 1.0)	(0.61, 0.82, 1.0)	(0.0, 0.44, 1.0)	(0.0, 0.0, 1.0)
	r_j^- = (0.0, 0.0, 1.0)				
W_j	(0.13, 0.18, 0.20)	(0.03, 0.04,0.04)	(0.27, 0.40,0.38)	(0.34, 0.06, 0.06)	(0.24, 0.32, 0.32)

Table 4.34: D_i^+ calculation

	C1	C2	C3	C4	C5
Bidder 1	(0,0,0)	(0.0081, 0.006, 0)	(0.0594, 0.056, 0)	(0.2822, 0.0216, 0)	(0.0744, 0.0672, 0)
Bidder 4	(0.0247, 0.018, 0)	(0.0015, 0.0012, 0)	(0.0324, 0.028, 0)	(0.0646, 0.006, 0.01)	(0,0,0)
Bidder 5	(0.0351, 0.0288, 0)	(0.0168, 0.0344, 0)	(0.0351, 0.024, 0)	(0.0782, 0.0072, 0)	(0.0576, 0.032, 0)
Bidder 6	(0.0351, 0.0288, 0)	(0.0048, 0,0)	(0.0324, 0.028, 0)	(0.2822, 0.0312, 0)	(0.1992, 0.3072, 0)

Table 4.35: D_i^- calculation

	C1	C2	C3	C4	C5
Bidder 1	(0,0,0)	(0.00024, 0.00024, 0)	(0.01604, 0.0224, 0)	(0.09595, 0.0013, 0)	(0.01786, 0.0215, 0)
Bidder 4	(0.00321, 0.00324, 0)	(0.00005, 0.00005, 0)	(0.00875, 0.0112, 0)	(0.02196, 0.00036, 0)	(0, 0, 0)
Bidder 5	(0.00456, 0.00518, 0)	(0.0005, 0.00138, 0)	(0.00948, 0.0096, 0)	(0.02659, 0.00043, 0)	(0.01382, 0.01024, 0)
Bidder 6	(0.00456, 0.00518, 0)	(0.00014, 0, 0)	(0.00875, 0.0112, 0)	(0.09595, 0.00187, 0)	(0.04781, 0.0983, 0)

Table 4.36: Final evaluation of alternatives

	D_i^+	D_i^-	$C_i = \frac{D_i^-}{D_i^- + D_i^+}$	CC_i	R_i	Rank
Bidder 1	(0.4241, 0.1508, 0)	(0.13009, 0.02328, 0)	(0.2347389, 0.1543767, 0)	0.142041	0.0526	3
Bidder 4	(0.1232, 0.0532, 0)	(0.03397, 0.01485, 0)	(0.7338518, 0.21822189, 0)	0.267790	1.0	1
Bidder 5	(0.2228, 0.1264, 0)	(0.05495, 0.02683, 0)	(0.197839, 0.15323, 0)	0.135127	0.0	4
Bidder 6	(0.5537, 0.3952, 0)	(0.15721, 0.11655, 0)	(0.221139, 0.227748)	0.188688	0.406	2

Here the result shows that Bidder 5 is all over least preferred by decision makers where Bidder 4 is the most preference by the decision makers. Ultimate decision could include Bidder 1 or Bidder 6 because if they could have good preference values (more than 50% as threshold) by decision makers. Order allocation or distribution among Bidder1, Bidder 5 and Bidder 6 could be done in that case.

Foriborz Zolai suggested for rework in his paper [5] to derive a full-fuzzy technique that can deduce result on quantity discount offer where his model did not support quantity discount model. In this thesis work, quantity discount offers have been considered before the criteria are weighted and suppliers are selected on the basis of the fuzzy rating. It has been felt quite difficult to remove the linear programming, mixed integer linear programming or goal programming technique to convert the process into full fuzzy model. But it has been tried to be achieved implementing pure Economic Order Quantity model in Phase 1 and feed the result into the fuzzy model over selected bidders. Interestingly only four bidders have been selected in Phase 1 among Six bidders and later only three bidders have found with selected ratings where four bidders were selected by Foriborz Zolai in his illustration [5].

4.3 Alternative approach

Instead of using Fuzzy MCDM and Fuzzy TOPSIS method to learn the weight values of decision criteria as per the decision makers' assessment to consider the criteria with their given weight and evaluation of the bidders using the determined weight values and bidders' suitability and preferences, we have incorporated AHP and AHP TOPSIS method in the Jolai Model [5] and then tried to compare the results. The modified diagram is shown in the Figure 4.3.

There is no modification in Phase 0 and Phase 1 in the model. In Phase 2, AHP has been used for supporting technique for calculation of evaluation of importance weight of decision criteria and in Phase 3, AHP TOPSIS has been shown for suppliers or bidders evaluation. The ranking of the selected bidder will be produced by AHP method implementation rather Fuzzy MCDM and Fuzzy TOPSIS.

While illustrating this modified approach we have taken the same considerations as it was in the Section 4.2 with same set of quotation offers and the same selection of four bidders after passing through Phase 1. First changes occur in Phase 2. We have still the same assessments given the decision makers mentioned in Table 4.10, Table 4.11, Table 4.12 and the aggregated matrix in Table 4.13. The matrix in Table 4.13 is normalized by dividing each element by the each respective column sum and a new normalized matrix in Table 4.37.

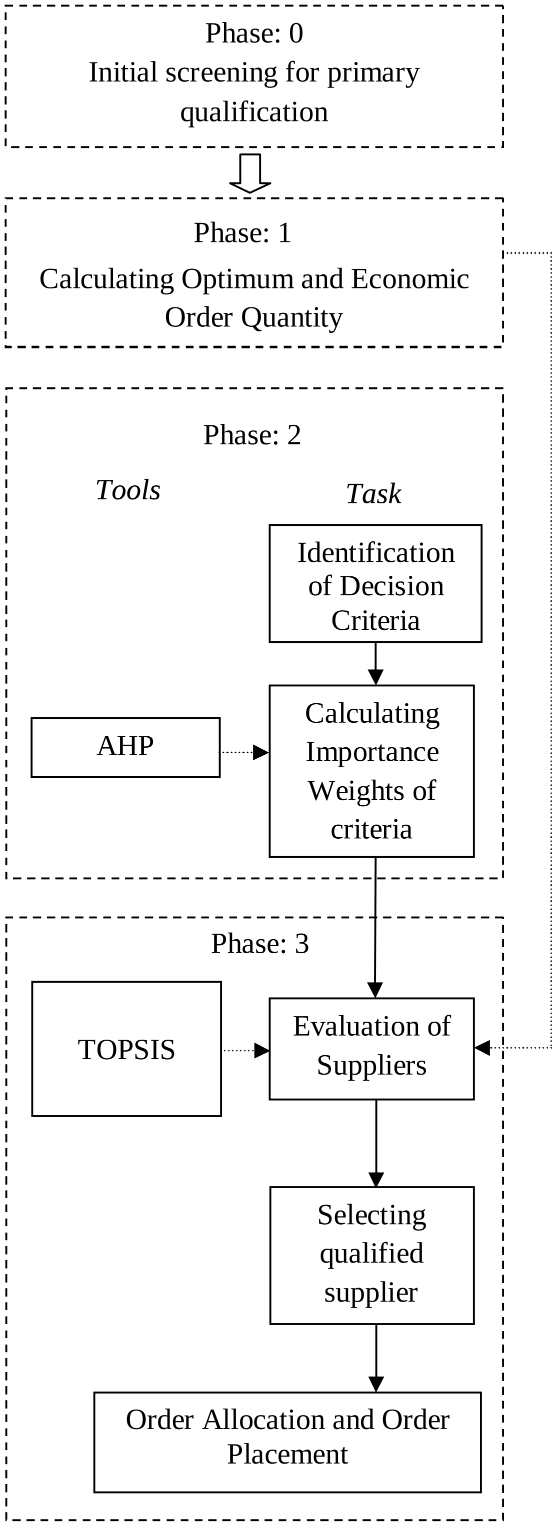

Figure 4.3: Modified model diagram of bidder selector using AHP and TOPSIS

Table 4.37: Aggregated pair wise comparison matrix
of criteria (over all decision makers) normalized by AHP Method

	c1	c2	c3	c4	c5
c1	(0.24096, 0.13643, 0.09381)	(0.25553, 0.26801, 0.27797)	(0.09836, 0.12227, 0.19444)	(0.22447, 0.26801, 0.27757)	(0.11009, 0.14769, 0.20325)
c2	(0.02892, 0.02183, 0.02251)	(0.06143, 0.04365, 0.03432)	(0.06011, 0.05677, 0.05)	(0.03772, 0.04035, 0.05993)	(0.05046, 0.04615, 0.04065)
c3	(0.34698, 0.47885, 0.51595)	(0.33784, 0.32562, 0.30199)	(0.54644, 0.43668, 0.27778)	(0.32291, 0.317, 0.31045)	(0.3211, 0.44307, 0.49593)
c4	(0.03614, 0.03001, 0.03846)	(0.04299, 0.06285, 0.08373)	(0.07104, 0.0786, 0.07778)	(0.09199, 0.05764, 0.04161)	(0.05963, 0.05538, 0.05691)
c5	(0.34699, 0.33288, 0.32927)	(0.30221, 0.29987, 0.30199)	(0.22404, 0.30568, 0.4)	(0.32291, 0.317, 0.31045)	(0.45872, 0.30769, 0.20325)

Tables 4.38: Comparison of decision criteria weight values

	AHP Weights	Fuzzy Weights
c1	(0.185882, 0.188482, 0.209408)	(0.13, 0.18, 0.2)
c2	(0.047728, 0.04175, 0.039353)	(0.03, 0.04, 0.04)
c3	(0.375054, 0.400244, 0.38042)	(0.27, 0.4, 0.38)
c4	(0.060358, 0.056896, 0.059698)	(0.34, 0.06, 0.06)
c5	(0.330974, 0.312624, 0.28624)	(0.24, 0.32, 0.32)

The row averages of Table 4.37 are summarized in Table 4.38 for comparing the Wj values determined in Table 4.14 which all graphically shown in Figure 4.4, Figure 4.5 and Figure 4.6 and found least gap between Fuzzy MCDM and AHP normalization results.

For Phase 3 calculation, we have considered the same ratings of the decision maker for four selected bidders selected by Phase 1 pass. The ratings shown in Table 4.15, Table 4.18, Table 4.21, Table 4.24, Table 4.27 and the aggregated ratings for all criteria of them for evaluation as in Table 4.30. Each value of Table 4.31 is multiplied by AHP generated Wj values {(0.185882, 0.188482, 0.209408), (0.047728, 0.04175, 0.039353), (0.375054, 0.400244, 0.38042), (0.060358, 0.056896, 0.059698), (0.330974, 0.312624, 0.28624)} for C1, C2, C3, C4 and C5 respectively and new matrix is formed in Table 4.39. New matrix in Table 4.39 is further normalized dividing each element by the respective column sum and taking the row averages determined the values of AHP Ci. AHP Ci values are converted into AHP CCi using equation 4.14 and Ranking values of AHP Ri using equation 4.15. Finally AHP and Fuzzy Ranking values are compared with each other as in Table 4.40 and graphical interpretations inn Figure 4.7, Figure 4.8, Figure 4.9 and Figure 4.10.

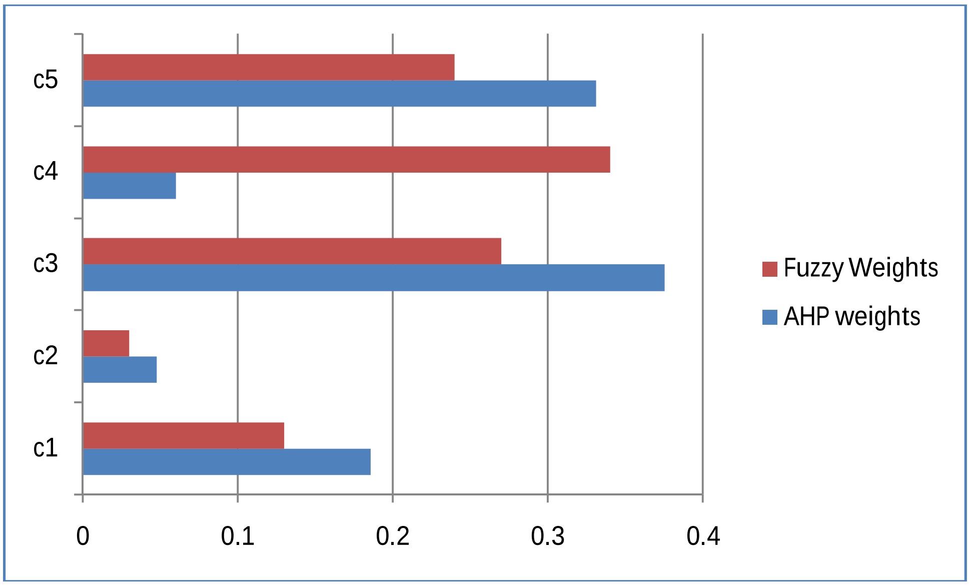

Figure 4.4: Comparison of decision criteria weight values (a of Triangle a,b,c)

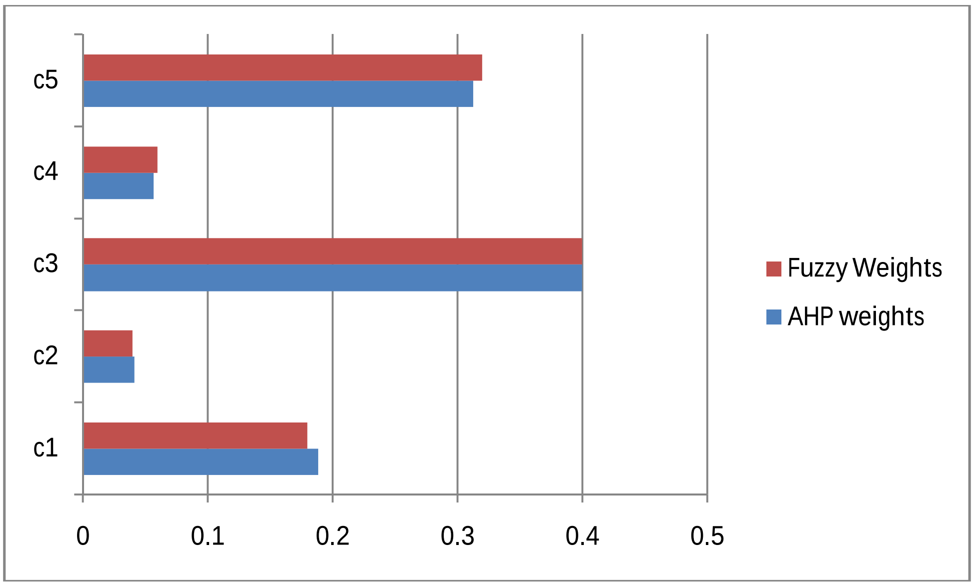

Figure 4.5: Comparison of decision criteria weight values (b of Triangle a,b,c)

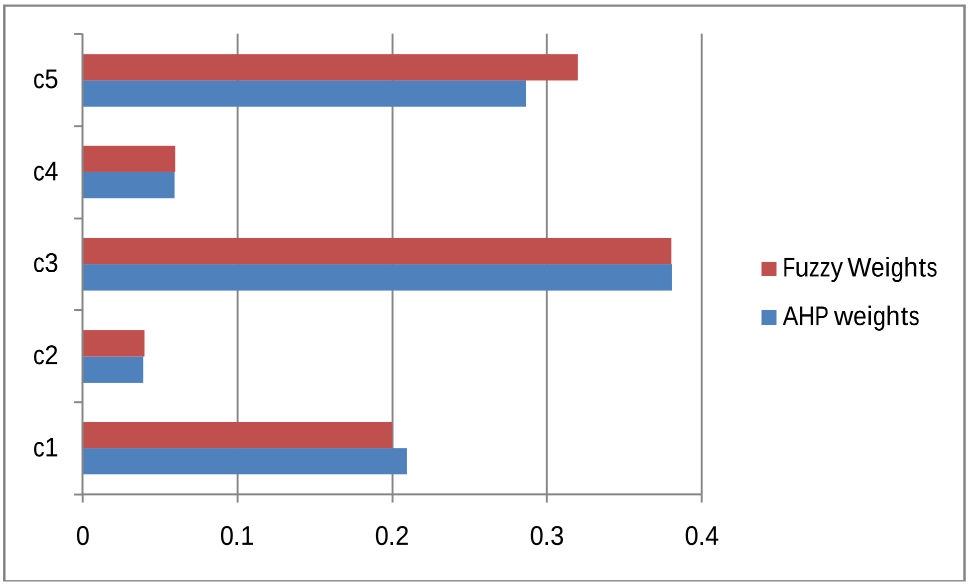

Figure 4.6: Comparison of decision criteria weight values (c of Triangle a,b,c)

Table 4.39: Normalized matrix of decision maker's ratings for all criteria of selected bidders by AHP Method

	C1	C2	C3	C4	C5
Bidder 1	(0.1505644, 0.1771731, 0.2052198)	(0.020523, 0.025885, 0.03030143)	(0.1912775, 0.2761684, 0.319553)	(0, 0.0199136, 0.0346248)	(0.1390091, 0.1907006, 0.231854)
Bidder 4	(0.1040939, 0.1413615, 0.182185)	(0.0348414, 0.036323, 0.03699135)	(0.2512862, 0.336205, 0.357595)	(0.0338005, 0.042672, 0.0519373)	(0.2680889, 0.2938666, 0.280515)
Bidder 5	(0.0873645, 0.1262829, 0.1759027)	(0.0319778, 0.03507, 0.03699135)	(0.2587873, 0.3522147, 0.372812)	(0.0313862, 0.0415341, 0.0519373)	(0.1820357, 0.2532254, 0.269066)
Bidder 6	(0.0873645, 0.1262829, 0.1759027)	(0.0224322, 0.027973, 0.02754675)	(0.2512862, 0.336205, 0.357595)	(0, 0.0096723, 0.0232822)	(0, 0, 0.077285)
W_j	(0.185882, 0.188482, 0.209408)	(0.047728, 0.04175, 0.039353)	(0.375054, 0.400244, 0.38042)	(0.060358, 0.056896, 0.059698)	(0.330974, 0.312624, 0.28624)

Table 4.40: Final evaluation of alternatives after AHP normalization

	AHP Ci	AHP CCi	AHP Ri	Rank
Bidder 1	(0.5013741, 0.689841, 0.8215533)	0.6803817	0.53493	3
Bidder 4	(0.692111, 0.850428, 0.9092236)	0.8338408	1	1
Bidder 5	(0.5915514, 0.808327, 0.9067085)	0.7885948	0.862878	2
Bidder 6	(0.3610829, 0.500133, 0.6616113)	0.5038708	0	4

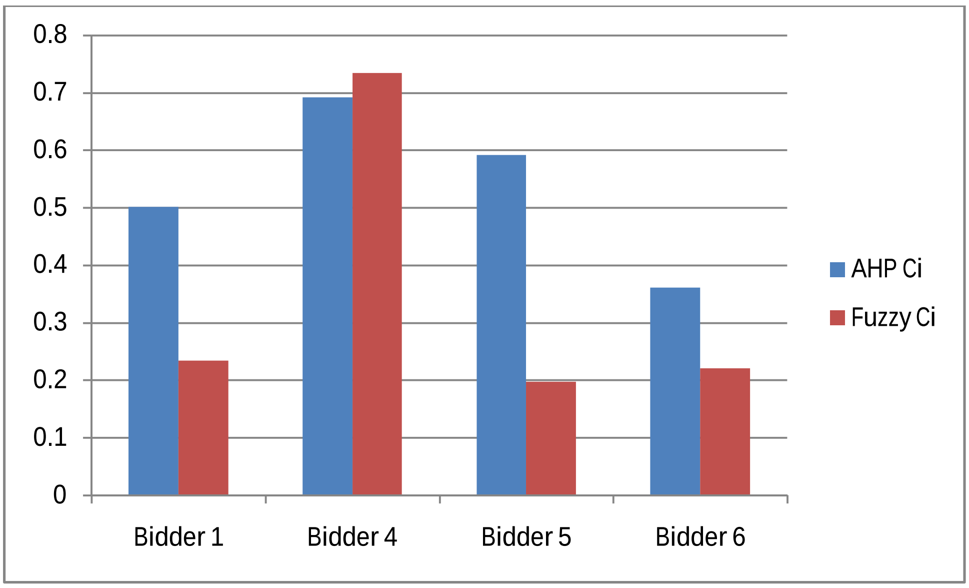

Figure 4.7: Comparison of Bidders' intermediate score determined by AHP and Fuzzy MCDM (a of triangle a,b,c)

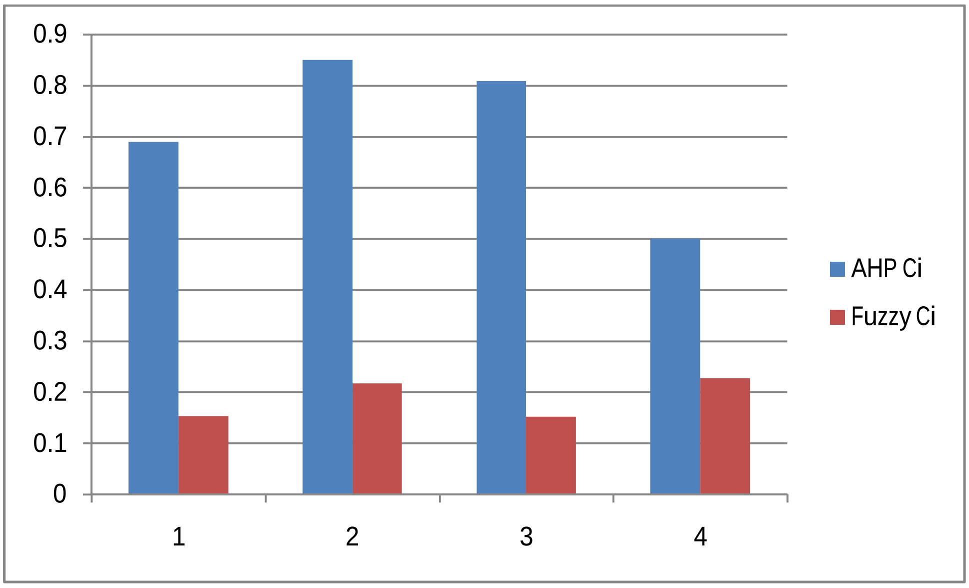

Figure 4.8: Comparison of Bidders' intermediate score determined by AHP and Fuzzy MCDM (b of triangle a,b,c)

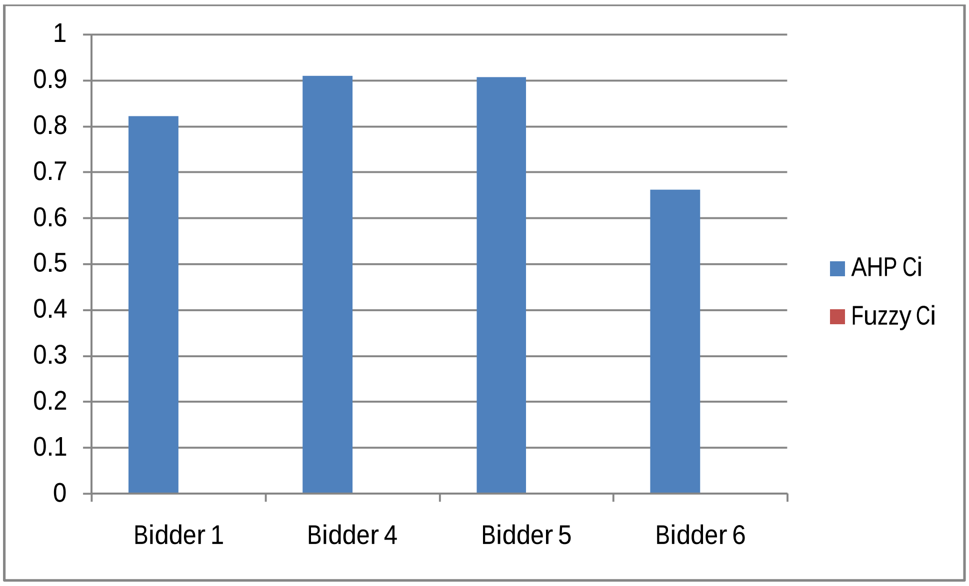

Figure 4.9: Comparison of Bidders' intermediate score determined by AHP and Fuzzy MCDM (c of triangle a,b,c)

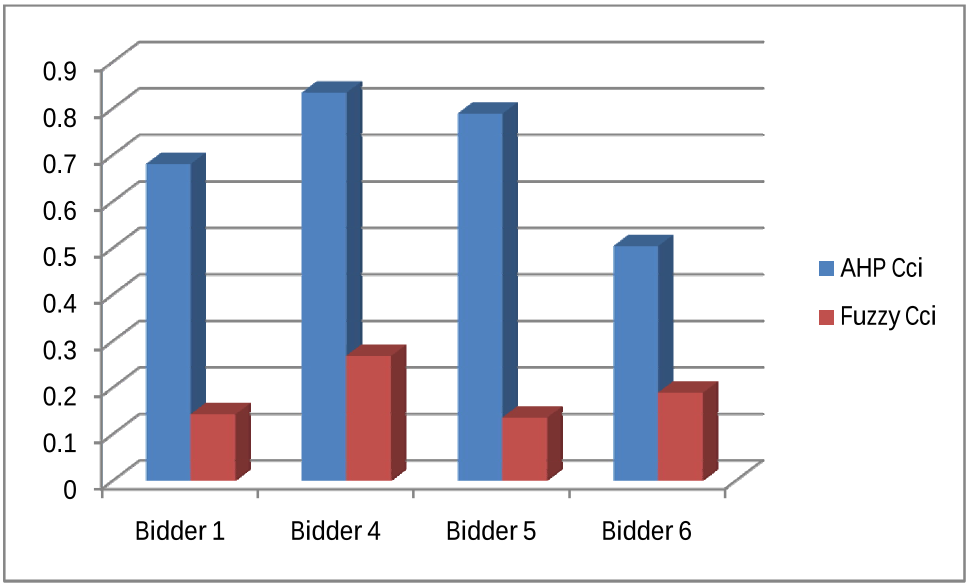

Figure 4.10: Comparison of intermediate ranking of AHP and Fuzzy MCDM method

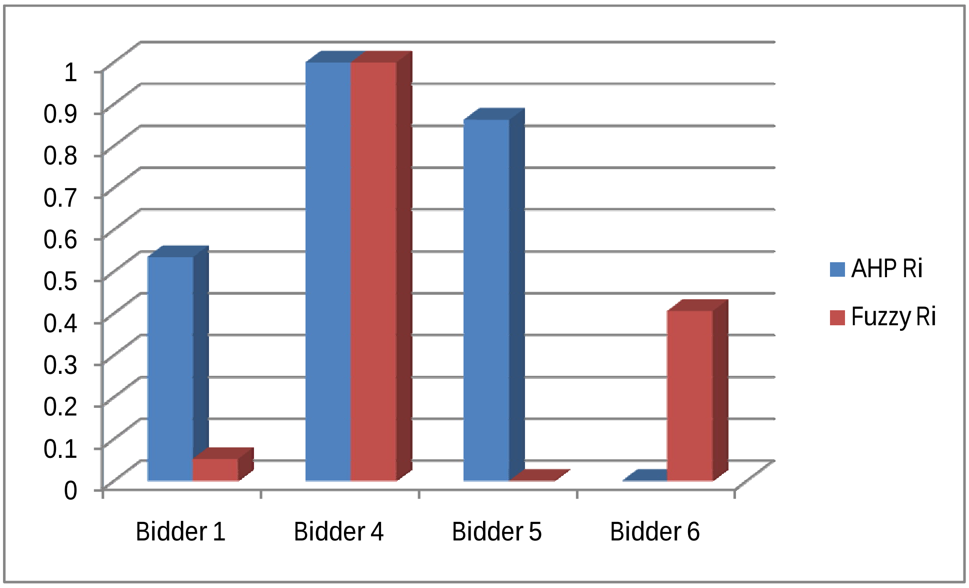

Figure 4.11: Comparison of final ranking of AHP and Fuzzy MCDM method

4.4 Discussion

According to Jolai Model using Fuzzy MCDM and his mathematical outline of his model, the result shows that Bidder 4 is mostly preferred by decision makers and Bidder 5 is the least preference by the decision makers as in Figure 4.11. When we have applied AHP method instead Fuzzy MCDM to fit into Jolai Model, we have found differences in selection values but same bidder is selected in this case i.e. Bidder 4 is the selection result of both AHP and Fuzzy MCDM method. If we like to select one bidder among many, we should select one with highest ranking or top ranked bidder. According to Jolai method, we have found Bidder 4 selected and we have got our selection for Bidder 4 using AHP method incorporated in Jolai Model i.e. AHP has successfully produce same result as produced by Fuzzy MCDM. Besides Jolai Model computes the values of Di+ and Di- which defines a particular range where optimized selection is resided and then the ranking is determined though human assessments can be varied and fluctuated. This is a strong feature of Jolai Model which can produce more acceptable values for bidder selection instead of AHP incorporated outline.

CHAPTER 5

PROCUREMENT MATURITY IDENTIFIER

5.1 Procurement Maturity Level Identification

According to Stephen Guth[13], procurement system's maturity is measured with respect to a best practice benchmark. Such benchmark is not an arbitrary consideration rather 60 best practices have been identified among many cases which all are set as the upper limit of quality of procurement service or benchmark level and a test case is measured with the gap analysis between the ceiling of best case and status level of test case.

Here it is quite difficult to find the best procurement cases where no best practice or better level of service for procurement is felt as requirement due to unhealthy, erroneous and corrupted practices found among the local procuring entities.

Though Stephen Guth[13] has shown the measurement process quite clearly with benchmarking, the test cases are measured on the basis or rating of auditors for quality judgment on which the rating score is further calculated. The calculation model is absent in his paper.

\As it is quite impossible to find such best procurement practice and deriving a benchmark, and it is unclear for implantation of this approach in case of absence of best practice cases and such benchmarks, fuzzy rating and MCDM is quite suitable method for judgment of a procurement case to determine its quality or professional maturity level.

5.2 Mathematical Outline for Maturity Calculation

In Table 5.1, a list of determinant for calculation of procurement maturity has been shown. This list is defined by Stephen Guth [13] with which we have applied the technique of Fuzzy MCDM. In the Illustrative Example 5.1, each major area of concentration is measured a fuzzy normalized rating value through comparison matrix of sub-criteria and normalized using the equation 3.1 and values of $f^{/}(X_k)$ are determined using equation 3.2 where the assessment by the decision maker is to carry out with the help of the linguistics of Table 5.2 which is same as Table 3.3. Then the normalized rating values of all major areas like

‘Customer’, ‘Organization’, ‘Policy’, ‘Process’, ‘Staff’, ‘Tools’, ‘Value’ and ‘Vendors’ are summed up using the equation 5.1 and positioned into the scale in Figure 5.1.

Table 5.1: Stephen Guth’s determinants list

Customer	Engagement(EGN), Procurement Instruction(PIS), Relationship Management(RMG), Satisfaction(STF), Status Reporting(SRT)
Organization	Best Practice(BPC), Business Plan(BPN), Executive Support(EXS), Mission Statement(MSN), Strategic Plan(SPN), Structure(STR), Vision Statement(VSN)
Policy	Approval authority levels(AUL), Business Continuity Plan(BCP), Delegation of spend(DSP), Procurement authority(PAT), Procurement policy(PPY), Procurement standards(PSD), Record retention(RRN)
Process	Audit(AUD), Competitive bidding plan(CBP), Cost reduction plans(CRP), Forecast(FRC), Negotiation planning(NGP), Purchase order generation(POG), Spend profile(SPL).
Staff	Certification(CRT), Commodity training(CTR), Customer engagement(CEG), Employee engagement(EEG), Job qualification(JQF), Performance Management(PMG), Performance objectives(PFO), Procurement Training(PRT), Training Plan(TRP)
Tools	Contract approval workflow automation(CWA), Contract labor sourcing system(CSS), Contract management system(CMS), Contract templates(CTL), eRFX(RFX) External Website(EXW), P-Cards(PCD), Procure-to-Process(PPO), Requisition(RQS), Reverse auctions(RVA), RFX templates(RFT), Third party research(TPR), Vendor profile system(VPS), Vendor relationship management system(VRM)
Value	Contract disputes(CDS), Contract risk level(Rv), Contract Template Ratio(CRO), Contract turnaround time(CTT), Cost savings(CVS), RFX turnaround time(RTT)
Vendors	Approved vendor list(AVL), Measurement and Matrices(MMS), Vendor categorization(VCN), Vendor qualification(VQN), Vendor Rationalization(VRN), Vendor Recognition(VRG)

Note: The value of Contract Risk Level of the identifier Value is substituted from the value calculated from the Risk Identifier subsystem of Procurement Decision Engine and rest of all are rated by fuzzy rating.

Table 5.2: Suggested numbers for maturity rating

$f(x_i, x_j)$	**Maturity level x_i with respect to x_j**
1	Low level maturity
3	Moderate level maturity
5	High level maturity
7	Very high level maturity
9	Extra high level maturity
2,4,6,8	Intermediate values between levels

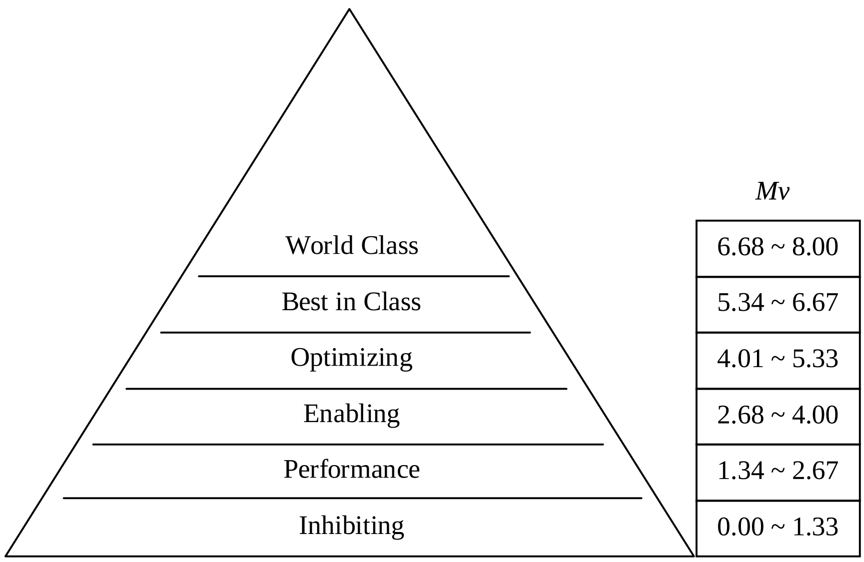

Figure 5.1: Maturity levels of procurement practice with equivalent value ranges

Generally in case of any changes in the attributes (customer, organization, policy, process, staff, tools, value, vendors) for addition or deletion of any attribute

$$Mv = \sum_{i=1}^{n} Calculated\ Score_{\ i} \qquad \dots 5.1$$

5.3 Illustrative Example

Value

Table 5.3: Fuzzy rating without numerical equivalence of the Risk Value of identifier 'Value'

	CDS	RV(=10–Rv)	CRO	CTT	CVS	RTT
CDS	1	(1 - 3.87)	5	3	4	2
RV(=10–Rv)	(1 - 3.87)	1	(1 - 3.87)	(1 - 3.87)	(1 - 3.87)	(1 - 3.87)
CRO	3	(1 - 3.87)	1	4	6	4
CTT	7	(1 - 3.87)	5	1	7	9
CVS	4	(1 - 3.87)	6	5	1	8
RTT	4	(1 - 3.87)	3	7	9	1

Table 5.4: Fuzzy rating of identifier 'Value' with Contract Risk value from Risk identifier subsystem

	CDS	RV	CRO	CTT	CVS	RTT
CDS	1	6.13	5	3	4	2
RV	6.13	1	6.13	6.13	6.13	6.13
CRO	3	6.13	1	4	6	4
CTT	7	6.13	5	1	7	9
CVS	4	6.13	6	5	1	8
RTT	4	6.13	3	7	9	1

Table 5.5: Normalized valued of Table 4.5

	CDS	RV	CRO	CTT	CVS	RTT
CDS	1.0	1.0	1.0	0.429	1.0	0.5
RV	1.0	1.0	1.0	1.0	1.0	1.0
CRO	0.6	1.0	1.0	1.0	1.0	1.0
CTT	1.0	1.0	1.0	1.0	1.0	1.0
CVS	1.0	1.0	1.0	0.714	1.0	0.89
RTT	1.0	1.0	0.75	1.0	1.0	1.0

$Calculated\ score\ (Value) = max\ [min(X_i)]$

= *max* (0.429, 1.0, 0.6, 1.0, 0.714, 0.75)

= 0.75

Customer

Engagement(EGN), Procurement Instruction(PIS), Relationship Management(RMG), Satisfaction(STF), Status Reporting(SRT)

Table 5.6: Fuzzy rating of procurement maturity identifier 'Customer'

	ENG	PIS	RMG	STF	SRT
ENG	1	5	2	5	7
PIS	5	1	6	3	3
RMG	4	4	1	1	1
STF	6	8	1	1	8
SRT	3	1	8	8	1

Table 5.7: Normalized Fuzzy rating of procurement maturity identifier 'Customer'

	ENG	PIS	RMG	STF	SRT
ENG	1.0	1.0	0.5	0.83	1.0
PIS	1.0	1.0	1.0	0.38	1.0
RMG	1.0	0.67	1.0	1.0	0.12
STF	1.0	1.0	1.0	1.0	0.12
SRT	0.43	0.33	1.0	1.0	1.0

$Calculated\ score\ (Customer) = max\ [min(X_i)]$

$= max(0.5, 0.38, 0.13, 1.0, 0.33)$

= 1.0

Organization

Best Practice(BPC), Business Plan(BPN), Executive Support(EXS), Mission Statement(MSN), Strategic Plan(SPN), Structure(STR), Vision Statement(VSN)

Table 5.8: Fuzzy rating of procurement maturity identifier 'Organization'

	BPC	BPN	EXS	MSN	SPN	STR	VSN
BPC	1	4	2	5	1	2	5
BPN	5	1	6	7	3	5	8
EXS	4	4	1	1	5	3	1
MSN	6	8	1	1	5	1	3
SPN	3	1	8	8	1	6	4
STR	5	6	6	7	3	1	9
VSN	4	4	3	1	5	4	1

Table 5.9: Normalized values of Fuzzy rating of procurement maturity identifier 'Organization'

	BPC	BPN	EXS	MSN	SPN	STR	VSN
BPC	1.0	0.8	0.5	0.83	0.33	0.4	1.0
BPN	1.0	1.0	1.0	0.88	1.0	0.83	1.0
EXS	1.0	0.67	1.0	1.0	0.62	0.5	0.33
MSN	1.0	1.0	1.0	1.0	0.62	0.14	1.0
SPN	1.0	0.33	1.0	1.0	1.0	1.0	0.8
STR	1.0	1.0	1.0	1.0	0.5	1.0	1.0
VSN	0.8	0.5	1.0	0.33	1.0	0.44	1.0

$Calculated\ score\ (Organization) = max\ [min(X_i)]$

$= max(0.33, 0.83, 0.33, 0.14, 0.33, 0.5, 0.33)$

= 0.5

Policy

Approval authority levels (AUL), Business Continuity Plan(BCP), Delegation of spend(DSP), Procurement authority(PAT), Procurement policy(PPY), Procurement standards(PSD), Record retention(RRN)

Table 5.10: Fuzzy rating of procurement maturity identifier 'Policy'

	AUL	BCP	DSP	PAT	PPY	PSD	RRN
AUL	1	3	1	7	2	3	6
BCP	7	1	7	8	2	3	7
DSP	4	1	1	3	5	4	2
PAT	1	7	3	1	3	5	4
PPY	8	1	7	7	1	8	7
PSD	5	5	6	6	1	1	8
RRN	3	4	8	8	8	1	1

Table 5.11: Normalized values of Fuzzy rating of procurement maturity identifier 'Policy'

	AUL	BCP	DSP	PAT	PPY	PSD	RRN
AUL	1.0	0.43	0.25	1.0	0.25	0.6	1.0
BCP	1.0	1.0	1.0	1.0	1.0	0.6	1.0
DSP	1.0	0.14	1.0	1.0	0.71	0.67	0.25
PAT	1.0	0.88	1.0	1.0	0.43	0.83	0.5
PPY	1.0	0.5	1.0	1.0	1.0	1.0	0.88
PSD	1.0	1.0	1.0	1.0	0.12	1.0	1.0
RRN	0.5	0.57	1.0	1.0	1.0	0.12	1.0

$Calculated\ score\ (Policy) = max\ [min(X_i)]$

$= max(0.25, 0.6, 0.14, 0.14, 0.5, 0.12, 0.12)$

$= 0.6$

Process

Audit(AUD), Competitive bidding plan(CBP), Cost reduction plans(CRP), Forecast(FRC), Negotiation planning(NGP), Purchase order generation(POG), Spend profile(SPL)

Table 5.12: Fuzzy rating of procurement maturity identifier 'Process'

	AUD	CBP	CRP	FRC	NGP	POG	SPL
AUD	1	4	6	9	3	2	7
CBP	9	1	7	1	3	3	6
CRP	8	2	1	4	2	4	3
FRC	4	5	1	1	5	5	5
NGP	4	2	5	6	1	7	8
POG	1	6	7	6	9	1	1
SPL	7	3	7	5	1	2	1

Table 5.13: Normalized values of Fuzzy rating of procurement maturity identifier 'Process'

	AUD	CBP	CRP	FRC	NGP	POG	SPL
AUD	1.0	0.44	0.75	1.0	0.75	1.0	1.0
CBP	1.0	1.0	1.0	0.2	1.0	0.5	1.0
CRP	1.0	0.29	1.0	1.0	0.4	0.57	0.43
FRC	0.44	1.0	0.25	1.0	0.83	0.83	1.0
NGP	1.0	0.67	1.0	1.0	1.0	0.78	1.0
POG	0.5	1.0	1.0	1.0	1.0	1.0	0.5
SPL	1.0	0.5	1.0	1.0	0.12	1.0	1.0

$Calculated\ score\ (Process) = max\ [min(X_i)]$

$= max\ (0.44, 0.2, 0.29, 0.25, 0.67, 0.5, 0.12)$

$= 0.67$

Staff

Certification(CRT), Commodity training(CTR), Customer engagement(CEG), Employee engagement(EEG), Job qualification(JQF), Performance Management(PMG), Performance objectives(PFO), Procurement Training(PRT), Training Plan(TRP)

Table 5.14: Fuzzy rating of procurement maturity identifier 'Staff'

	CRT	CTR	CEG	EEG	JQF	MPG	PFO	PRT	TRP
CRT	1	3	7	5	1	2	6	3	7
CTR	4	1	5	6	8	7	8	5	1
CEG	8	2	1	4	2	4	3	1	9
EEG	4	5	1	1	5	5	5	4	5
JQF	5	5	3	1	1	8	4	7	6
MGP	1	6	7	6	9	1	1	7	2
PFO	9	9	7	1	3	3	1	6	2
PRT	1	4	6	9	3	2	7	1	3
TRP	4	3	6	7	8	3	6	4	1

Table 5.15: Normalized values of Fuzzy rating of procurement maturity identifier 'Staff'

	CRT	CTR	CEG	EEG	JQF	MPG	PFO	PRT	TRP
CRT	1.0	0.75	0.88	1.0	0.2	1.0	0.67	1.0	1.0
CTR	1.0	1.0	1.0	1.0	1.0	1.0	0.89	1.0	0.33
CEG	1.0	0.4	1.0	1.0	0.67	0.57	0.43	0.17	1.0
EEG	0.8	0.83	0.25	1.0	1.0	0.83	1.0	0.44	0.71
JQF	1.0	0.62	1.0	0.2	1.0	0.89	1.0	1.0	0.75
MGP	0.5	0.86	1.0	1.0	1.0	1.0	0.33	1.0	0.67
PFO	1.0	1.0	1.0	0.2	0.75	1.0	1.0	0.86	0.33
PRT	0.33	0.8	1.0	1.0	0.43	0.29	1.0	1.0	0.75
TRP	0.57	1.0	0.67	1.0	1.0	1.0	1.0	1.0	1.0

$Calculated\ score\ (Staff) = max\ [min(X_i)]$

= max $(0.2, 0.33, 0.17, 0.25, 0.2, 0.33, 0.2, 0.29, 0.57)$

= 0.57

Tools

Contract approval workflow automation(CWA), Contract labor sourcing system(CSS), Contract management system(CMS), Contract templates(CTL), eRFX(RFX), External Website(EXW), P-Cards(PCD), Procure-to-Process(PPO), Requisition(RQS), Reverse auctions(RVA), RFX templates(RFT), Third party research(TPR), Vendor profile system(VPS), Vendor relationship management system(VRM)

Table 5.16: Fuzzy rating of procurement maturity identifier ‘Tools’

	CWA	CSS	CMS	CTL	RFX	EXW	PCD	PPO	RQS	RVA	RFT	TPR	VPS	VRM
CWA	1	7	8	4	7	3	7	1	6	7	7	3	7	5
CSS	6	1	9	1	4	2	5	9	9	7	4	2	5	6
CMS	1	3	1	6	8	2	5	1	4	6	8	2	5	4
CTL	9	3	2	1	4	5	1	4	3	6	4	5	1	2
RFX	7	3	7	5	1	2	9	9	1	2	5	5	3	1
EXW	4	2	5	6	8	1	3	3	6	5	1	6	7	6
PCD	8	2	5	4	2	4	1	2	7	2	2	5	4	2
PPO	4	5	1	2	5	5	3	1	5	7	5	1	2	5
RQS	5	5	3	1	7	8	9	3	1	7	4	5	3	2
RVA	4	5	1	2	5	5	5	4	5	1	4	3	1	1
RFT	5	5	3	1	7	8	4	7	6	6	1	1	9	8
TPR	8	2	5	4	2	4	3	3	1	2	5	1	5	7
VPS	2	5	5	5	4	6	9	2	3	1	7	8	1	9
VRM	3	1	8	8	3	5	1	3	3	6	8	2	5	1

Table 5.17: Normalized values of Fuzzy rating of procurement maturity identifier ‘Tools’

	CWA	CSS	CMS	CTL	RFX	EXW	PCD	PPO	RQS	RVA	RFT	TPR	VPS	VRM
CWA	1.0	1.0	1.0	0.44	1.0	0.75	0.88	0.25	1.0	1.0	1.0	0.38	1.0	1.0
CSS	0.86	1.0	1.0	0.33	1.0	1.0	1.0	1.0	1.0	1.0	0.8	1.0	1.0	1.0
CMS	0.12	0.33	1.0	1.0	1.0	0.4	1.0	1.0	1.0	1.0	1.0	0.4	1.0	0.5
CTL	1.0	1.0	0.33	1.0	0.86	0.83	0.25	1.0	1.0	1.0	1.0	1.0	0.2	0.25
RFX	1.0	0.75	0.88	1.0	1.0	0.25	1.0	1.0	0.14	0.4	0.71	1.0	0.75	0.33
EXW	1.0	1.0	1.0	1.0	1.0	1.0	0.75	0.6	0.75	1.0	0.12	1.0	1.0	1.0
PCD	1.0	0.4	1.0	1.0	0.22	1.0	1.0	0.67	0.78	0.4	0.5	1.0	0.44	1.0
PPO	1.0	0.56	1.0	0.5	0.56	1.0	1.0	1.0	1.0	1.0	0.71	0.33	1.0	1.0
RQS	0.83	0.56	0.75	0.33	1.0	1.0	1.0	0.6	1.0	1.0	0.67	1.0	1.0	0.67
RVA	0.57	0.71	0.17	0.33	1.0	1.0	1.0	0.57	0.71	1.0	0.67	1.0	1.0	0.17
RFT	0.71	1.0	0.38	0.25	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.2	1.0	1.0
TPR	1.0	1.0	1.0	0.8	0.4	0.67	0.6	1.0	0.2	0.67	1.0	1.0	0.62	1.0
VPS	0.29	1.0	1.0	1.0	1.0	0.86	1.0	1.0	1.0	1.0	0.78	1.0	1.0	0.2
VRM	0.60	0.17	1.0	1.0	1.0	0.83	0.5	0.6	1.0	1.0	1.0	0.29	1.0	1.0

$Calculated\ score\ (Tools) = max\ [min(X_i)]$

= max (0.25, 0.33, 0.12, 0.2, 0.14, 0.12, 0.22, 0.33, 0.33, 0.17, 0.2, 0.2, 0.2, 0.17)

= 0.33

Vendors

Approved vendor list(AVL), Measurement and Matrices(MMS), Vendor categorization(VCN), Vendor qualification(VQN), Vendor Rationalization(VRN), Vendor Recognition(VRG)

Table 5.18: Fuzzy rating of procurement maturity identifier 'Vendors'

	AVL	MMS	VCN	VQN	VRN	VRG
AVL	1	5	4	2	4	3
MMS	5	1	2	5	5	5
VCN	5	3	1	7	8	4
VQN	6	7	6	1	9	1
VRN	9	7	1	3	1	6
VRG	4	6	9	3	2	1

Table 5.19: Normalized values of Fuzzy rating of procurement maturity identifier 'Vendors'

	AVL	MMS	VCN	VQN	VRN	VRG
AVL	1.0	1.0	0.8	0.33	0.44	0.75
MMS	1.0	1.0	0.67	0.71	0.71	0.83
VCN	1.0	1.0	1.0	1.0	1.0	0.44
VQN	1.0	1.0	0.86	1.0	1.0	0.33
VRN	1.0	1.0	0.12	0.33	1.0	1.0
VRG	1.0	1.0	1.0	1.0	0.33	1.0

$Calculated\ score\ (Vendors) = max\ [min(X_i)]$

$= max\ (0.33, 0.67, 0.44, 0.33, 0.12, 0.33)$

= 0.67

Table 5.20: Summery of fuzzy scores obtained for each procurement maturity identifier

i	Parameters	Values
1	Calculate score (Customer)	1.0
2	Calculated score (Organization)	0.5
3	Calculated score (Policy)	0.6
4	Calculated score (Process)	0.67
5	Calculated score (Staff)	0.57
6	Calculate score (Tools)	0.33
7	Calculated score (Value)	0.75
8	Calculated score (Vendors)	0.67

$Mv = \sum_{i=1}^{8} Calculated\ Score\ _i$ =5.09(Optimizing Stage)

5.4 Alternative approach

In this alternative approach, we have used triangular fuzzy numbers instead of using single valued fuzzy ratings. Here the triangular numbers are shown in Table 5.21 defined for some linguistics made convenient for fuzzy rating which are substituted in a fuzzy pair wise comparison matrix and normalized using equation 2.1. Values of each row are summed up and average is taken to determine the maturity value of each attribute of Table 5.1. The whole process is repeated for all major eight areas defined in Table 5.1 and final score is determined using equation 5.2. The process is illustrated in Illustrative Example 5.2

Table 5.21: Triangular Fuzzy number suggested for maturity grading

$f(a,b,c)$	**Linguistics**
(1,1,2)	Very Low level maturity (VL)
(1,2,3)	Low level maturity (L)
(3,4,5)	Good level maturity (G)
(5,6,7)	High level maturity (H)
(7,8,9)	Very High level maturity (VH)
(8,9,9)	Extra High level maturity (EH)

Generally in case of any changes in the attributes (customer, organization, policy, process, staff, tools, value, vendors) e.g. for addition or deletion of any attribute, we have equation 5.2 for determination of overall Maturity Level.

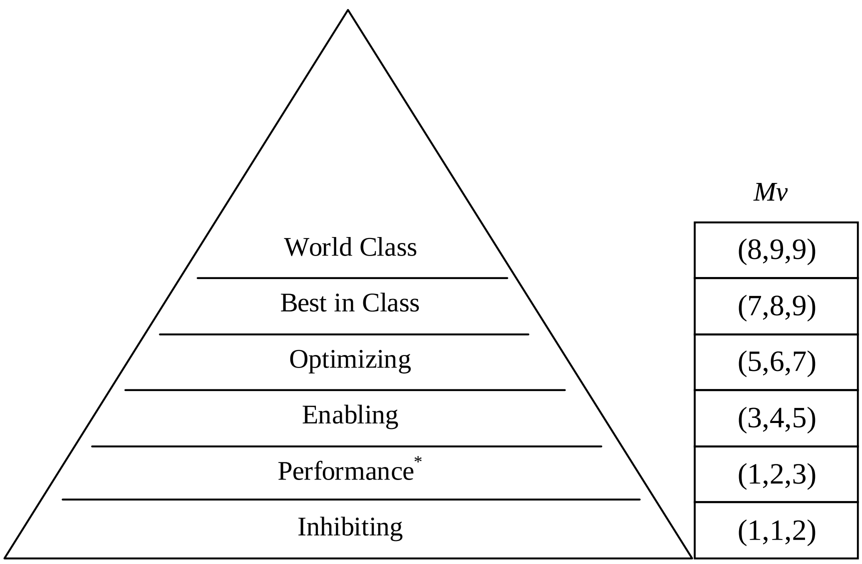

Figure 5.2: Maturity levels of procurement practice with equivalent fuzzy triangles

$$Mv = \sum_{i=1}^{n} Calculated\ Score_{(a,b,c)_i} / n \quad \ldots 5.2$$

5.5 Illustrative Example

The fuzzy rating using triangular fuzzy numbers are shown below which is then normalized and a scale value is obtained by summing up the calculated scores for each attribute. The scale values of other maturity areas like customer, policy, process, staff etc. are summarized in Table 5.25 and finally an aggregated maturity level is obtained and shown in the scale graphically in Figure 5.3.

Table 5.22: Rating of PMM identifier 'Organization' using triangular fuzzy number

	BPC	BPN	EXS	MSN	SPN	STR	VSN
BPC	(1,1,1)	(3,4,5)	(1/5,1/6,1/7)	(5,6,7)	(1/7,1/8,1/9)	(1,1,2)	(7,8,9)
BPN	(1/3,1/4,1/5)	(1,1,1)	(1,1,1/2)	(7,8,9)	(1/5,1/6,1/7)	(1,1/2,1/3)	(7,8,9)
EXS	(5,6,7)	(1,1,2)	(1,1,1)	(1,1,2)	(3,4,5)	(1/8,1/8,1/9)	(1/7,1/8,1/9)
MSN	(1/5,1/6,1/7)	(1/7,1/8,1/9)	(1,1,1/2)	(1,1,1)	(3,4,5)	(1,1,2)	(1,1,2)
SPN	(7,8,9)	(5,6,7)	(1/3,1/4,1/5)	(1/3,1/4,1/5)	(1,1,1)	(1/5,1/6,1/7)	(5,6,7)
STR	(1,1,1/2)	(1,2,3)	(8,8,9)	(1,1,1/2)	(5,6,7)	(1,1,1)	(1,1,1/2)
VSN	(1/7,1/8,1/9)	(1/7,1/8,1/9)	(7,8,9)	(1,1,1/2)	(1/5,1/6,1/7)	(1,1,2)	(1,1,1)

Table 5.23: Normalized values of fuzzy ratings of Table 5.22

	BPC	BPN	EXS	MSN	SPN	STR	VSN
BPC	(0.11, 0.1, 0.11)	(0.49, 0.55, 0.49)	(0.01, 0, 0.01)	(0.75, 0.78, 0.75)	(0, 0, 0)	(0.11, 0.21, 0.11)	(1, 1, 1)
BPN	(0.01, 0.01, 0.01)	(0.11, 0.1, 0.11)	(0.11, 0.04, 0.11)	(1, 1, 1)	(0, 0, 0)	(0.04, 0.02, 0.04)	(1, 1, 1)
EXS	(1, 1, 1)	(0.15, 0.27, 0.15)	(0.15, 0.13, 0.15)	(0.15, 0.27, 0.15)	(0.66, 0.71, 0.66)	(0, 0, 0)	(0, 0, 0)
MSN	(0.01, 0.01, 0.01)	(0, 0, 0)	(0.23, 0.08, 0.23)	(0.23, 0.18, 0.23)	(1, 1, 1)	(0.23, 0.39, 0.23)	(0.23, 0.39, 0.23)
SPN	(1, 1, 1)	(0.74, 0.77, 0.74)	(0.01, 0.01, 0.01)	(0.01, 0.01, 0.01)	(0.11, 0.1, 0.11)	(0, 0, 0)	(0.74, 0.77, 0.74)
STR	(0, 0, 0)	(0.14, 0.29, 0.14)	(1, 1, 1)	(0, 0, 0)	(0.71, 0.76, 0.71)	(0, 0.06, 0)	(0, 0, 0)
VSN	(0, 0, 0)	(0, 0, 0)	(1, 1, 1)	(0.11, 0.04, 0.11)	(0.01, 0, 0.01)	(0.11, 0.21, 0.11)	(0.11, 0.1, 0.11)

Table 5.24: Resulting matrix of normalized values

Organization's attributes	**(a,b,c)**
BPC	(2.64, 2.38, 2.47)
BPN	(2.17, 2.38, 2.27)
EXS	(2.38, 2.13, 2.11)
MSN	(2.05, 2.22, 1.93)
SPN	(2.66, 2.58, 2.61)
STR	(2.11, 1.57, 1.85)
VSN	(1.35, 1.37, 1.34)

The PMM value for 'Organization' is found (2.194, 2.09, 2.0828) which can be treated as the maturity for organizational practice is at Performance level. Similarly we can determine values of all other attributes and summarize as follows. Here the calculations are not mentioned.

Table 5.25: Summary of PMM attributes' values with triangular fuzzy number

PMM attribute	**(a,b,c)**
Customer	(3.123, 3.42,4.897)
Organization	(2.194, 2.09, 2.0828)
Policy	(1.33, 2.58, 2.545)
Process	(3.76, 3.99, 5.121)
Staff	(6.99, 7.89, 8.45)
Tools	(5.3, 5.99, 7.111)
Value	(5.131, 6.254, 6.879)
Vendors	(1.11, 1.32, 1.98)

We get the maturity value (3.61725, 4.19175, 4.883225) which shows the maturity level at Enabling level as shown in Figure 5.3

5.6 PMM and Procurement Maturity Framework

A clear Procurement Maturity quantification is achieved in above mathematical model and illustration where the level of procurement maturity is measured. According to Wilco Van Duinkerken, Ronald Hatenburg and Johan Versendaal[14], Procurement Maturity Framework (PMF) describes the assessment level of a procurement method where it begins from

Transaction level and the level of practices are uplifted from Transaction to Commercial level, Purchasing level, Internal level, External level up to Value chain level.

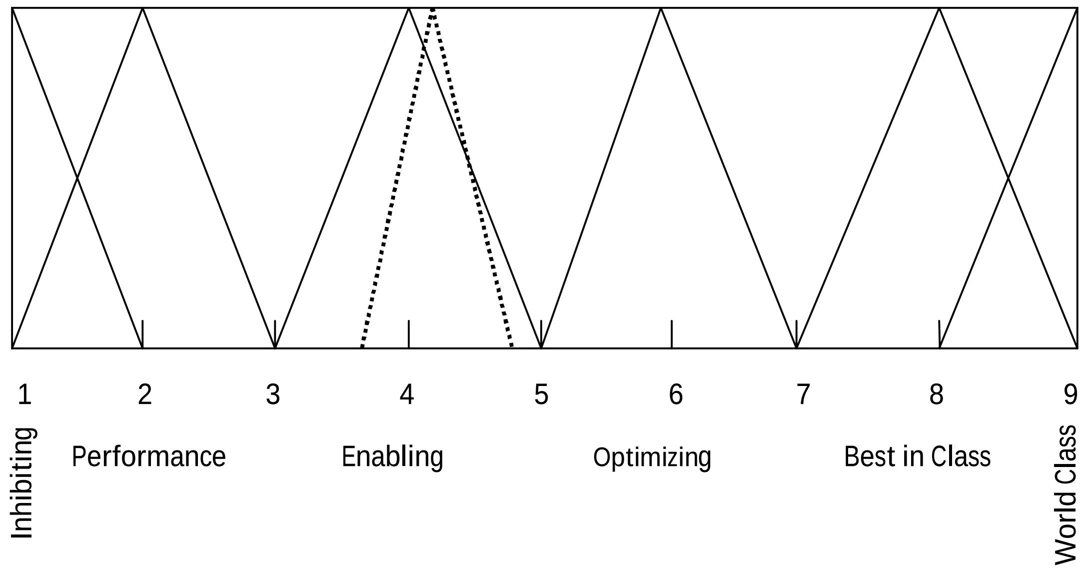

Figure 5.3: Procurement Maturity Value by fuzzy triangle in Stephen Guth's Scale

As per the suggestions of Stephen Guth[13] procurement maturity is highly obtained by establishing a separate department for procurement works in procuring agency organization and dedicated procurement professionals working in such area. In the proposed model described in this book have more versatile opportunity where the professionals not only belonged to the procuring agency but also from the funding agency, other procurement agencies, development partners, tendering community people can put their preferences of weight values for different procurement criteria and ratings for different offers from various bidders by selected decision makers from different domain. Therefore this model has made the procurement department not as an internal strategic player but as an open environmental integrating mechanism which can achieve a high level of clarity in decision making where suppliers, service providers or bidders are treated as resources for the organization. Thus this model has crossed the levels of Purchase Co-ordination, Internal Integration and External Integration levels of Wilco Van's maturity framework [14].

Now we can try to know how the proposed e-procurement model can contribute the entire consumer supply chain.

(i) The documentation templates, documentation process and documentation functions have become major attributes in determining Maturity level calculation. So that electronic documentation with proper formats (e.g eRFX) with processing functions running behind the system of documentations reduces delay in preparation of tender documents, generating decision and distributing orders among bidders. Otherwise maturity value (Mv) will reduce the rank of procurement

(ii) This model has openized the door of all possible bidders through e-marketplace model frame and features

(iii) In case of public procurement which is subjected to serve people directly, the proposed model can give opportunity to people to react in civilized way and relevant people engaged in procurement profession can reduce the maturity level of practice in a real life which is always a subject to reach at the peak of maturity level of hierarchy.

Through the above assessments, we can conclude that our proposed model of e-Procurement in this book almost fulfills the criteria of Value Chain Integration level of e-Procurement Maturity Framework derived by Wilco Van [14]. A comparison between Stephen Guth and Wilco Van's maturity levels is discussed in Section 5.6.

5.7 Procurement Maturity Grading System

A maturity determination scale has been presented in section produced by Stephen Guth consist of six different level of maturity specially defined for procurement practice. The problem exist in the scale interpretation in Table 5.26 is that every successive pair of maturity levels are identified for the requirement criteria to achieve the desired level of practice. Each and every level of maturity should be defined for criteria specification so that the numerical value of each level specified in Figure 5.1 and Figure 5.2 can clearly hold the requirement specification to achieve the maturity level in business practices rather couple of maturity levels which is ambiguous.

Table 5.26: Stephen Guth's maturity scale's interpretation [13]

Maturity Level	Interpretations
World Class	-Procurement is Strategic, Core Competency
Best in Class	-Proficient at Expected Business Practices (High degree of Customer and Supplier Satisfaction) -Staffed with High Qualified (e.g. Degreed and Certified) Professionals -High degree of Automation -Matrix Driven -Organization looks beyond itself (e.g. Supplier Delivery, Rationalization and Development)
Optimizing	-Procurement seen as 'Value-add' function
Enabling	-Some executive support and Investment -Customers and Suppliers satisfied for the most part -Employees Engaged (Some view Procurement as a 'Job') -Some pursuit of Best Practices
Performing	-Procurement an Afterthought, that a Core Corruptency
Inhibiting	-Customers and Suppliers Avoid interaction -Employees Activity Disengaged

Table 5.27: e-Procurement maturity framework defined by Wilco Van [14]

Maturity Level	Interpretation
Value chain integration	The procurement department is contributing to the effectiveness of the entire consumer supply chain
External integration	Suppliers and considered valuable integrated resources for the organization
Internal integration	The procurement department is considered as a strategic internally integrated part of the overall organization
Purchasing coordination	Basic sourcing and purchasing optimization is in place within the procurement department
Commercial orientation	Mainly Cost oriented purchasing
Transaction orientation	No procurement strategy, procurement is just acting on purchasing requests from the rest of the organization

Table 5.28: Matching between Stephen Guth and Wilco Van maturity levels and new maturity grades

Maturity Grade	Scale Value		Maturity Levels	Maturity level requirement specifications
	Single values	Triangular values		
A	6.68~8.00	(8,9,9)	World Class/Value Chain integration	-The procurement department is contributing to the effectiveness of the entire consumer supply chain by practicing procurement as strategic goal for business proficiency with core competency,
B	5.34~6.67	(7,8,9)	Best in Class/External integration	-Staffed with High Qualified (e.g. Degreed and Certified) Professionals -High degree of Automation -Matrix Driven -Organization looks beyond itself (e.g. Supplier Delivery, Rationalization and Development) - Suppliers are considered valuable integrated resources for the organization
C	4.01~5.33	(5,6,7)	Optimizing/ Internal Integration	-The procurement department is considered as a strategic internally integrated part of the overall organization -Some pursuit of Best Practices -Customers and Suppliers satisfied for the most part
D	2.68~4.00	(3,4,5)	Enabling/ Purchasing orientation	-Procurement seen as 'Value-add' function -Some executive support and Investment -Employees Engaged (Some view Procurement as a 'Job')
E	0.00~2.67	(1,2,3)	Inhibiting/ Performing/ Transaction/ Commercial orientation	-Mainly Cost oriented purchasing - No procurement strategy, procurement is just acting on purchasing requests from the rest of the organization -Procurement an Afterthought, that a Core Corruptency -Customers and Suppliers Avoid interaction -Employees Activity Disengaged

In Table 5.28 we have combined two maturity scales and formulate a new grading system for maturity determination in procurement practice. The grading result of the illustrations in Illustrative Example 5.1 and Illustrative Example 5.2 of this chapter can be said 'D level/grade of maturity' according to their result 2.933664 and (3.61725, 4.19175, 4.883225) respectively.

5.8 Discussion

In the discussion of electronic procurement with Procurement Maturity Model, the opportunity to react by the people should be done through proper documentation templates and procurement policy of all organizations should have clear intention to allow it. The proposed e-procurement model is restricted to electronic revolt massacre through implementation of Information Transaction Subsystems in Security subsystems of Information Management. So, allowing people to react electronically is strongly encouraged

Stephen Guth's gap analysis has lost its requirement in the proposed model in this book. Because scores for individual maturity attributes have been calculated on the basis of fuzzy ratings where Maturity value (Mv) scores are classified and related to the PMM model to determine maturity level for particular cases. In our illustration, we have got only the value of Rv from Risk Identifier subsystem of e-GP access revised model. If all the maturity identifier gets its parameter values from each corresponding subsystems, the role of fuzzy rating and fuzzy scoring for Procurement maturity identification will become non existence.

In this research work, both Fuzzy MCDM and AHP method has been used for determination of results and compared with each other. Let us see in Chapter 6 for Data Analysis for achieving the conception of both methods' behavior for these illustrations in this book.

CHAPTER 6

DATA COMPARISON & ANALYSIS

6.1 Comparison of Fuzzy MCDM with AHP

We have tried to compare weight values determined using AHP method with the results of equation 3.2 after normalizing by equation 3.1 applying fuzzy MCDM. AHP normalization is performed by taking row averages of each row of a matrix formed of dividing each element of original matrix data by column sum o f each column. Let's consider the Table 3.6 to feed into AHP method. Summing the each row and dividing each element of this table, we get a normalized matrix which will give the resulting matrix taking the row averages of each row of normalized matrix.

Table 6.1: Normalized matrix of Table 3.4

	RELY	DURN	CPLX	CPIS	CADP	SCAP	WSZE	WSKL	SEXP	UMTG	SCED	PMEX	PDTH	RISK	RVOL
RELY	0.016	0.053	0.101	0.17	0.163	0.12	0.051	0.057	0.088	0.094	0.053	0.021	0.073	0.106	0.111
DURN	0.079	0.018	0.043	0.094	0.116	0.04	0.119	0.057	0.053	0.094	0.158	0.064	0.073	0.035	0.2
CPLX	0.143	0.088	0.014	0.17	0.209	0.12	0.119	0.103	0.088	0.132	0.088	0.149	0.073	0.106	0.111
CPIS	0.048	0.053	0.072	0.019	0.023	0.04	0.051	0.057	0.053	0.019	0.053	0.106	0.073	0.082	0.022
CADP	0.143	0.018	0.014	0.019	0.023	0.013	0.051	0.034	0.088	0.094	0.053	0.064	0.024	0.082	0.022
SCAP	0.079	0.123	0.072	0.057	0.023	0.013	0.119	0.08	0.053	0.019	0.088	0.149	0.024	0.106	0.022
WSZE	0.016	0.158	0.101	0.019	0.023	0.04	0.017	0.103	0.053	0.057	0.088	0.021	0.024	0.035	0.022
WSKL	0.111	0.123	0.072	0.094	0.023	0.067	0.051	0.011	0.088	0.057	0.123	0.021	0.024	0.106	0.067
SEXP	0.016	0.018	0.043	0.019	0.023	0.067	0.051	0.08	0.018	0.019	0.018	0.064	0.024	0.035	0.022
UMTG	0.111	0.088	0.072	0.057	0.07	0.12	0.051	0.08	0.053	0.019	0.053	0.106	0.073	0.106	0.156
SCED	0.016	0.088	0.101	0.019	0.023	0.067	0.153	0.103	0.053	0.094	0.018	0.021	0.122	0.082	0.067
PMEX	0.048	0.018	0.014	0.057	0.023	0.093	0.051	0.057	0.123	0.094	0.053	0.021	0.171	0.012	0.022
PDTH	0.016	0.018	0.101	0.057	0.023	0.067	0.051	0.057	0.018	0.019	0.018	0.064	0.024	0.012	0.022
RISK	0.079	0.123	0.13	0.132	0.07	0.093	0.051	0.103	0.088	0.17	0.053	0.064	0.073	0.012	0.111
RVOL	0.079	0.018	0.043	0.019	0.163	0.04	0.017	0.011	0.088	0.019	0.088	0.064	0.122	0.082	0.22

The row averages of matrix in Table 6.1 are compared with the result of $f'(X_k)$ of Table 3.8.

Table 6.2: Comparison data of AHP and fuzzy MCDM against risk attributes

	AHP data	Fuzzy data
RELY	0.085	0.33
DURN	0.083	0.429
CPLX	0.114	0.33
CPIS	0.051	0.33
CADP	0.05	0.11
SCAP	0.069	0.11
WSZE	0.052	0.11
WSKL	0.069	0.11
SEXP	0.034	0.2
UMTG	0.081	0.6
SCED	0.068	0.33
PMEX	0.057	0.143
PDTH	0.038	0.2
RISK	0.09	0.429
RVOL	0.058	0.11

Similarly some other matrices have been normalized applying AHP method and compared with the results of Fuzzy MCDM method

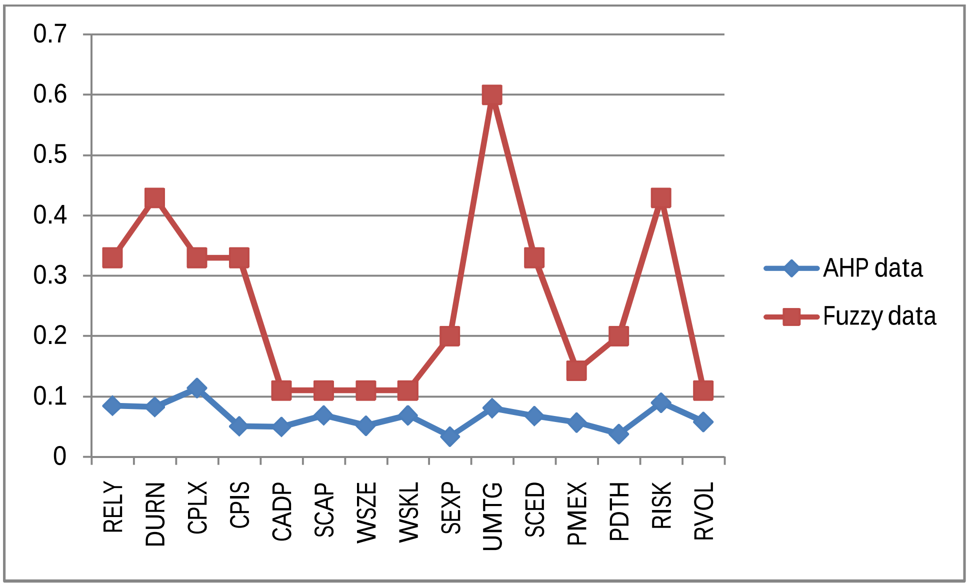

Figure 6.1: Comparison of AHP and fuzzy MCDM for risk attributes

Similarly we have performed comparisons of AHP and Fuzzy MCDM data values below.

Table 6.3: Normalized matrix of Table 5.6

	ENG	PIS	RMG	STF	SRF
ENG	0.053	0.263	0.111	0.278	0.35
PIS	0.263	0.053	0.333	0.167	0.15
RMG	0.211	0.211	0.056	0.056	0.05
STF	0.316	0.421	0.056	0.056	0.4
SRF	0.058	0.053	0.444	0.444	0.05

Table 6.4: Comparison data of AHP and fuzzy MCDM against attributes of 'Customer'

	AHP data	Fuzzy data
ENG	0.211	0.5
PIS	0.193	0.38
RMG	0.116	0.12
STF	0.25	0.12
SRF	0.23	0.33

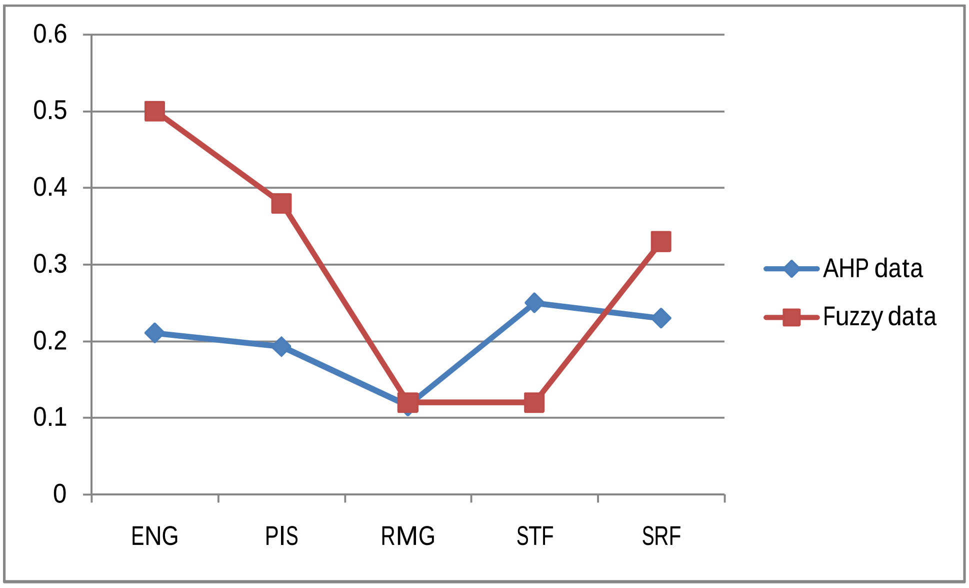

Figure 6.2: Comparison of AHP and fuzzy MCDM for PMM attribute 'Customer'

Table 6.5: Normalized matrix of Table 5.8

	BPC	BPN	EXS	MSN	SPN	STR	VSN
BPC	0.036	0.143	0.074	0.167	0.043	0.091	0.161
BPN	0.179	0.036	0.222	0.233	0.13	0.227	0.258
EXS	0.143	0.143	0.037	0.033	0.217	0.136	0.032
MSN	0.214	0.286	0.037	0.033	0.217	0.045	0.097
SPN	0.017	0.036	0.296	0.267	0.043	0.273	0.129
STR	0.179	0.214	0.222	0.233	0.13	0.045	0.29
VSN	0.143	0.143	0.111	0.033	0.217	0.182	0.032

Table 6.6: Comparison data of AHP and
Fuzzy MCDM against maturity attributes of 'Organization'

	AHP data	Fuzzy data
BPC	0.102	0.33
BPN	0.184	0.83
EXS	0.106	0.33
MSN	0.133	0.14
SPN	0.164	0.33
STR	0.188	0.5
VSN	0.123	0.33

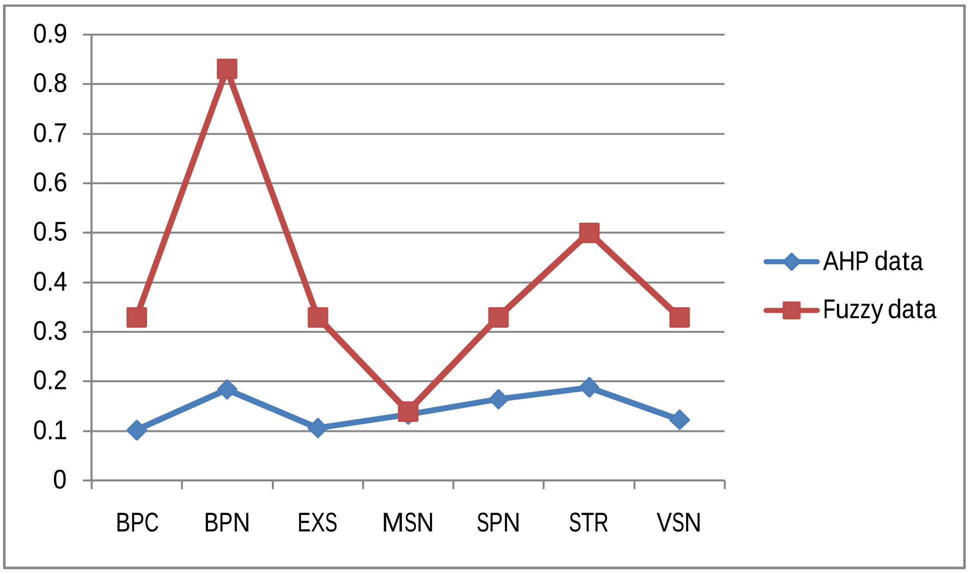

Figure 6.3: Comparison of AHP and fuzzy MCDM for PMM attribute 'Organization'

Table 6.7: Normalized matrix of Table 5.10

	AUL	BCP	DSP	PAT	PPY	PSD	RRN
AUL	0.034	0.136	0.03	0.175	0.091	0.12	0.171
BCP	0.241	0.045	0.212	0.2	0.091	0.12	0.2
DSP	0.138	0.045	0.03	0.075	0.227	0.16	0.057
PAT	0.034	0.318	0.091	0.025	0.136	0.2	0.114
PPY	0.276	0.045	0.212	0.175	0.045	0.32	0.2
PSD	0.172	0.227	0.182	0.15	0.045	0.04	0.229
RRN	0.103	0.182	0.242	0.2	0.364	0.04	0.029

Table 6.8: Comparison data of AHP and
Fuzzy MCDM against maturity attributes of 'Policy'

	AHP data	Fuzzy data
AUL	0.108	0.25
BCP	0.159	0.6
DSP	0.105	0.14
PAT	0.131	0.14
PPY	0.182	0.5
PSD	0.149	0.12
RRN	0.166	0.12

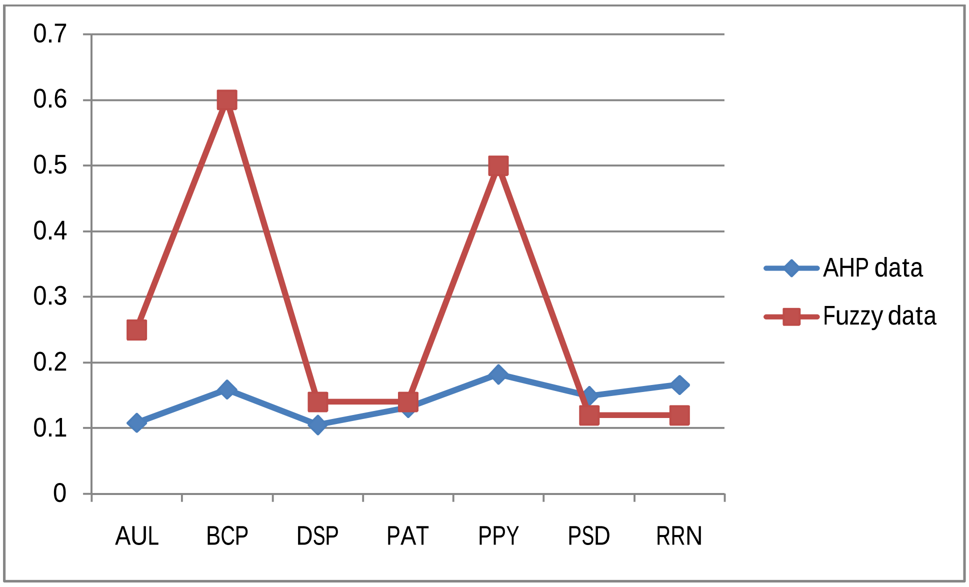

Figure 6.4: Comparison of AHP and fuzzy MCDM for PMM attribute 'Policy'

Table 6.9: Normalized matrix of Table 5.12

	AUD	CBP	CRP	FRC	NGP	POG	SPL
AUD	0.029	0.174	0.176	0.281	0.125	0.083	0.226
CBP	0.265	0.043	0.206	0.031	0.125	0.125	0.194
CRP	0.235	0.087	0.029	0.125	0.083	0.167	0.097
FRC	0.118	0.217	0.029	0.031	0.208	0.208	0.161
NGP	0.118	0.087	0.147	0.188	0.042	0.292	0.258
POG	0.029	0.261	0.206	0.188	0.375	0.042	0.032
SPL	0.206	0.13	0.206	0.156	0.042	0.083	0.032

Table 6.10: Comparison data of AHP and
fuzzy MCDM against maturity attributes of 'Process'

	AHP data	Fuzzy data
AUD	0.156	0.44
CBP	0.141	0.2
CRP	0.118	0.29
FRC	0.139	0.25
NGP	0.162	0.67
POG	0.162	0.5
SPL	0.122	0.12

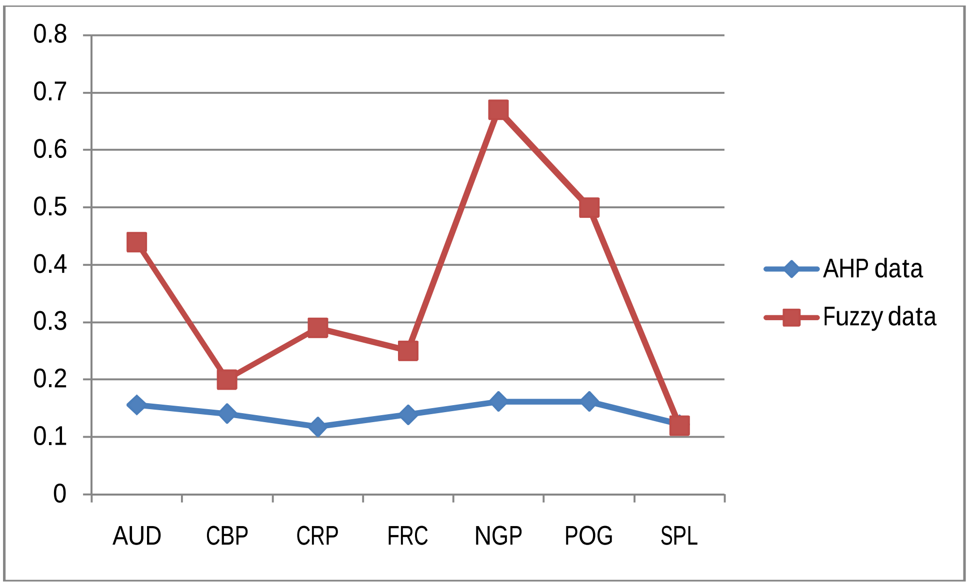

Figure 6.5: Comparison of AHP and fuzzy MCDM for PMM attribute 'Process'

Table 6.11: Normalized matrix of Table 5.14

	CRT	CTR	CEG	EEG	JQF	MPG	PFO	PRT	TRP
CRT	0.027	0.079	0.163	0.125	0.025	0.057	0.146	0.079	0.194
CTR	0.108	0.026	0.116	0.15	0.2	0.2	0.195	0.132	0.028
CEG	0.216	0.053	0.023	0.1	0.05	0.114	0.073	0.026	0.25
EEG	0.108	0.132	0.023	0.025	0.125	0.143	0.122	0.105	0.139
JQF	0.135	0.132	0.07	0.025	0.025	0.229	0.098	0.184	0.167
MGP	0.027	0.158	0.163	0.15	0.225	0.029	0.024	0.184	0.056
PFO	0.243	0.237	0.163	0.025	0.075	0.086	0.024	0.158	0.056
PRT	0.027	0.105	0.14	0.225	0.075	0.057	0.171	0.026	0.083
TRP	0.108	0.079	0.14	0.175	0.2	0.086	0.146	0.105	0.028

Table 6.12: Comparison data of AHP and
Fuzzy MCDM against maturity attributes of ‘Staff’

	AHP data	Fuzzy data
CRT	0.1	0.2
CTR	0.128	0.33
CEG	0.101	0.17
EEG	0.102	0.25
JQF	0.118	0.2
MGP	0.113	0.33
PFO	0.118	0.2
PRT	0.101	0.29
TRP	0.119	0.57

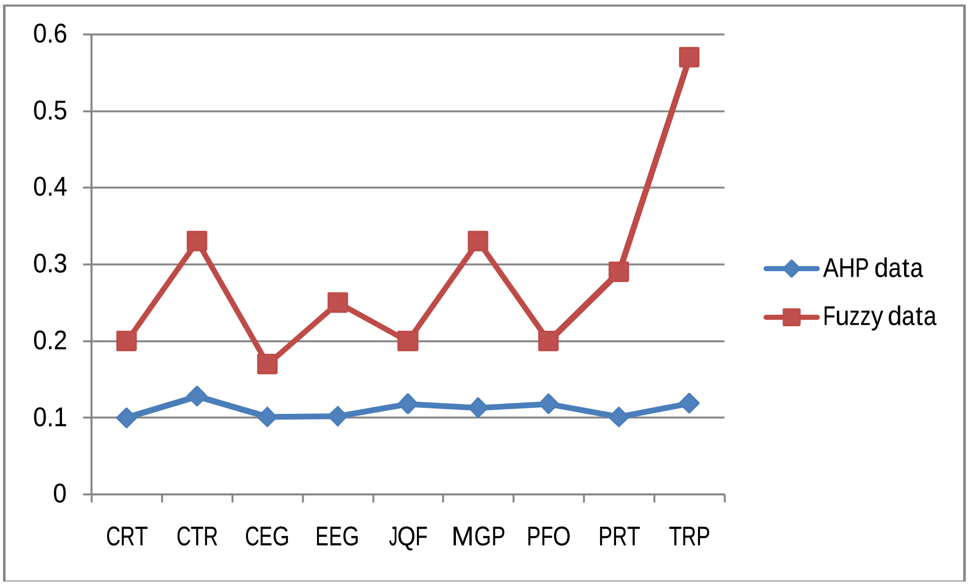

Figure 6.6: Comparison of AHP and fuzzy MCDM for PMM attribute ‘Staff’

Table 6.13: Normalized matrix of Table 5.16

	CWA	**CSS**	**CMS**	**CTL**	**RFX**	**EXW**	**PCD**	**PPO**	**RQS**	**RVA**	**RFT**	**TPR**	**VPS**	**VRM**
CWA	0.015	0.143	0.127	0.08	0.104	0.05	0.108	0.019	0.1	0.108	0.108	0.061	0.121	0.085
CSS	0.09	0.02	0.143	0.02	0.06	0.033	0.077	0.173	0.15	0.108	0.062	0.041	0.086	0.102
CMS	0.015	0.061	0.016	0.12	0.119	0.033	0.077	0.019	0.067	0.092	0.123	0.041	0.086	0.068
CTL	0.134	0.061	0.032	0.02	0.06	0.083	0.015	0.077	0.05	0.092	0.062	0.102	0.017	0.034
RFX	0.104	0.061	0.111	0.1	0.015	0.033	0.138	0.173	0.017	0.031	0.077	0.102	0.052	0.017
EXW	0.06	0.041	0.079	0.12	0.119	0.017	0.046	0.058	0.1	0.077	0.015	0.122	0.121	0.102
PCD	0.119	0.041	0.079	0.08	0.03	0.067	0.015	0.038	0.117	0.031	0.031	0.102	0.069	0.034
PPO	0.06	0.102	0.016	0.04	0.075	0.083	0.046	0.019	0.083	0.108	0.077	0.02	0.034	0.085
RQS	0.075	0.102	0.048	0.02	0.104	0.133	0.138	0.058	0.017	0.108	0.062	0.102	0.052	0.034
RVA	0.06	0.102	0.016	0.04	0.075	0.083	0.077	0.077	0.083	0.015	0.062	0.061	0.017	0.017
RFT	0.075	0.102	0.048	0.02	0.104	0.133	0.062	0.135	0.1	0.092	0.015	0.02	0.155	0.136
TPR	0.119	0.041	0.079	0.08	0.03	0.067	0.046	0.058	0.017	0.031	0.077	0.02	0.086	0.119
VPS	0.03	0.102	0.079	0.1	0.06	0.1	0.138	0.038	0.05	0.015	0.108	0.163	0.017	0.153
VRM	0.045	0.02	0.127	0.16	0.045	0.083	0.015	0.058	0.05	0.092	0.123	0.041	0.086	0.017

Table 6.14: Comparison data of AHP and fuzzy MCDM against maturity attributes of ‘Tools’

	AHP data	Fuzzy data
CWA	0.088	0.25
CSS	0.083	0.33
CMS	0.067	0.12
CTL	0.06	0.2
RFX	0.074	0.14
EXW	0.077	0.12
PCD	0.061	0.22
PPO	0.061	0.33
RQS	0.075	0.33
RVA	0.056	0.17
RFT	0.086	0.2
TPR	0.062	0.2
VPS	0.082	0.2
VRM	0.069	0.17

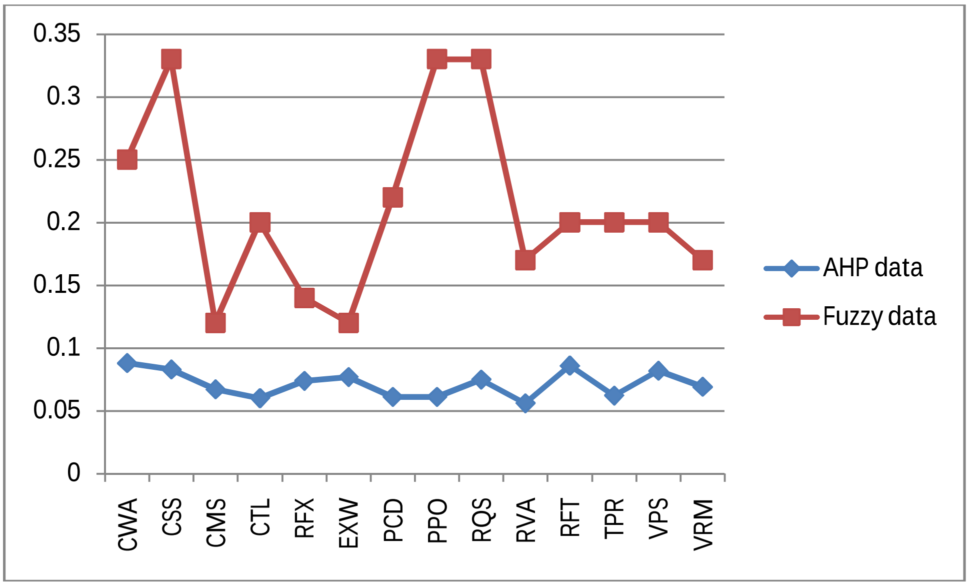

Figure 6.7: Comparison of AHP and fuzzy MCDM for PMM attribute ‘Tools’

Table 6.15: Normalized matrix of Table 5.18

	AVL	MMS	VCN	VQN	VRN	VRG
AVL	0.033	0.172	0.174	0.095	0.138	0.15
MMS	0.167	0.034	0.087	0.238	0.172	0.25
VCN	0.167	0.103	0.043	0.333	0.276	0.2
VQN	0.2	0.241	0.261	0.048	0.31	0.05
VRN	0.3	0.241	0.043	0.143	0.034	0.3
VRG	0.133	0.207	0.391	0.143	0.069	0.05

Table 6.16: Comparison data of AHP and fuzzy MCDM against maturity attributes of ‘Vendors’

	AHP data	Fuzzy data
AVL	0.127	0.33
MMS	0.158	0.67
VCN	0.187	0.44
VQN	0.185	0.33
VRN	0.177	0.12
VRG	0.166	0.33

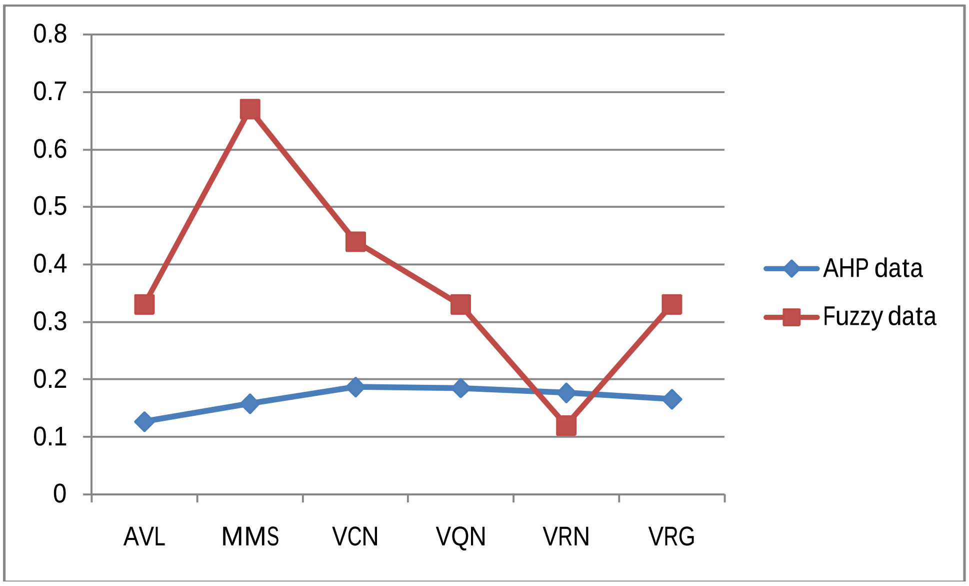

Figure 6.8: Comparison of AHP and fuzzy MCDM for PMM attribute ‘Vendor’

Now we have summarized another set of values from above data sets. In AHP operations, the highest values in the weight matrixes are the possible decision for each case are listed in ‘AHP decision values’ in Table 6.17 for comparison with fuzzy decision values through application of Fuzzy MCDM. We have tried to observe the characteristics in this case in Figure 6.9. Finally the observations are tabularized and summery of characteristics of both AHP and Fuzzy MCDM are determined in Table 6.20.

Table 6.17: Comparison data of AHP and fuzzy MCDM of decision values of specific PMM attributes

	AHP decision values	Fuzzy decision values
Customer	0.25	0.5
Organization	0.188	0.83
Policy	0.182	0.6
Process	0.162	0.67
Staff	0.128	0.57
Tools	0.088	0.33
Vendors	0.187	0.67

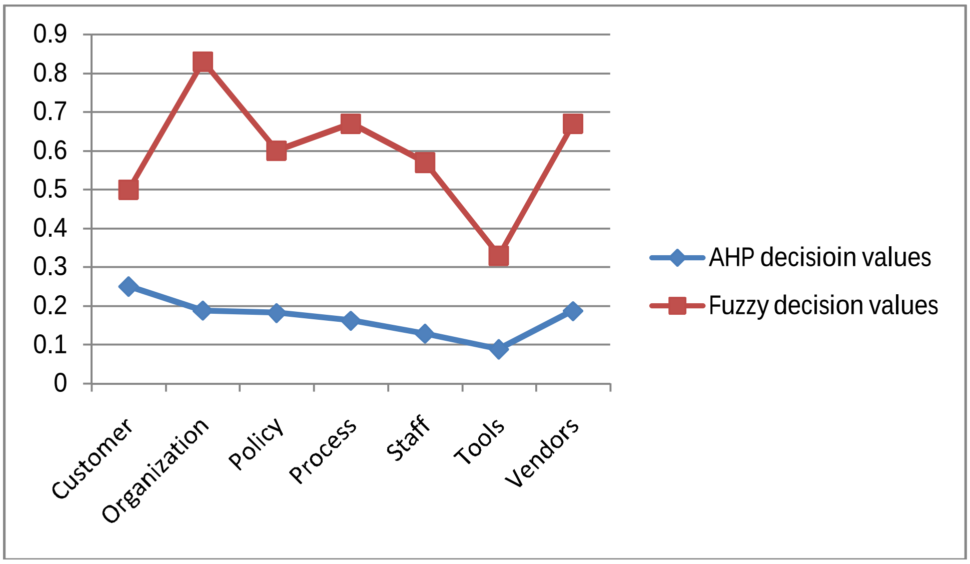

Figure 6.9: Comparison of AHP and fuzzy MCDM for PMM attributes

Table 6.18: Observation records of AHP and Fuzzy MCDM comparison graphs

	Increase in AHP, Increase in Fuzzy	**Increase in AHP, Decrease in Fuzzy**	**Decrease in Fuzzy, Increase in AHP**	**Decrease in AHP, decrease in Fuzzy**	**Increase/Decrease in AHP, Fuzzy unchanged**	**Increase/Decrease in Fuzzy, AHP unchanged**	**Total observations**
Risk Identifier	2	2	3	3	4	×	14
Customer	×	×	1	2	1	×	4
Organization	3	1	×	2	×	×	6
Policy	2	×	×	2	2	×	6
Process	1	1	1	2	×	1	6
Staff	3	2	2	1	×	×	8
Tools	1	2	3	3	3	1	13
Vendors	1	1	1	2	×		5
Few decision ratings	1	×	2	3	×	×	6

Table 6.19: Observation summery of AHP and Fuzzy MCDM comparison curves

Increase in AHP, increase in Fuzzy MCDM	20.59%
Increase in AHP, decrease in Fuzzy MCDM	13.24%
Decrease in AHP, increase in Fuzzy MCDM	19.12%
Decrease in AHP, decrease in Fuzzy MCDM	29.41%
Increase or decrease in AHP, Fuzzy remain unchanged	14.71%
Increase or decrease in Fuzzy, AHP remain unchanged	2.94%

Table 6.20: Observation result of AHP and Fuzzy MCDM comparison

Increase or decrease in AHP makes increase or decrease in Fuzzy respectively	**50%**
Increase or decrease in AHP makes reverse swing in Fuzzy	32.36%
Either AHP or Fuzzy remain unchanged for any slope of Fuzzy or AHP respectively	17.64%

6.2 Discussion

We have taken the same matrices used in different illustrative examples in this book and applied the method of AHP. We got AHP normalized matrices and AHP weight values. We have Fuzzy Normalized matrices in the illustrations and row matrix of $f^{/}(x)$ for each. We have drawn graphs for such comparison in Figure 6.1 through Figure 6.9. In Table 6.19, a summary of total observations are snapped and findings are further condensed in Table 6.20. We have noticed that fuzzy curve is quite similar in nature with AHP curve characteristics. When fuzzy data is increased, we see that AHP data is successively increased and decreased for fuzzy decrease and the vibration of both the curve is same for many samples for most of the cases except some few. The rise of Fuzzy data makes the rise in AHP and vice versa is secured for 50% of the cases we considered.

In Chapter 3, we have computed Risk Value using Fuzzy MCDM and AHP as well as compared the results of $f^{/}(x)$ and row averages of AHP normalized matrix. Comparing the results we got significant difference for all attributes and found Fuzzy MCDM showing better result for following reason discussed.

While incorporating decision engine into electronic procurement model, we could use normal AHP method for selecting bidder, normalizing risk attributes' ratings and normalizing the maturity attributes' values but we have used fuzzy MCDM sometimes called fuzzy AHP instead of normal AHP. We have found that both the method uses stochastic process to deal with some uncertainty but major advantage of fuzzy MCDM over normal AHP is that maximizing the desired result or minimizing potential threats i.e. an optimization with Max-Min function is performed in fuzzy MCDM whereas normal AHP determines a deterministic result only. Here we have quoted form George J Klir & Bo Yuan [11]: "A decision is made under condition of risk, on the other hand, when the only available knowledge concerning the outcomes consists of their conditional probability distributions, one for each action. In this case, the decision making problem becomes an optimization problem of maximizing the expected utility. When probabilities of outcomes are not known, or may not even be relevant, and outcomes for each action are characterized only approximately, we say that decisions are made under uncertainty. This is the prime domain for fuzzy decision making."

In Chapter 4, we have tested supplier selection model using both Fuzzy MCDM with Fuzzy TOPSIS and AHP with AHP TOPSIS method for criteria weight value determination and finding the successful bidder. Interestingly we got same or less deviated result for criteria weight calculation but failure of AHP method to produce suppliers' ranking over Foriborz Joali's Fuzzy based supplier selection model due to updated normalization techniques used with Fuzzy TOPSIS method.

Therefore, in our research work we realized Fuzzy MCDM is a better technique to implement in the subsystems of electronic procurement model specially our model will work on the basis of human evaluators and their ratings given by the help of their experience and knowledge.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

A Decision Engine has been modeled and incorporated in a recognized electronic procurement model known as e-GP Access Model which is prescribed by World Bank, the largest development partner of the world's underdeveloped countries. Incorporation of such a Decision Engine is an enrichment of e-GP Access Model which has following features.

(i) The Risk Identifier produces a Risk Value associated with a procurement case as a project that enables procurement personnel to understand about the chance of failure of the procurement project. Even it indicates the area of failure potentialities with numerical value in a particular scale. Professionals can take necessary actions to resolve the problem in indicated areas as per the messages generated by the execution of Risk Mitigation Algorithm.

(ii) The Bidder Selector can select bidder among many who quote their products with quantity discount offers and rank the bidders with respect to some specific criteria. This provides consensus decision for every procurement cases and separate procurement professional group under the umbrella of third party based procurement site provides better scope of unbiased decision in procurement of commodities or services.

(iii) The Maturity Identifier can assess the professionalisms present in the practice of procurement cases and indicates the level of professional attitudes and maturity is exhibited in the execution of procurement. If there is insufficiency in procurement, necessary actions can easily be taken to improve the maturity in procurement system in organization.

(iv) The subsystem of Anti spam wire can prohibit electronic revolt and make the electronic existence of procurement system safe implementing the prescribed model.

All above features makes e-GP Access model enhanced, maker bidder selection methodological and faster. Moreover, in a comparison of AHP weight values with Fuzzy MCDM preference of choice values aggregated, we have found that the common phenomena is increase of AHP data makes increase in Fuzzy normalized data and similarly decrease in AHP data makes decrease in Fuzzy MCDM data values. This above tendency is found for 50% of all mathematical operations.

7.2 Recommendations for Future Work

Reliability measure of proposed e-Procurement model is badly necessary. We don't like to suggest to go for direct implementation of the proposed model rather we like to encourage to assess the decisions taken in many tendering and procurement samples collected from public and private sectors and feed into our model and analyze the deviations including the thorough studies of the procurement attributes comparing with the maturity attributes of PMM discussed in Chapter 5. This particular job has not been done in this thesis work as it may require for couple of years and a team to collect information as well. Moreover, a function module for automatic ranking of procurement professionals and procurement cases should be developed. We also like to suggest for development of complete software on the basis of the mathematical foundation illustrated in this thesis which is to be located at the backend of the web portal or the e-Marketplace and perform more data synthesizing. Moreover, a model for feedback analysis of post procurement assessment is essential for development.

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APPENDIX

Table 8.1: Knowledge Base or Rule Base generated on the basis of General Purpose Procurement Risk Attributes

RULE	DESCRIPTION
RELY-DURN	Reliability with limited duration of supply or service
RELY-CPLX	Reliability with complex job or product type
RELY-CPIS	Reliability upon complementary infrastructure is required
RELY-CADP	Reliability for customer skill and adaptability
RELY-SCAP	Reliable capability of supplier or service provider is essential
RELY-WSZE	Reliable optimum size of workforce of supplier or service provider is highly required
RELY-WSKL	Reliable workforce skill is mandatory for supplier or service provider
RELY-SEXP	Reliable experience in relevant field is suggested for bidder
RELY-UMTG	Reliable usage of modern technologies by the supplier or service provider
RELY-SCED	Reliability to supply or service providing within tight schedule
RELY-PMEX	Reliable experience for customer for similar supply or service process
RELY-PDTH	Reliable process documents with thoroughness is required
RELY-RISK	Reliability for risk assumptions by assessors
RELY-RVOL	Reliability to non volatility of requirements
DURN-RELY	Optimized duration of procured product or service should be reliably calculated
DURN-CPLX	Optimized duration determination for particular level of job complexity
DURN-CPIS	Optimized duration determination for complementary infrastructure development
DURN-CADP	Optimized duration determination for development of customer skills and adaptability
DURN-SCAP	Optimized duration determination as per supplier’s or provider’s capability
DURN-WSZE	Optimized date line determination to do the job with supplier’s or provider’s workforce size
DURN-WSKL	Optimized date line determination to do the job with supplier’s or provider’s workforce skills
DURN-SEXP	Optimized date line determination to do the job with supplier’s or provider’s relevant experience
DURN-UMTG	Optimized date line determination to do the job with supplier’s or provider’s usage of modern technologies
DURN-SCED	Optimized duration determination to do the job within tight schedule
DURN-PMEX	Optimized date line determination to do the job with existing process experience
DURN-PDTH	Optimized duration determination to do the job as per the thoroughness of documentations
DURN-RISK	Optimized duration determination to do the job avoiding maximum risk
DURN-RVOL	Maximum duration determination to do the job with provision of requirement volatility
CPLX-RELY	Optimization of product or job complexity to maximize reliability

RULE	DESCRIPTION
CPLX-DURN	Optimization of product or job complexity to supply, install or service providing within limited duration
CPLX-CPIS	Optimization of product or job complexity to minimize the requirement of complementary product infrastructure
CPLX-CADP	Optimization of product or job complexity to minimize customer’s skills and adaptability requirements
CPLX-SCAP	Optimization of product or job complexity to minimize bidder’s skills and capability requirements
CPLX-WSZE	Optimization of product or job complexity for best fit of bidder’s work force size
CPLX-WSKL	Optimization of product or job complexity for best fit of bidder’s work force skill
CPLX-SEXP	Optimization of product or job complexity for best fit of bidder’s relevant service experience
CPLX-UMTG	Optimization of product or job complexity for best fit of bidder’s usage of modern technologies
CPLX-SCED	Optimization of product or job complexity for delivering product or service within tight schedule
CPLX-PMEX	Optimization of product or job complexity for best fit of process experience
CPLX-PDTH	Optimization of product or job complexity for best fit of available process documents thoroughness
CPLX-RISK	Optimization of product or job complexity to avoid all potential risks
CPLX-RVOL	Optimize product or job complexity to minimize requirements volatility
CPIS-RELY	Complementary Product or service Infrastructure is required to be reliable upon situation demands
CPIS-DURN	Complementary product or service infrastructure is required to be installed within limited duration
CPIS-CPLX	Complementary product or service infrastructure is required be minimized complexity
CPIS-CADP	Complementary product or service infrastructure needed is required to be adapted by customers
CPIS-SCAP	Complementary product or service infrastructure is required to be suited to supplier or service provider’s capability
CPIS-WSZE	Complementary product or service infrastructure is required to be suited for supplier and customer’s workforce size
CPIS-WSKL	Complementary product or service infrastructure is required to best suited for supplier and customer’s workforce skill
CPIS-SEXP	Complementary product or service infrastructure is required to be suited for bidder’s experience
CPIS-UMTG	Complementary product or service infrastructure is required to be suited to supplier or service provider’s and customer’s usage to modern technologies
CPIS-SCED	Complementary product or service infrastructure is required to be suited for proper supply, installation or service within tight schedule
CPIS-PMEX	Complementary product or service infrastructure is required to suitable for bidder’s and customer’s relevant process experience

RULE	DESCRIPTION
CPIS-PDTH	Complementary product or service infrastructure is required to be matched with process documentation thoroughness
CPIS-RISK	Complementary product or service infrastructure is required to be risk less
CPIS-RVOL	Complementary product or service infrastructure is required to be sufficient to adjust the requirement volatility
CADP-RELY	Customer’s adaptability is required to be reliably favorable for new procurement project items and implementation
CADP-DURN	Customer’s adaptability to accept and increase skills and technical knowhow within limited duration
CADP-CPLX	Customer’s adaptability is required to accept any level of complexity of product or services
CADP-CPIS	Customer’s adaptability is required to accept complementary product or infrastructure if needed
CADP-SCAP	Customer’s adaptability is required to be adjusted with supplier’s capability
CADP-WSZE	Customer is required to be adaptive to work with supplier or service provider with any workforce size
CADP-WSKL	Customer is required to be adaptive to work with supplier or service provider of different level of workforce skill
CADP-SEXP	Customer is required to be adaptive to various different level of experienced supplier or service provider
CADP-UMTG	Customer is required to be adaptive to using modern technologies
CADP-SCED	Customer is required to be adaptive to work within tight schedule
CADP-PMEX	Customer is required to be adaptive to procurement process experience
CADP-PDTH	Customer is required to be adaptive to various level of thoroughness to process documentations
CADP-RISK	Customer is required to be adaptive to possible risk situations
CADP-RVOL	Customer is required to be adaptive for risk volatility found
SCAP-RELY	Supplier or service provider’s capability should be reliable for doing the job
SCAP-DURN	Supplier or service provider is required to be capable to do the job within limited duration
SCAP-CPLX	Supplier or service provider is required to be capable to do jobs with any level of complexity
SCAP-CPIS	Supplier or service provider is required to be capable with any complementary product or service structure available or installed or sanctioned
SCAP-CADP	Supplier or service provider is required to be capable to work with customer of any level of adaptability
SCAP-WSZE	Supplier or service provider is required to be capable to work with customer of any size of workforce
SCAP-WSKL	Supplier or service provider is required to be capable to work with customer of any level of workforce skills
SCAP-SEXP	Supplier or service provider is required to be capable to achieve different level of relevant service experience
SCAP-UMTG	Supplier or service provider is required to be capable to cope with the usage of modern technologies

RULE	DESCRIPTION
SCAP-SCED	Supplier or service provider is required to be capable to work within tight schedule
SCAP-PMEX	Supplier or service provider is required to be capable to cope with required process experience
SCAP-PDTH	Supplier or service provider is required to be capable to work with any level of thoroughness of product documentations
SCAP-RISK	Supplier or service provider is required to be capable to work with high risk potentialities.
SCAP-RVOL	Supplier or service provider is required to be capable to cope with requirements volatility
WSZE-RELY	Optimized workforce size of supplier or service provider is required to be reliable to achieve successful completion of job ordered
WSZE –DURN	Optimized workforce size of supplier or service provider is required to finish any assignments within limited duration
WSZE –CPLX	Optimized workforce size of supplier or service provider is required to do jobs given in any complexity level
WSZE –CPIS	Optimized workforce size of supplier or service provider is required to cope with the complementary infrastructure available
WSZE –CADP	Optimized workforce size of supplier or service provider is required to adjust with customer’s adaptability
WSZE –SCAP	Optimized workforce size of supplier or service provider is required to be maximized capability
WSZE –WSKL	Optimized workforce size of supplier or service provider is required to be of maximum required skills
WSZE –SEXP	Optimized workforce size of supplier or service provider is required to have sufficient relevant service experience
WSZE –UMTG	Optimized workforce size of supplier or service provider is required to have using modern technologies
WSZE –SCED	Optimized workforce size of supplier or service provider is required to finish any given job within tight schedule
WSZE –PMEX	Optimized workforce size of supplier or service provider is required to have adequate relevant process experience
WSZE –PDTH	Optimized workforce size of supplier or service provider is required to work with available thoroughness of process documentations
WSZE –RISK	Optimized workforce size of supplier or service provider is required to work with maximum risk potentialities
WSZE –RVOL	Optimized workforce size of supplier or service provider is required to be fit for requirement volatility
WSKL-RELY	Workforce skills of supplier or service provider is required to be reliable for successful implementation of ordered job
WSKL-DURN	Workforce skills of supplier or service provider is required to be sufficient for successful completion of order job within limited duration
WSKL-CPLX	Workforce skills of supplier or service provider is required to be sufficient for facing the complexity of the ordered job or product
WSKL-CPIS	Workforce skills of supplier or service provider is required to be sufficient for available complementary infrastructure
WSKL-CADP	Workforce skills of supplier or service provider is required to be suitable for matching with customer’s adaptability

RULE	DESCRIPTION
WSKL-SCAP	Workforce skills of supplier or service provider is required to have proper capability to fit in the required job
WSKL-WSZE	Workforce skills of supplier or service provider is required to be optimized with workforce size
WSKL-SEXP	Workforce skills of supplier or service provider is required to consist of significant relevant service experience
WSKL-UMTG	Workforce skill of supplier or service provider is required to consist of modern technology usage
WSKL-SCED	Workforce skill of supplier or service provider is required to be suitable to cope with tight schedule
WSKL-PMEX	Workforce skill of supplier or service provider is required to consist for relevant process experience
WSKL-PDTH	Workforce skill of supplier or service provider is required to cope with available thoroughness of process documentation
WSKL-RISK	Workforce skill of supplier or service provider is required to be sufficient for managing risk potentialities
WSKL-RVOL	Workforce skill of supplier or service provider is required to be fit for requirement volatility
SEXP-RELY	Relevant service experience of bidder should have sufficient reliability for doing bidding job
SEXP-DURN	Relevant service experience of bidder should show the jobs done within limited duration successfully
SEXP-CPLX	Relevant service experience of bidder should show the successful works with various level of complexity
SEXP-CPIS	Relevant service experience of bidder should show the successful work with complementary product or service infrastructure
SEXP-CADP	Relevant service experience of bidder should show the fitness to work with various level of customer's adaptability
SEXP-SCAP	Relevant service experience of bidder should show the fitness of relevant service capability
SEXP-WSZE	Relevant service experience of bidder should show the fitness to work with different workforce size
SEXP-WSKL	Relevant service experience of bidder should show the successful achievement of adequate workforce skills
SEXP-UMTG	Relevant service experience of bidder should show the history of modern technology usage
SEXP-SCED	Relevant service experience of bidder should show the history of successful completion of assignments within tight schedule
SEXP-PMEX	Relevant service experience of bidder should show significant process experience
SEXP-PDTH	Relevant service experience of bidder should show the history to cope with available thoroughness of process documentations.
SEXP-RISK	Relevant service experience of bidder should show the history of successful cope with risk potentialities
SEXP-RVOL	Relevant service experience of bidder should show the history of adjustment with requirement volatility
UMTG-RELY	Bidder's usage of modern technology is required to have significant reliability

RULE	DESCRIPTION
UMTG –DURN	Bidder’s usage of modern technology is required to have success to finish job within limited duration
UMTG –CPLX	Bidder’s usage of modern technology is required to be fit for any level of job or product complexity
UMTG –CPIS	Bidder’s usage of modern technology is required to show coping up any complementary product or service infrastructure available
UMTG –CADP	Bidder’s usage of modern technology is required to adjust with customer’s adaptability
UMTG –SCAP	Bidder’s usage of modern technology is required to show uplift their capability
UMTG –WSZE	Bidder’s usage of modern technology is required to optimize workforce size
UMTG –WSKL	Bidder’s usage of modern technology is required to show significant workforce skills
UMTG –SEXP	Bidder’s usage of modern technology is required to show significant service experience
UMTG –SCED	Bidder’s usage of modern technology is required to show history of successful job completion within tight schedule
UMTG –PMEX	Bidder’s usage of modern technology is required to be related with relevant process experience
UMTG –PDTH	Bidder’s usage of modern technology is required to be overcoming the barriers of available thoroughness of process documentations
UMTG –RISK	Bidder’s usage of modern technology is required to be minimizing risk potentialities
UMTG –RVOL	Bidder’s usage of modern technology is required to be cope able with any kind of requirement volatility
SCED-RELY	Procurement schedule to be fixed for required reliability
SCED –DURN	Procurement schedule to be fixed for suitable duration
SCED –CPLX	Procurement schedule to be fixed as per the complexity of job, product or service
SCED –CPIS	Procurement schedule to be fixed as per complementary infrastructure available
SCED –CADP	Procurement schedule to be fixed as per customers adaptability
SCED –SCAP	Procurement schedule to be fixed as per bidder’s capability
SCED –WSZE	Procurement schedule to be fixed as per bidder’s workforce size
SCED –WSKL	Procurement schedule to be fixed as per bidder’s workforce skill
SCED –SEXP	Procurement schedule to be fixed as per bidder’s relevant service experience
SCED –UMTG	Procurement schedule to be fixed as per bidder’s usage of modern technologies
SCED –PMEX	Procurement schedule to be fixed as per bidder’s relevant process experience
SCED –PDTH	Procurement schedule to be fixed as per available thoroughness of documentations
SCED –RISK	Procurement schedule to be fixed as per risk factors or potentialities
SCED –RVOL	Procurement schedule to be fixed as per chances of requirement volatility
PMEX-RELY	Bidder’s process experience should be significantly reliable

RULE	DESCRIPTION
PMEX –DURN	Bidder’s process experience should be sufficient to ensure assignment finish within limited duration
PMEX –CPLX	Bidder’s process experience should be sufficient to ensure assignment with any level of complexity to be done
PMEX –CPIS	Bidder’s process experience should be sufficient to ensure assignment to be done with available complementary infrastructure
PMEX –CADP	Bidder’s process experience should be shown fit to work with customer’s adaptability
PMEX –SCAP	Bidder’s process experience should be shown to have significant capability to do the assignment
PMEX –WSZE	Bidder’s process experience should be shown optimized for available workforce size
PMEX –WSKL	Bidder’s process experience should be shown sufficient for available workforce skill
PMEX –SEXP	Bidder’s process experience should significantly comes from service experience
PMEX –UMTG	Bidder’s process experience should hold sufficient usage of modern technologies
PMEX –SCED	Bidder’s process experience should hold the success of assignment with tight schedule
PMEX –PDTH	Bidder’s process experience should consist of working record with limited thoroughness of documentations
PMEX –RISK	Bidder’s process experience should consists of success record coping up different type of risk potentialities
PMEX –RVOL	Bidder’s process experience should consist of significant record to work with requirement volatility
PDTH-RELY	Process documentation thoroughness is required to be significantly reliable
PDTH –DURN	Process documentation thoroughness is to be suitable for proper project implementation within limited duration
PDTH –CPLX	Process documentation thoroughness is to be optimized to product or service complexity
PDTH –CPIS	Process documentation thoroughness is to be suited for complementary infrastructure
PDTH –CADP	Process documentation thoroughness is to be suitable for customer’s adaptability
PDTH –SCAP	Process documentation thoroughness is to be suitable for bidder’s capability
PDTH –WSZE	Process documentation thoroughness is to be convenient for bidder’s workforce size
PDTH –WSKL	Process documentation thoroughness is to be suited for bidder’s workforce skill
PDTH –SEXP	Process documentation thoroughness is to be sufficient to understand by bidder from relevant service experience
PDTH –UMTG	Process documentation thoroughness is to be convenient for modern technology usage
PDTH –SCED	Process documentation thoroughness is to be convenient for assignment with tight schedule

RULE	DESCRIPTION
PDTH –PMEX	Process documentation thoroughness is to be suited for bidder’s relevant process experience
PDTH –RISK	Process documentation thoroughness is to cover the risk potentialities
PDTH –RVOL	Process documentation thoroughness is to be suited for requirement volatility
RISK-RELY	Risk potentialities is to be optimized with reliable supporting activities
RISK-DURN	Risk potentialities is to be optimized with assignment duration
RISK-CPLX	Risk potentialities is to be optimized for assignment complexity
RISK-CPIS	Risk potentialities is to be optimized for available complementary infrastructure
RISK-CADP	Risk potentialities is to be optimized with customer’s adaptability
RISK-SCAP	Risk potentialities is to be optimized with bidder’s capability
RISK-WSZE	Risk potentialities is to be optimized for bidder’s available workforce size
RISK-WSKL	Risk potentialities is to be optimized for bidder’s available workforce skill
RISK-SEXP	Risk potentialities is to be optimized for bidder’s relevant service experience
RISK-UMTG	Risk potentialities is to be optimized for modern technology usage
RISK-SCED	Risk potentialities is to be optimized for tight assignment schedule
RISK-PMEX	Risk potentialities is to be optimized for relevant process experience
RISK-PDTH	Risk potentialities is to be optimized with process documentation thoroughness
RISK-RVOL	Risk potentialities is to be optimized for requirement volatility
RVOL-RELY	Requirement volatility to be assessed for expected reliability
RVOL-DURN	Requirement volatility to be assessed for fixed assignment duration
RVOL-CPLX	Requirement volatility to be assessed for assignment complexity
RVOL-CPIS	Requirement volatility to be assessed for available complementary infrastructure
RVOL-CADP	Requirement volatility to be assessed as per customer’s volatility
RVOL-SCAP	Requirement volatility to be assessed as per bidder’s capability
RVOL-WSZE	Requirement volatility to be assessed to cope with bidder’s workforce size
RVOL-WSKL	Requirement volatility to be assessed to cope with bidder’s workforce skill
RVOL-SEXP	Requirement volatility to be assessed to cope with bidder’s service experience
RVOL-UMTG	Requirement volatility to be assessed to adjust with the usage of available modern technologies
RVOL-SCED	Requirement volatility to be assessed to adjust with scheduling
RVOL-PMEX	Requirement volatility is to assessed for the adjustment with process experience available
RVOL-PDTH	Requirement volatility is to be assessed for the adjustment with available process documents thoroughness
RVOL-RISK	Requirement volatility is to be assessed for optimization of risk potentialities

Table 3.2: Fuzzy Matrix of procurement risk attributes pair

$f(x_i, x_j)$	**RELY**	**DURN**	**CPLX**	**CPIS**	**CADP**	**SCAP**	**WSZE**	**WSKL**	**SEXP**	**UMTG**	**SCED**	**PMEX**	**PDTH**	**RISK**	**RVOL**
RELY	1	RELY-DURN	RELY-CPLX	RELY-CPIS	RELY-CADP	RELY-SCAP	RELY-WSZE	RELY-WSKL	RELY-SEXP	RELY-UMTG	RELY-SCED	RELY-PMEX	RELY-PDTH	RELY-RISK	RELY-ROVL
DURN	DURN-RELY	1	DURN-CPLX	DURN-CPIS	DURN-CADP	DURN-SCAP	DURN-WSZE	DURN-WSKL	DURN-SEXP	DURN-UMTG	DURN-SCED	DURN-PMEX	DURN-PDTH	DURN-RISK	DURN-RVOL
CPLX	CPLX-RELY	CPLX-DURN	1	CPLX-CPIS	CPLX-CADP	CPLX-SCAP	CPLX-WSZE	CPLX-WSKL	CPLX-SEXP	CPLX-UMTG	CPLX-SCED	CPLX-PMEX	CPLX-PDTH	CPLX-RISK	CPLX-RVOL
CPIS	CPIS-RELY	CPIS-DURN	CPIS-CPLX	1	CPIS-CADP	CPIS-SCAP	CPIS-WSZE	CPIS-WSKL	CPIS-SEXP	CPIS-UMTG	CPIS-SCED	CPIS-PMEX	CPIS-PDTH	CPIS-RISK	CPIS-RVOL
CADP	CADP-RELY	CADP-DURN	CADP-CPLX	CADP-CPIS	1	CADP-SCAP	CADP-WSZE	CADP-WSKL	CADP-SEXP	CADP-UMTG	CADP-SCED	CADP-PMEX	CADP-PDTH	CADP-RISK	CADP-RVOL
SCAP	SCAP-RELY	SCAP-DURN	SCAP-CPLX	SCAP-CPIS	SCAP-CADP	1	SCAP-WSZE	SCAP-WSKL	SCAP-SEXP	SCAP-UMTG	SCAP-SCED	SCAP-PMEX	SCAP-PDTH	SCAP-RISK	SCAP-RVOL
WSZE	WSZE-RELY	WSZE-DURN	WSZE-CPLX	WSZE-CPIS	WSZE-CADP	WSZE-SCAP	1	WSZE-WSKL	WSZE-SEXP	WSZE-UMTG	WSZE-SCED	WSZE-PMEX	WSZE-PDTH	WSZE-RISK	WSZE-RVOL
WSKL	WSKL-RELY	WSKL-DURN	WSKL-CPLX	WSKL-CPIS	WSKL-CADP	WSKL-SCAP	WSKL-WSZE	1	WSKL-SEXP	WSKL-UMTG	WSKL-SCED	WSKL-PMEX	WSKL-PDTH	WSKL-RISK	WSKL-RVOL
SEXP	SEXP-RELY	SEXP-DURN	SEXP-CPLX	SEXP-CPIS	SEXP-CADP	SEXP-SCAP	SEXP-WSZE	SEXP-WSKL	1	SEXP-UMTG	SEXP-SCED	SEXP-PMEX	SEXP-PDTH	SEXP-RISK	SEXP-RVOL
UMTG	UMTG-RELY	UMTG-DURN	UMTG-CPLX	UMTG-CPIS	UMTG-CADP	UMTG-SCAP	UMTG-WSZE	UMTG-WSKL	UMTG-SEXP	1	UMTG-SCED	UMTG-PMEX	UMTG-PDTH	UMTG-RISK	UMTG-RVOL
SCED	SCED-RELY	SCED-DURN	SCED-CPLX	SCED-CPIS	SCED-CADP	SCED-SCAP	SCED-WSZE	SCED-WSKL	SCED-SEXP	SCED-UMTG	1	SCED-PMEX	SCED-PDTH	SCED-RISK	SCED-RVOL
PMEX	PMEX-RELY	PMEX-DURN	PMEX-CPLX	PMEX-CPIS	PMEX-CADP	PMEX-SCAP	PMEX-WSZE	PMEX-WSKL	PMEX-SEXP	PMEX-UMTG	PMEX-SCED	1	PMEX-PDTH	PMEX-RISK	PMEX-RVOL
PDTH	PDTH-RELY	PDTH-DURN	PDTH-CPLX	PDTH-CPIS	PDTH-CADP	PDTH-SCAP	PDTH-WSZE	PDTH-WSKL	PDTH-SEXP	PDTH-UMTG	PDTH-SCED	PDTH-PMEX	1	PDTH-RISK	PDTH-RVOL
RISK	RISK-RELY	RISK-DURN	RISK-CPLX	RISK-CPIS	RISK-CADP	RISK-SCAP	RISK-WSZE	RISK-WSKL	RISK-SEXP	RISK-UMTG	RISK-SCED	RISK-PMEX	RISK-PDTH	1	RISK-RVOL
RVOL	RVOL-RELY	RVOL-DURN	RVOL-CPLX	RVOL-CPIS	RVOL-CADP	RVOL-SCAP	RVOL-WSZE	RVOL-WSKL	RVOL-SEXP	RVOL-UMTG	RVOL-SCED	RVOL-PMEX	RVOL-PDTH	RVOL-RISK	1

3.6 Illustrative Example

Table 3.11: Risk ratings for Risk attributes using triangular fuzzy numbers

	RELY	DURN	CPLX	CPIS	CADP	SCAP	WSZE	WSKL	SEXP	UMTG	SCED	PMEX	PDTH	RISK	RVOL
RELY	(1,1,1)	(4,6,8)	(1/5,1/7,1/9)	(3,5,7)	(1/7,1/9,1/9)	(1,1,3)	(4,6,8)	(7,7,9)	(1,1/3,1/5)	(4,6,8)	(1/5,1/7,1/9)	(7,9,9)	(1,1/3,1/5)	(1/7,1/7,1/9)	(2,4,6)
DURN	(1/4,1/6,1/8)	(1,1,1)	(1,1,1/3)	(4,6,8)	(1/5,1/7,1/9)	(1/2,1/4,1/6)	(7,7,9)	(1/2,1/4,1/6)	(3,5,7)	(1,1,1/3)	(1/2,1/4,1/6)	(1,1,1/3)	(1,1,3)	(1/7,1/7,1/9)	(1,1,3)
CPLX	(5,7,9)	(1,1,3)	(1,1,1)	(1,1,3)	(3,5,7)	(1/4,1/6,1/8)	(1/4,1/6,1/8)	(5,7,9)	(4,6,8)	(1,1,1/3)	(5,7,9)	(1,1/3,1/5)	(1,1,3)	(1/7,1/7,1/9)	(1/5,1/7,1/9)
CPIS	(1/3,1/5,1/7)	(1/4,1/6,1/8)	(1,1,1/3)	(1,1,1)	(3,5,7)	(1,1,3)	(1,1,3)	(4,6,8)	(1/5,1/7,1/9)	(1,1,1/3)	(1/4,1/6,1/8)	(1,3,5)	(1,1,1/3)	(5,7,9)	(1,1,1/3)
CADP	(7,9,9)	(5,7,9)	(1/3,1/5,1/7)	(1/3,1/5,1/7)	(1,1,1)	(1/5,1/7,1/9)	(5,7,9)	(1/7,1/7,1/9)	(2,4,6)	(1/2,1/4,1/6)	(5,7,9)	(1/4,1/6,1/8)	(2,4,6)	(7,7,9)	(1,1,1/3)
SCAP	(1,1,1/3)	(2,4,6)	(4,6,8)	(1,1,1/3)	(5,7,9)	(1,1,1)	(1,1/3,1/5)	(1/2,1/4,1/6)	(4,6,8)	(2,4,6)	(1/5,1/7,1/9)	(1,1/3,1/5)	(1,1,1/3)	(1/3,1/5,1/7)	(2,4,6)
WSZE	(1/4,1/6,1/8)	(1/7,1/7,1/9)	(4,6,8)	(1,1,1/3)	(1/5,1/7,1/9)	(1,3,5)	(1,1,1)	(1/4,1/6,1/8)	(1/2,1/4,1/6)	(1/2,1/4,1/6)	(4,6,8)	(2,4,6)	(1,3,5)	(1/4,1/6,1/8)	(1,1,1/3)
WSKL	(1/7,1/7,1/9)	(2,4,6))	(1/5,1/7,1/9)	(1/4,1/6,1/8)	(7,7,9)	(2,4,6)	(4,6,8)	(1,1,1)	(5,7,9)	(1,1,1/3)	(1/3,1/5,1/7)	(2,4,6)	(1,1/3,1/5)	(5,7,9)	(1,1,1/3)
SEXP	(1,3,5)	(1/3,1/5,1/7)	(1/4,1/6,1/8)	(5,7,9)	(1/2,1/4,1/6)	(1/4,1/6,1/8)	(2,4,6)	(1/5,1/7,1/9)	(1,1,1)	(1,1,3)	(1/3,1/5,1/7)	(1/4,1/6,1/8)	(1,1,1/3)	(3,5,7)	(1/2,1/4,1/6)
UMTG	(1/4,1/6,1/8)	(1,1,3)	(1,1,3)	(1,1,3)	(2,4,6)	(1/2,1/4,1/6)	(2,4,6)	(1,1,3)	(1,1,1/3)	(1,1,1)	(7,7,9)	(2,4,6)	(1,1,1/3)	(1,1,1/3)	(1,1,3)
SCED	(5,7,9)	(2,4,6)	(1,5,1/7,1/9)	(4,6,8)	(1/5,1/7,1/9)	(5,7,9)	(1/4,1/6,1/8)	(3,5,7)	(3,5,7)	(1/7,1/7,1/9)	(1,1,1)	(4,6,8)	(1/4,1/6,1/8)	(3,5,7)	(1/4,1/6,1/8)
PMEX	(1/7,1/9,1/9)	(1,1,3)	(1,3,5)	(1,1/3,1/5)	(4,6,8)	(1,3,5)	(1/2,1/4,1/6)	(1/2,1/4,1/6)	(4,6,8)	(1/2,1/4,1/6)	(1/4,1/6,1/8)	(1,1,1)	(3,5,7)	(7,7,9)	(3,5,7)
PDTH	(1,3,5)	(1,1,1/3)	(1,1,1/3)	(1,1,3)	(1/2,1/4,1/6)	(1,1,3)	(1,1/3,1/5)	(1,3,5)	(1,1,3)	(1,1,3)	(4,6,8)	(1/3,1/5,1/7)	(1,1,1)	(1/5,1/7,1/9)	(2,4,6)
RISK	(7,7,9)	(7,7,9)	(7,7,9)	(1/5,1/7,1/9)	(1/7,1/7,1/9)	(3,5,7)	(4,6,8)	(1/5,1/7,1/9)	(1/3,1/5,1/7)	(1,1,3)	(1/3,1/5,1/7)	(1/7,1/7,1/9)	(5,7,9)	(1,1,1)	(1/7,1/7,1/9)
RVOL	(1/2,1/4,1/6)	(1,1,1/3)	(5,7,9)	(1,1,3)	(1,1,3)	(1/2,1/4,1/6)	(1,1,3)	(1,1,3)	(2,4,6)	(1,1,1/3)	(4,6,8)	(1/3,1/5,1/7)	(1/2,1/4,1/6)	(7,7,9)	(1,1,1)

Table 3.12: Normalized fuzzy matrix with triangular fuzzy numbers

	RELY	DURN	CPLX	CPIS	CADP	SCAP	WSZE	WSKL	SEXP	UMTG	SCED	PMEX	PDTH	RISK	RVOL
RELY	(0.12, 0.1, 0.1)	(0.56, 0.66, 0.89)	(0.01, 0, 0)	(0.42, 0.55, 0.78)	(0, 0, 0)	(0.12, 0.1, 0.33)	(0.56, 0.66, 0.89)	(1, 0.78, 1)	(0.12, 0.02, 0.01)	(0.56, 0.66, 0.89)	(0.01, 0, 0)	(1, 1, 1)	(0.12, 0.02, 0.01)	(0, 0, 0)	(0.27, 0.44, 0.66)
DURN	(0.02, 0, 0)	(0.12, 0.12, 0.1)	(0.12, 0.12, 0.02)	(0.56, 0.85, 0.89)	(0.01, 0, 0)	(0.05, 0.02, 0.01)	(1, 1, 1)	(0.05, 0.02, 0.01)	(0.42, 0.71, 0.78)	(0.12, 0.12, 0.02)	(0.05, 0.02, 0.01)	(0.12, 0.12, 0.02)	(0.12, 0.12, 0.33)	(0, 0, 0)	(0.12, 0.12, 0.33)
CPLX	(1, 1, 1)	(0.18, 0.12, 0.33)	(0.18, 0.12, 0.1)	(0.18, 0.12, 0.33)	(0.59, 0.71, 0.78)	(0.02, 0, 0)	(0.02, 0, 0)	(1, 1, 1)	(0.79, 0.85, 0.89)	(0.18, 0.12, 0.02)	(1, 1, 1)	(0.18, 0.03, 0.01)	(0.18, 0.12, 0.33)	(0, 0, 0)	(0.01, 0, 0)
CPIS	(0.03, 0.01, 0)	(0.01, 0, 0)	(0.17, 0.12, 0.02)	(0.17, 0.12, 0.1)	(0.58, 0.71, 0.78)	(0.17, 0.12, 0.33)	(0.17, 0.12, 0.33)	(0.79, 0.85, 0.89)	(0, 0, 0)	(0.17, 0.12, 0.02)	(0.01, 0, 0)	(0.17, 0.42, 0.55)	(0.17, 0.12, 0.02)	(1, 1, 1)	(0.17, 0.12, 0.02)
CADP	(1, 1, 1)	(0.71, 0.77, 1)	(0.03, 0.01, 0)	(0.03, 0.01, 0)	(0.12, 0.1, 0.1)	(0.01, 0, 0)	(0.71, 0.77, 1)	(0, 0, 0)	(0.27, 0.44, 0.66)	(0.05, 0.01, 0.01)	(0.71, 0.77, 1)	(0.02, 0, 0)	(0.27, 0.44, 0.66)	(1, 0.77, 1)	(0.12, 0.1, 0.02)
SCAP	(0.17, 0.12, 0.02)	(0.37, 0.56, 0.66)	(0.79, 0.85, 0.89)	(0.17, 0.12, 0.02)	(1, 1, 1)	(0.17, 0.12, 0.1)	(0.17, 0.03, 0.01)	(0.06, 0.02, 0.01)	(0.79, 0.85, 0.89)	(0.37, 0.56, 0.66)	(0, 0, 0)	(0.17, 0.03, 0.01)	(0.17, 0.12, 0.02)	(0.03, 0.01, 0)	(0.03, 0.56, 0.66)
WSZE	(0.48, 0, 0)	(0, 0, 0)	(1, 1, 1)	(0.22, 0.15, 0.03)	(0.01, 0, 0)	(0.22, 0.49, 0.62)	(0.22, 0.15, 0.11)	(0.03, 0, 0)	(0.09, 0.02, 0.01)	(0.09, 0.02, 0.01)	(1, 1, 1)	(0.48, 0.66, 0.75)	(0.22, 0.49, 0.62)	(0.03, 0, 0)	(0.22, 0.15, 0.03)
WSKL	(0, 0, 0)	(0.27, 0.56, 0.66)	(0.01, 0, 0)	(0.02, 0, 0)	(1, 1, 1)	(0.27, 0.56, 0.66)	(0.56, 0.85, 0.89)	(0.12, 0.12, 0.1)	(0.71, 1, 1)	(0.12, 0.12, 0.02)	(0.03, 0.01, 0)	(0.27, 0.56, 0.66)	(0.12, 0.03, 0.01)	(0.71, 1, 1)	(0.12, 0.12, 0.02)
SEXP	(0.17, 0.42, 0.55)	(0.03, 0.01, 0)	(0.01, 0, 0)	(1, 1,1)	(0.06, 0.02, 0.01)	(0.01, 0, 0)	(0.37, 0.56, 0.66)	(0, 0, 0)	(0.17, 0.12, 0.1)	(0.17, 0.12, 0.33)	(0.03, 0.01, 0)	(0.01, 0, 0)	(0.17, 0.12, 0.02)	(0.58, 0.71, 0.78)	(0.06, 0.02, 0.01)
UMTG	(0, 0, 0)	(0.11, 0.12, 0.32)	(0.11, 0.12, 0.32)	(0.11, 0.12, 0.32)	(0.26, 0.56, 0.66)	(0.04, 0.01, 0)	(0.26, 0.56, 0.66)	(0.11, 0.12, 0.32)	(0.11, 0.12, 0.02)	(0.11, 0.12, 0.1)	(1, 1, 1)	(0.26, 0.56, 0.66)	(0.11, 0.12, 0.02)	(0.11, 0.12, 0.02)	(0.11, 0.12, 0.32)
SCED	(1, 1, 1)	(0.38, 0.56, 0.66)	(0.01, 0, 0)	(0.79, 0.85, 0.89)	(0.01, 0, 0)	(1, 1, 1)	(0.02, 0, 0)	(0.59, 0.71, 0.78)	(0.59, 0.71, 0.78)	(0, 0, 0)	(0.18, 0.12, 0.1)	(0.79, 0.85, 0.89)	(0.02, 0, 0)	(0.59, 0.71, 0.78)	(0.02, 0, 0)
PMEX	(0, 0, 0)	(0.12, 0.13, 0.33)	(0.12, 0.42, 0.55)	(0.12, 0.03, 0.01)	(0.56, 0.85, 0.89)	(0.12, 0.42, 0.55)	(0.05, 0.02, 0.01)	(0.05, 0.02, 0.01)	(0.56, 0.85, 0.89)	(0.05, 0.02, 0.01)	(0.02, 0.01, 0)	(0.12, 0.13, 0.1)	(0.42, 0.71, 0.78)	(1, 1, 1)	(0.42, 0.71, 0.78)
PDTH	(0.21, 0.49, 0.62)	(0.21, 0.15, 0.03)	(0.21, 0.15, 0.03)	(0.21, 0.15, 0.37)	(0.08, 0.02, 0.01)	(0.21, 0.15, 0.37)	(0.21, 0.03, 0.01)	(0.21, 0.49, 0.62)	(0.21, 0.15, 0.37)	(0.21, 0.15, 0.37)	(1, 1, 1)	(0.03, 0.02, 0)	(0.21, 0.15, 0.11)	(0, 0, 0)	(0.47, 0.66, 0.75)
RISK	(1, 1, 1)	(1, 1, 1)	(1, 1, 1)	(0.01, 0, 0)	(0, 0, 0)	(0.42, 0.71, 0.78)	(0.56, 0.85, 0.89)	(0.01, 0, 0)	(0.03, 0.01, 0)	(0.12, 0.12, 0.33)	(0.03, 0.01, 0)	(0, 0, 0)	(0.71, 1, 1)	(0.12, 0.12, 0.1)	(0, 0, 0)
RVOL	(0.03, 0.01 , 0)	(0.1, 0.12, 0.02)	(0.7, 1, 1)	(0.1, 0.12, 0.32)	(0.1, 0.12, 0.32)	(0.03, 0.01, 0)	(0.1, 0.12, 0.32)	(0.1, 0.12, 0.32)	(0.25, 0.56, 0.66)	(0.1, 0.12, 0.02)	(0.55, 0.85, 0.89)	(0, 0, 0)	(0.03, 0.01, 0)	(1, 1, 1)	(0.1, 0.12, 0.1)