A FUZZY APPROACH TO RISK ASSESSMENT IN CONSTRUCTION INDUSTRY

Submitted in partial fulfilment of the requirements

for the degree of

MASTER OF ENGINEERING

in

CIVIL ENGINEERING

(With specialization in Construction Engineering and Management)

by

Tasneem Azam

(Registration Number: Anjuman-21)

Under the guidance of

Dr. R. B. Magar

Department of Civil Engineering

School of Engineering and Technology

Anjuman-I-Islam's Kalsekar Technical Campus

New Panvel, Navi Mumbai-410206

2017

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CERTIFICATE

This is to certify that the project entitled **"A Fuzzy Approach to Risk Assessment in Construction Industry"** is a bonafide work of **Ms. Tasneem Azam (15CEM18)** submitted to the University of Mumbai in partial fulfilment of the requirement for the award of the degree of "Master of Engineering" in "Civil Engineering (With Specialization in Construction Engineering and Management)"

Dr. R. B. Magar	**Dr. Abdul Razak Honnutagi**
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APPROVAL SHEET

This dissertation report entitled "A Fuzzy Approach to Risk Assessment in Construction Industry" by Tasneem Azam is approved for the degree of "Civil Engineering with Specialization in Construction Engineering and Management"

Examiners

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Supervisors:

1. ....

2. ....

Date:

Place: Panvel

DECLARATION

I declare that this written submission represents my ideas in our own words and where others ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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ABSTRACT

The increasing complexity and dynamism of construction projects have imposed substantial uncertainties and subjectivities in the risk analysis process. Traditional risk models are based on probability and classical set theory. In contrast, fuzzy logic models are built upon fuzzy set theory and fuzzy logic, and they are useful for analyzing risks with insufficient knowledge or imprecise data. The work presents a risk assessment methodology based on the Fuzzy Sets Theory, which is an effective tool to deal with subjective judgment, which is used to structure large number of risks. The project deals with the use of fuzzy logic as a support of evaluation of total project risk. A brief description of actual project risk management, fuzzy set theory, fuzzy logic and the process of calculation is given. The major goal is to present a new expert decision-making fuzzy model for evaluating total project risk. This fuzzy model is based on RIPRAN method. RIPRAN (RIsk PRoject ANalysis) method is an empirical method for the analysis of project risks. The Fuzzy Logic Toolbox in MATLAB software was used to create the decision-making fuzzy model. This model evaluates the total project risk based on two parameters: the number of sub-risks and the total value of sub risk. The model includes attributes of both input and output variable, membership function, rule block and M-file. With this approach it is possible to simulate the risk value and uncertainty that are always associated with real projects.

Keywords— Risk assessment; fuzzy logic; decision-making model.

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ABBREVIATION NOTATION AND NOMENCLATURE

RIPRAN	Risk Project Analysis
FST	Fuzzy Set Theory
NSR	Number of sub risk
TVSR	Total value of sub risk
TVPR	Total value of project risk
MATLAB	Matrix Laboratory
ERP	Enterprise resource project
GA	Genetic algorithm
AHP	Analytic hierarchy process
EVM	Expected Value Method
PMBOK	Project Management Book of Knowledge

Chapter 1

Introduction

1.1 General

Risk management is the systematic process of identifying, analyzing and responding to project risk. Risk is defined as “a situation where there exists no knowledge of its outcomes”. It includes maximizing the probability and consequences of positive events and minimizing the probability and consequences of adverse events to achieve project objectives. Nowadays, almost every project is subjected to risks. It is uncertainty in plans and possibility of something happening that can affect prospects of achieving, project goals. Evaluating and analyzing the risks of a project and planning to manage them are the most critical steps should be done in the project definition stage. (Jayasudha *et al.* 2014)

The track record of construction industry is very poor in terms of coping with risks, resulting in the failure of many projects to meet time schedules, targets of budget and sometimes even the scope of work. As a result, a lot of suffering is inflicted to the clients and contractors of such projects and also to the general public. More often, Project Managers try to assess risk using exact values and fail. Since risk cannot be quantified in straight, crisp terms it must be taken and analyzed as a distribution. Fuzzy logic is built on the concept of imprecise and ambiguous data. Therefore, fuzzy logic is an appropriate method to analyze risk. The main objective is to remove as much as possible the potential impact and to increase the level of control of risk. The process of risk management does not aim to remove completely all risks from a project. Its objective is to develop an organized framework to assist decision makers to manage the risks, especially the critical ones, effectively and efficiently. (Ismail *et al*. 2008)

1.2 Motivation

Construction projects take place in a complex and challenging environment. High levels of risk are associated with this industry. A reliable way to analyze the associated risks is vital to make success. Construction project managers can predict the overall risk of the project before start the implementation. An overall risk index can be used as early indicators of project problems or potential difficulties by using fuzzy logic. Fuzzy logic makes the analysis of risk quick and easy.

1.3 Objectives of the Work

A decision making model is created using Fuzzy Logic Toolbox of the MATLAB software based on input data collected by expert judgement. The parameters of membership functions can be adjusted and balanced for each of the variables. Following objectives are proposed in the present investigation.

- Risk preparing: Agreement on the process, identification of materials, team building, and identification of relationships.
- Risk identification: Identification of threats and scenarios. Risk trees can be used.
- Risk quantification: Identification of probabilities of threats and impact of scenarios.
- Risk response: Identification of steps to reduce the risk.
- Risk assessment: Total project risk evaluation based on the number of sub-risks and the total value of sub-risks.

1.4 Scope of the Work

In view of the fore mentioned problem as specified from the literature review, following scope is outlined for the present investigation. The scope of the project is to the use of fuzzy logic as a support of evaluation of total project risk by using fuzzy logic toolbox of MATLAB software.

1.5 Organization of Dissertation

The dissertation report is subdivided into five chapters. The brief contents have been discussed as below:

Chapter 1 Discusses the dissertation review, need of study, scope, objective of work and methodology adopted to complete dissertation. Also include efforts have been taken to introduce the topic to considerable extent, its requirement and the way in which project is to be taken forward.

Chapter 2 Describes the Literature Review Focuses on Fuzzy Logic used in risk assessment in brief and explains the concept to considerable extent.

Chapter 3 Explains about the general introduction about the Fuzzy Logic, Fuzzy Set Theory etc. This Chapter provides a relation to Fuzzy Logic used in risk assessment in construction industry, Principle and Application of fuzzy logic by using MATLAB software for creating a Decision Making Model. It also explains the work performed in the course of project. The details of the project have been explained step by step in the chapter. This chapter describes the methodology used for creating a Decision Making model which also includes Risk Assessment.

Chapter 4 Concludes the dissertation giving the potential benefits of Fuzzy Logic system used in Risk Assessment of Construction Projects as explained in the subsequent chapters. It also gives the suggestions for future improvements or addition which can possibly be made to this study.

Chapter 2

Literature Review

2.1 General

In recent years, it is noticeable the increased interest of the risk problem from the perspective of the construction industry. The research areas in the risk management are focused on the identification of random factors, determination of the probability of their occurrence and their impact on the course of a construction project. The problems, which often occur in terms of the risk analysis in the listed publications, are the following ones:

- Methodology/procedure of risk analysis for a project [Baccarini *et al* (2001)].
- Proposition of risk classification according to the source of origin, type, consequences [Baccarini *et a*l (2001), Kapliński *et al* (2002)].
- Review and classification of selected methods supporting the risk management in projects [Dziadosz *et al* (2010), Raz, *et al* (2001)].
- Analytical application of method/tool to a specific problem in the scope of risk analysis [Dziadosz (2013)].
- Risk management in construction projects–theory and practice [Turskis *et al* (2012)].

A risk, as a measurable part of the uncertainty, is most often treated in the literature as a possibility of incurring of a loss. The number and scope of the problems associated with the execution of the project is large. Before we start their in-depth analysis (in terms of risk analysis) we should find the answers to at least two key questions: (a) Decision Problem (b) Decision making Procedure in Risk Management. Risk identification is a repetitive process which is performed by a part of project management team. According to Baker *et al*. (1999), the risk management has been applied formally in the construction projects as an integrated process in the recent decades. This is due to fast growth of technology. Therefore, risk and risk management is the construction projects is a certain issue in recent decades.

2.2 Overview of Literature Review

There have been several studies on the Risk Assessment Using Fuzzy Logic:

In modern mathematical society, fuzzy is defined as a branch of modern mathematics that was formulated by Zadeh (1965) to model vagueness intrinsic in human cognitive process and to solve ill-defined and complicated problems because of ambiguous, incomplete, vague, and imprecise information that characterize the real-world system.

Lorterapong and Moselhi (1996) presented a new network scheduling method based on FST to estimate the durations of construction activities. The proposed method incorporated a number of new techniques that facilitate: (1) the representation of imprecise activity durations; (2) the calculation of scheduling parameters; and (3) the interpretation of the fuzzy results generated.

Fayek (1998) developed a competitive bidding strategy model by using FST to help a company achieve its objectives in bidding. He stated that the use of FST allows assessments to be made in qualitative and approximate terms, which suit the subjective nature of the margin-size decision. He concluded that the competitive bidding strategy model can improve the quality of the decision-making process used in setting a margin and can help contractors gain a competitive edge in bidding.

Holt (1998) pointed out that the need for judicious construction contractor selection is increasing. For this reason, he reviewed a number of contractor evaluation and selection modeling methods. The methods include: (1) bespoke approaches; (2) multi-attribute analysis; (3) multi-attribute utility theory; (4) cluster analysis; (5) multiple regression; (6) FST; and (7) multivariate discriminant analysis. The merits and demerits as well as previous and future applications of each methodology were discussed.

Okoroh and Torrance (1999) developed a subcontractor selection and appointment model for analyzing the subcontractor's risk elements in construction refurbishment projects. The model is based on the use of FST with the fuzzy set representing the overall weighted average rating of refurbishment contractors' criterion for the selection of subcontractors. It was believed that the implementation of the model in linguistic terms enables the user to interact with the system in a very friendly manner using natural language expressions.

Kumar et al. (2000) asserted that the assessment of working capital requirement in construction projects was subjective and based on uncertainty. There is an inherent difficulty in the classical approach to assess the effect of qualitative factors for the evaluation of working capital requirement. Kumar et al. (2000) developed a methodology to incorporate linguistic variables into workable mathematical propositions for the assessment of working capital using FST after considering the uncertainty associated with many of the project resource variables.

Leu et al. (2001) proposed a new optimal construction time-cost trade-off model in which the effects of both uncertain activity duration and time-cost trade-off were taken into consideration. FST was adopted to model the uncertainties of activity durations. A searching technique using genetic algorithm (GA) was used to search for the optimal construction project time-cost trade-off profiles under different risk levels. This method provided an insight into the optimal balance of time and cost under various risk levels as defined by decision makers. It should be emphasized that the proposed classification systems are by no means mutually exclusive. Some papers can be grouped in more than one category.

Site layout planning can affect productivity and is crucial to project success Tam et al. (2002). Nevertheless, since construction is heterogeneous in the nature of its organizations, project designs, and time constraints. Site layout planning for each project becomes unique (Tam et al. 2002). Therefore, site layout planning is a typical multi-objective problem because it is affected by many uncertainties and variations.

Knight and Fayek (2002) used fuzzy logic to predict potential cost overruns on engineering design projects. By doing so, it assists in assessing the amount of possible risk on a project and the likelihood of making a profit on the job. In particular, the research used fuzzy logic to model the relationships between the characteristics of a project and the potential risk events that may occur, and the associated cost overruns caused by combinations of the project characteristics and risk events.

Timely resource allocation is vital to avoid unnecessary waiting time of resources and delay of activities for construction activities. Zhang and Tam (2003) opined that timely resource allocation is a dynamic decision-making process dependent on real-time information during a construction process.

Having considered operational and stochastic characteristics of construction operations and the fuzziness of multiple-decision objectives for an appropriate allocation policy, Zhang and Tam (2003) developed a fuzzy dynamic resource allocation based on fuzzy set/fuzzy logic and the fuzzy decision-making approach. They explained that this model can finally help improve construction productivity by making the best use of resource allocation.

Zhang et al. (2004) observed that it is always problematic to define uncertain information input for construction-oriented discrete-event simulation. Therefore, they proposed incorporating FST with discrete-event simulation to handle the vagueness, imprecision, and subjectivity in the estimation of activity duration, based on an improved activity scanning simulation algorithm, a fuzzy distance ranking measure was used in fuzzy simulation time advancement and event selection for simulation experimentation. Baloi and Price (2003) factors' modeling, assessment, and management. Their preliminary indications showed that FST is a viable technology for modeling, assessing, and managing global risk factors that affect construction cost performance and therefore a fuzzy decision framework for risk management can be successfully developed.

Lin and Chen (2004) studied bid/no-bid decision making and stated that they were associated with uncertainty and complexity. They adopted a fuzzy logic approach because subjective considerations, such as nature, competition, value of the bid opportunity, resource capabilities, and the reputation of the company are relevant to the bid/no-bid decision. By using this approach, assessments were described subjectively in linguistic terms while screening criteria were weighted by their corresponding level of importance using fuzzy logic and fuzzy values. A practical example proved that this method could provide the analyst with more convincing and reliable results and cost saving for a company.

Seo et al. (2004) attempted several alternatives to obtain the sustainable residential buildings based on the acceptable level of environmental impact and socioeconomic characteristics of residential building. However, these criteria are in conflict with each other. Therefore, it is very difficult to assess the sustainable residential buildings. To solve this problem, Seo et al. (2004) adopted a methodology, which is based on FST, to assess a residential building that is intended to assist the decision making for the building planners or industrial practitioners.

Choi et al. (2004) presented a risk assessment methodology for underground construction projects, in which they developed a formalized procedure and associated tools to evaluate and manage the risks involved in underground construction. The main tool of the proposed risk assessment methodology is the risk analysis software and this software is built upon an uncertainty model based on fuzzy set. In more detail, the fuzzy-based uncertainty model was designed to consider the uncertainty range that represented the degree of uncertainties involved in both probabilistic parameter estimates and subjective judgments.

Zheng and Ng (2005) pointed that the duration and cost of each construction activity could change dynamically as a result of many uncertain variables, such as productivity, resource availability, and weather. Project managers have to take these uncertainties into account so as to provide an optimal balance of time and cost, based on their own knowledge and experience. For this reason, FST was applied to model the managers' behavior in predicting time and cost pertinent to a specific option within a construction activity.

Dziadosza and Rejmentb (2015)-presented three different methods of the risk analysis as well as highlighting their disadvantages, advantages and primary areas of application (selection or pre-estimation). These methods differ in their methodology from each other. The verification was started from the simplest techniques using some qualitative variables. The methods are based on the considerable subjectivity of a decision maker although it is relatively simple and easy to use. The analysis was finished on the statistical method, which determines the type of used data therefore it affects the quality of the results.

Andi (2004)-proposed a step by step procedure. In the first step, project risks were identified. Influence diagramming technique was employed to identify and to show how the risks affect the project cost elements and also the relationships among the risks themselves. The second step is to assess the project costs with regards to the risks under consideration. Using a linguistic approach, the degree of uncertainty of identified project risks is assessed and quantified.

The problem of dependency between risks is taken into consideration during this analysis. For the final step, as the main purpose of this paper, a method for allocating appropriate contingency is presented. Two types of contingencies, i.e. project contingency and management reserve are proposed to accommodate the risks. An illustrative example is presented at the end to show the application of the methodology.

Tseng et al. (2004) defined "a multifunctional team" in the e-world as a group of people from various functional departments or different areas of work responsibility to work together and exchange information through networks. In fact, multifunctional teams are becoming more and more important because organizations often require group cooperation across functional lines and the members may not be in the same location. However, the literature did not provide any analytical solutions for forming multifunctional teams under uncertain information environment.

In order to handle the underlying complexities of the multifunctional teams' formation process, Tseng et al. (2004) developed a methodology based on FST and grey decision theory for the multifunctional team formation. FST was applied to deal with problems involving ambiguities, which were normally confronted in multifunctional teams' formation practice and formed groups, when there was no clear boundary for relationship between customers' requirements and project characteristics. Grey decision theory was used to select desired team members through abstract information.

It was concluded that the application of the fuzzy and gray approaches demonstrated its capability of forming a good multifunctional team and it was promising to deal with insufficient information at the team forming stage (Tseng et al. 2004). It is understandable that construction activity duration is uncertain due to variations in the outside environment, such as weather, site congestion and productivity level. Because of different resource utilization, construction activity duration might need to be adjusted and the project direct cost could also be changed accordingly.

Zayed and Halpin (2004) viewed that in the piling process, both qualitative and quantitative factors have to be considered so as to estimate productivity efficiently. To assess the effect of subjective factors on bored pile construction productivity, Zayed and Halpin (2004) developed a productivity index model mainly based on fuzzy logic to represent the subjective effect in refining productivity assessment using simulation and deterministic techniques.

Shang et al. (2005) developed an innovative risk assessment approach for distributing project teams. The approach was based on a client and server architecture and used fuzzy logic and web-based technology. It was found that the use of a web-based risk assessment system for distributing project team members had major benefits in terms of use of linguistic terms to express risk assessment, ease of communication, ease of maintenance, and greater consistency.

Wei and Wang (2004) developed a comprehensive framework, which combined objective data obtained both from external professional report and subjective data derived from internal interviews with vendors, to select an appropriate Enterprise Resource Planning (ERP) project. By doing so, a hierarchical attribute structure was suggested to evaluate the ERP projects systematically. In addition, FST was adopted to aggregate the linguistic evaluation descriptions and weights.

Bonnal et al. (2004) pointed out that stochastic project-scheduling approaches are used by many project schedulers. However, the axiom associated with the theory of probabilities is always incompatible with decision-making situations. They analyzed that fuzzy project scheduling approaches are most suited to fuzzy situations, and they proposed a framework, which was based on fuzzy sets, to address the resource constrained fuzzy project-scheduling problem.

Singh and Tong (2005) stated that contractor selection in a multi-criteria environment is largely dependent upon the uncertainty inherent in the nature of construction projects and subjective judgment of decision makers. For this reason, they used a systematic procedure, based on FST, to evaluate the capability of a contractor to deliver the project as per the owner's requirements. The notion of Shapley value was used to determine the global value or relative importance of each criterion in accomplishing the overall objective of the decision-making process.

Zheng and Ng (2005) believed that by incorporating the concept of fuzzy sets, managers and planners can represent the range of possible time-cost values and their associated degree of belief. They claimed that this model can support decision makers in analyzing their time-cost optimization decision in a more flexible and realistic manner.

Oliveros and Fayek (2005) developed a fuzzy logic model that integrates daily site reporting of activity progress and delays, with a schedule updating and forecasting system for construction project monitoring and control. This model can help with the analysis of the effects of delays on a project's completion date because the use of fuzzy logic allows linguistic and subjective assessments to be made, and thereby suiting the actual practices commonly used in the construction industry.

Sánchez et al. (2005) developed a fuzzy set-based approach for representing and synthesizing information about the various kinds of variables involved in the evaluation of a project's value in the context of construction in civil engineering. This methodology for summarizing and normalizing values aims at contributing to decision-making analysis in the context of multiple-criteria evaluation and group decision making.

Morote and Vila (2011)-presented a risk assessment methodology based on the Fuzzy Sets Theory, which is an effective tool to deal with subjective judgement, and on the Analytic Hierarchy Process (AHP), which is used to structure a large number of risks. The proposed methodology incorporates knowledge and experience acquired from many experts, all of these factors are expressed by qualitative scales which are defined by trapezoidal fuzzy numbers to capture the vagueness in the linguistic variables. An illustrative example on risk assessment of a rehabilitation project of a building is used to demonstrate the proposed methodology.

Ingle, *et al.* (2011)- reported the methodology to solve risk analysis problems with the purpose of determining the project's attractiveness. The model presented in this paper was developed using fuzzy logic and designed for the software development industry. Fuzzy logic was used since it is a tool capable of modeling complex and uncertain or vague data using simple terminology such as IFTHEN statements.

Rezakhani (2011)-described the development of a risk analysis model to assess the risk associated with construction project. At the end of the paper, the proposed model is used to assess the associated risk with the construction operations based on the evaluations of three evaluators. The results arrived from this model indicate a systematic and effective way of risk analysis.

Sarkar and Dutta (2011)-discussed a method of measurement of project risk, based on the expected value method (EVM). Project risk management primarily comprises cost and schedule uncertainties and risks associated with each activity of the project network. They identified the major risk sources and quantified the risks in terms of likelihood, impact and severity in a complex infrastructure project for the construction of an underground corridor for metro railways.

Ossama et al (2013)-proposed a process of risk assessment is about risk quantification and determining appropriate controls. The issue under this study is the application of Fuzzy Logic to develop a Fuzzy Model to enhance the risk assessment process which is dealing with uncertainties that arise in each phase of the risk assessment process.

Yue (2014)-Author thoroughly discussed the project cost risk determinants, and to analyze the formation stage of construction project cost risk, building construction project cost risk management mechanism. Author through the study of optimal allocation of resources based on the cost of construction projects planned application of limited resources to proactively investigate the optimal allocation of project cost plan by early in the project development, the rational allocation of resources, and the cost of the construction project for effective risk prevention.

Banaitiene et al (2011) presents a research in area of construction projects. The aim of the research is to discover how construction companies perceive the significance of the construction projects risks they face and the extent to which they employ potential risk responses. Zhang and Li (2011) presents the use of fuzzy mathematical theory and gray relational analysis method in the risk evaluation of construction project.

Jayasudha et al (2014)-initiated in complex and dynamic problems resulting in circumstances of high uncertainty and risk, which are compounded by demanding time and cost constrains. The general methodology is to study risks largely on the survey questionnaire which will be collected from the various bridge project construction contractors and project manager of different sizes by mail or personnel meeting. The responses were analyzed like bar charts were subjected to using the software of SPSS. They also suggested Risk is a multi-faucet concept. in the context of construction industry, it could be the likelihood of the occurrence of a definite event/factors which occur during the whole process of construction to determine the project a lack of predictability about structure outcome or consequences in a decision or planning situation, the uncertainty associated with estimates of outcomes-there is a chance that results could be better than expected as well as worse than expected etc.

Construction projects tends to be subjected to the external risk such as unawareness of the social conditions, economic and political scenarios, unknown and new procedural formalities, regulatory framework and governing authority, etc. The main objective is to remove as much as possible the potential impact and to increase the level of control of risk. The more control of one mitigation measure on the risk the more effective the measure is the process of risk management does not aim to remove completely all risks from a project. Its objective is to develop an organized framework to assist decision makers to manage the risks, especially the critical ones, effectively and efficiently.

Siddhappa et al. (2016)-The authors report the methodology to solve risk analysis problems related to Construction industry with the purpose of determining the project's attractiveness. The literature presented in this paper is related with use of fuzzy logic risk analysis of construction projects. This logic is perfect to deal with the uncertainty risk plays in a projects development. This methodology provides a quick and efficient tool for project managers in their use of project evaluation, by allowing the project manager to scrap useless projects without putting the least amount of effort into an analysis.

Singh et al (2017)- stated that risk management in a project encompasses the identification of influencing factors which could negatively impact the cost schedule or quality objectives of the project, quantification of the associated impact of the potential risk and implementation of measures to mitigate the potential impact of the risk. The riskier the activity is, the costlier will be the consequences in case a wrong decision is made. Proper evaluation and analysis of risks will help decide justification of costly measures to reduce the level of risk. Some risks such as natural disasters are virtually unavoidable and effect many people.

A risk is defined as the potential for complications and problems with respect to the completion of a project and the achievement of a project goal and as an uncertain future event or condition with the occurrence rate of greater than 0% but less than 100% that has an effect on at least one of project objectives (i.e., scope, schedule, cost, or quality, etc.). In addition, the impact or consequences of this future event must be unexpected or unplanned (Chia, 2006). It is well accepted that risk can be effectively managed to mitigate its' adverse impacts on project objectives, even if it is inevitable in all project undertakings. The source of risk includes inherent uncertainties and issues relative to company's fluctuating profit margin, competitive bidding process, weather change, job-site productivity, the political situations, inflation, contractual rights, and market competition, etc.

2.3 Summary

The review of literature has highlighted that use of Fuzzy Logic in Risk Management is increasing manifold. It has proved to be a promising development tool for the Risk Assessment in Construction industry. Fuzzy Logic proves to be of great use to resolve every Risk involved in a construction project.

The fuzzy logic is quite tedious if performed manually, but if it is done by using some soft computing techniques, it becomes an easy task and the time for risk analysis can be reduced to a large extent. Project managers can predict the overall risk of the project before starting the implementation. The fuzzy risk analysis provides a systematic, efficient and a more natural way to analyse the associated risks. Evaluators can just use the risk evaluation check list and the linguistic terms to evaluate the project risk level.

Chapter 3

Methodology

3.1 General

Risk management is the systematic process of identifying, analysing and responding to project risk. It includes maximizing the probability and consequences of positive events and minimizing the probability and consequences of adverse events to project objectives. Generally, risk is a choice in an environment rather than a fate. It is uncertainty inherent in plans and possibility of something happening that can affect prospects of achieving, business or project goals. The money spend fund shipments overseas was the first example of risk business in the early days of travel. Each and every activity we do involve risk, only the amount of risk varies.

Risk is defined as "a situation where there exists no knowledge of its outcomes". In Macquarie dictionary, it is defined as "Exposure to the change of injury or loss; a hazard or dangerous chance, to run risks". In general, "Every risk is proportional to the expected losses which can be caused by a risky event and to the probability of this event".

3.2 Risks associated with the construction industry are categorized into:

a. **Technical risks**:

- Inadequate site investigation
- Incomplete design
- Appropriateness of specifications
- Uncertainty over the source and availability of materials.

b. **Logistical risks:**

- Availability of sufficient transportation facilities
- Availability of resources-particularly construction equipment spare parts, fuel and labor.

c. **Management related risks:**

- Uncertain productivity of resources
- Industrial relations problems.

d. **Environmental risks**:

- Weather and seasonal implications
- Natural disasters

e. **Financial risks:**

- Availability and fluctuation in foreign exchange
- Delays in Payment
- Inflation
- Local taxes
- Repatriation of funds

f. **Socio-political risks**:

- Constraints on the availability and employment of expatriate staff
- Customs and import restrictions and procedures
- Difficulties in disposing of plant and equipment
- Insistence on use of local firms and agents

It is important for the construction companies to face these uncertain risks by assessing their effects on the project objectives because a risk quantitative method allows deciding which of the project is riskier, planning for the potential sources of risk in each project, and managing each source during construction. It is noteworthy that risk is distinguished from uncertainty. The one is measurable uncertainty; the other is immeasurable risk.

Construction projects with large investment, long construction period, involving a wide range, complex technology, encountered many risks in the process of development. The biggest risk is cost risk. The cost of fluctuations, directly affect the enterprise management decision, should cause the attention of all stakeholders. Construction project cost is determined the basic cost in the framework of the planning and design. In the forming process of the cost will be adjusted, each risk will bring the cost fluctuation.

3.3 Quantitative Risk Analysis

A quantitative risk analysis is a further analysis of the highest priority risks during which a numerical or quantitative rating is assigned in order to develop a probabilistic analysis of the project. A quantitative analysis:

- Quantifies the possible outcomes for the project and assesses the probability of achieving specific project objectives
- Provides a quantitative approach to making decisions when there is uncertainty
- Creates realistic and achievable cost, schedule or scope targets

In order to conduct a quantitative risk analysis, you will need high-quality data, a well-developed project model, and a prioritized lists of project risks (usually from performing a qualitative risk analysis). Fig 3.3 shows a flow chart of quantitative risk analysis process.

The quantitative risk analysis process aims to numerically analyze the probability of each risk and its consequences on the project objectives as well as the extent of overall project risk. This process uses such techniques as 'Monte Carlo' simulation and decision theory to:

- Determine the probability of achieving a specific project objective;
- Quantify the risk exposure for the project and determine the size of cost and schedule contingency reserves that may be needed;
- Identify the risks which require the most attention by quantifying their relative contributions to project risk;
- Identify realistic and achievable costs, schedule, or scope of work targets.

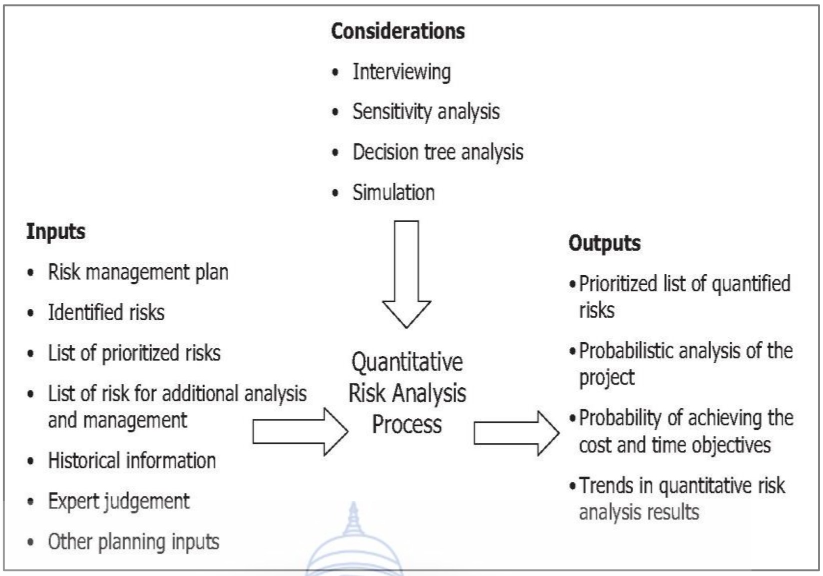


Figure 3.1 Quantitative Risk Analysis Process

Table 3.2 shows the difference between the qualitative and quantitative risk analysis process.

Table 3.1 Summary

Qualitative	**Quantitative**
Risk-level	Project-level
Subjective evaluation of probability and impact	Probabilistic estimates of time and cost
Quick and easy to perform	Time consuming
No special software or tools required	May require specialized tools

3.4 Methods used in quantitative analysis:

Many ways have been proposed to determine the risk. Below is a list of methods that appear in project management literature:

3.4.1 Heuristic Methods

Heuristic methods use experience-based or expert-based techniques to estimate contingency; these include:

1. Percentage of Total Values (Moselhi, 1997);
2. Predetermined Guidelines (Hollmann *et al.*, 2012);

3. Controlled Interval and Memory (Chapman and Cooper, 1983, MacDonald and Chapman, 1985)
4. Case-based Reasoning Model (Kim and Kang, 2004).

3.4.2 Expected Value Methods

Expected value methods multiply the probability of a risk by the maximum time/cost exposure of the risk to obtain a contingency value; these methods include:

1. Method of Moments (Moselhi, 1997)
2. Expected value of individual risks (Mak, *et al.*, 1998).

3.4.3 Probability Distribution Methods

Probability distribution methods base the calculation of contingency on predefined statistical distributions; these include:

1. Monte Carlo Simulation (Kwak and Ingall, 2007, Whiteside, 2008)
2. Range Estimating (Curran, 1990, Humphreys *et al.*, 2008).

3.4.4 Mathematical Modelling

Mathematical modelling methods use theoretical mathematical models to determine contingency values. These models typically make use of both linear and non-linear equations, and include:

1. Artificial Neural Networks (Günaydın and Doğan, 2004, Kim *et al.*, 2004)
2. Fuzzy Sets (Nieto-Morote and Ruz-Vila, 2011, Paek, *et al* 1993).

3.4.5 Interdependency Models

Interdependency models use the logical and resource constrained dependencies between activities to determine contingency; these methods include:

1. Influence Diagrams (Diekmann and Featherman, 1998);
2. Theory of Constraints (Leach, 2003)
3. Analytical Hierarchy Process (Dey, *et al*, 1994, Kang *et al* 2007).

3.4.6 Empirical Methods (Benchmarking)

Empirical methods use historical projects to determine factors that drive risk. These factors are then applied to prospective projects to determine the contingency-based characteristics that are shared with the historical projects; these methods include:

1. Regression (Lowe et al 2006, Williams, 2003)
2. Factor Rating (Hollmann, 2012, Trost and Oberlender, 2003).

This project uses mathematical modelling (Fuzzy logic) for risk assessment.

3.5 Procedure for Project Risk Assessment

With all the components, a fuzzy logic system can be built in the following steps shown in Figure 4.9:

Step 1. Independent variables are selected as the key determinants or indicators of the dependent variable.

Step 2. Fuzzy sets are created for both independent and dependent variables. Instead of using the numerical value, fuzzy sets in terms of human language are used to describe a variable. The degree of truth that each variable belongs to a certain fuzzy set is specified by the membership function.

Step 3. Inference rules are built in the system. A fuzzy hedge may be used to tweak the membership function according to the description of the inference rules.

Step 4. The output fuzzy set of the dependent variable is generated based on the independent variables and the inference rules. After defuzzification, a numerical value may be used to represent the output fuzzy set.

Step 5. The result is then used for informed decision-making.

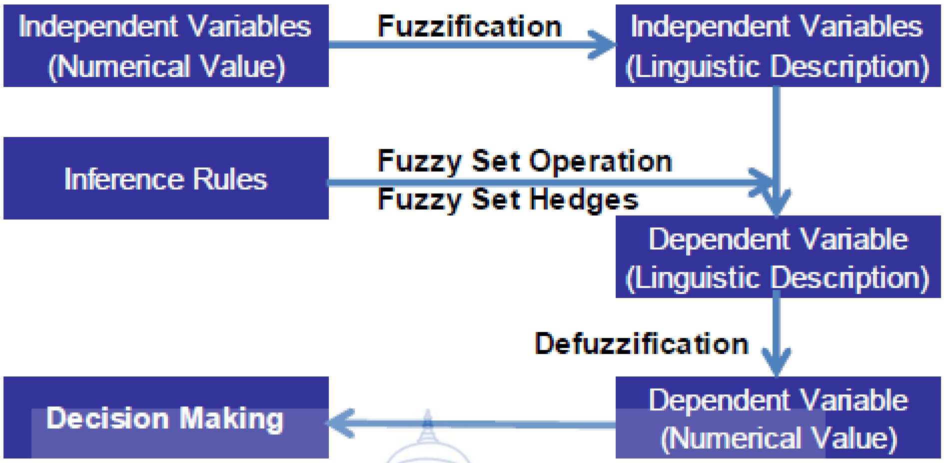


Figure 3.2 Fuzzy logic system (Zadeh, 1965)

3.6 Detailed methodology of Experimental program:

The particulars of the tools used in the present investigation along with the methodology of investigation are described in this section.

In this Experimental Work, the proposed methodology utilizes the Fuzzy logic to measure the certainty or uncertainty of how much the element belongs to the set. By means of fuzzy logic it is possible to find the solution of given task from rules, which were defined for analogous tasks. The calculation of fuzzy logics consists of three basic steps: fuzzification, fuzzy inference and defuzzification as shown in Figure 4.10

1. Fuzzification – transforms real variables to linguistic variables using their attributes. The variable has five attributes. The attribute and membership functions are defined for input and output variables. The degree of membership of attributes is expressed by mathematical function. A fuzzy set is a set whose elements have degrees of membership. Fuzzy set was introduced as an extension of the classical notion of set and can be applied in many fields of human activity (Zadeh, 1965). Fuzzy set determines “how much” the element belongs to the set. This is the basic principle of fuzzy set. A fuzzy set is defined following:

$$A = [x / \mu A(x)] \tag{1}$$

Where, A = fuzzy set, $\mu A(x)$ = a membership value between zero and one, and x = an element of universe X. In order to make it simple, x can be defined as a scale element between zero and hundred, which in this study is figured out as the degree, from lower to higher, of uncertainty.

2. Fuzzy inference – defines the behavior of system by using of rules of type <When>, <Then> on linguistic level. Conditional clauses typically have the following form: <When> [Input a1 <And> Input a2<And> ... <And> Input an] < And > [Input b1 <And> Input b2 <And> ... <And> Input bm] <Then> Output 1. Each combination of attributes of input and output variables, occurring in condition <When>, <Then>, presents one rule. The rules are created by the user.

3. Defuzzification – transfers the results of fuzzy inference (numerical values) on output variables by linguistic values. It describes results verbally. The system with fuzzy logic works as an automatic system. The user must enter input data only. The ouput is received by generating an executable file called M-file in the MATLAB software. When the M-file is run the output is generated.

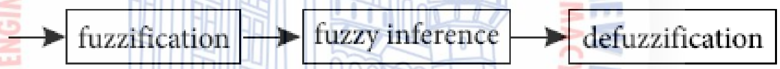


Figure 3.3 Decision-making solved by fuzzy processing

Chapter 4

Concept of Risk and Fuzzy Logic

4.1 General

There are two methods to determine risks in a project, namely the qualitative and quantitative approach. The quantitative analysis relies on statistics to calculate the probability of occurrence of risk and the impact of the risk on the project. The most common way of employing quantitative analysis is to use decision tree analysis, which involves the application of probabilities to two or more outcomes. Another method is Monte Carlo simulation, which generates value from a probability distribution and other factors.

The qualitative approach relies on judgments and it uses criteria to determine outcome. A common qualitative approach is the precedence diagramming method, which uses ordinal numbers to determine priorities and outcomes. Another way of employing qualitative approach is to make a list of the processes of a project in descending order, calculate the risks associated with each process and list the controls that may exist for each risk.

It is important for the construction companies to face these uncertain risks by assessing their effects on the project objectives because a risk quantitative method allows deciding which of the project is riskier, planning for the potential sources of risk in each project, and managing each source during construction. It is noteworthy that risk is distinguished from uncertainty. The one is measurable uncertainty; the other is immeasurable risk.

4.2 Concept of Risk and Risk Management

The following are the several factors of risk exposure:

- **Team size**: the larger the team, the higher the probability of a problem arising. For example, communications can be more difficult as the number of participants increases. The number of interactions among people increases and thus they require greater coordination.
- **History**: newer projects are riskier because the processes have not been refined. The more times a project of a similar nature has been done, the greater the likelihood of success.
- **Staff expertise and experience**: if the staff lacks direct experience and knowledge of the subject, people will struggle to learn as they go along, robbing the project of time and possibly introducing errors.
- **Complexity**: the more sophisticated a project, there is a greater the opportunity of a mistake or problem.
- **Management stability**: management stability implies unity of direction, which in turn means reaching goals. Management irritability can lead to unrealistic scheduled and insufficient use of resources.
- **Time compression**: if a schedule is highly compressed, then the risks are magnified. Having more times means greater flexibility and the opportunity to prevent or mitigate the impact of errors.
- **Resource availability**: the more resources that are available, the greater the ability to respond to problem as they arise. Plentiful resource, of course, do not guarantee protection from risk; however, they do provide the means to respond to it.

The concept of risk is multi-dimensional. In the context of construction industry, the probability that a definite factor detrimental to the overall project occurs is always present. A lack of predictability related to the consequences of a planning situation and the associated uncertainty of estimated outcomes leads to the consequence that results can either be better than expected or can be worse. In addition to the different definitions of risks, risks can be categorized for different purposes as well. The broad categories of construction risks are external risks and internal risks; while some other categories curtail risks as political, social and safety risk etc.

4.3 Risk Classification

There are many suggestions for classifying risks of construction projects, which, however, reflect different underlying concepts and conclusions and, therefore, cannot be universally accepted. Apart from the nature and timing of occurrence criteria, there are many other criteria sets used for risk classification such as the mitigation measures for a risk (Bing and Tiong 1999, Hastak and Shaked 2000) or systemic criteria such as internal, project-specific, and external risks for a construction project (Bing et al. 1999, Aleshin 2001). A critical observation is that all these approaches focus on a specific aspect of risk, which is used as the criterion for the classification; this criterion would be the nature of the risk or the timing of occurrence or the mitigation measures used, etc. This leaves outside of consideration other aspects that may be of significant importance. The classification approach already discussed above merges two different criteria for classifying risks: (a) according to the source of origin in the project's context and (b) according to their nature. Therefore, when a risk is introduced as a variable in risk assessment, it bears concurrently more than one facets (i.e., nature and source of origin), thus increasing the accuracy of the assessment. Three main categories were identified, according to the criterion of the risks' nature, namely financial, technical, and legal, and five categories, according to the criterion of source of origin for each risk in the project's framework, namely state-rooted, Risks concessionaire-rooted, market-rooted, contract package-rooted, and miscellaneous. Table 3.1 shows the risk events and conditions associated with different project elements.

Table 4.1 Risk events and conditions

Project Element	Risk Events	Risk conditions
Management Integration	Incorrect start of integrated PM relative to project life cycle.	Inadequate project planning, integration or resource allocation, inadequate or lack of post project review.
Information Management	Inaction or wrong action due to incorrect information or communication failure.	Carelessness in communicating. Improper handling of complexity. Lack of adequate consultation with project's "publics" (internal/external).
Human Resources	Strikes, terminations, organizational breakdown.	Conflict not managed. Poor organization, definition or allocation of responsibility, or otherwise absence of motivation. Poor use of accountability. Absence of leadership, or vacillating management. Consequences of ignoring or avoiding risk.
Procurement Management	Contractor insolvency. Claims settlement or litigation.	Unenforceable conditions/clauses. Incompetent or financially unsound workers/contractors. Adversarial relations. Inappropriate or unclear contractual assignment of risk.
Cost Management	Impacts of accidents, fire, theft. Unpredictable price changes.	Estimating errors, including estimating uncertainty. Lack of investigation of predictable problems. Inadequate productivity, cost or change control. Poor maintenance, security, purchasing, etc.
Scheduling	Specific delays, e.g., strikes, labor or material availability, extreme weather, rejection of work.	Errors in estimating time or resource availability. Poor allocation and management of float. Scope of work changes without due allowance for time extensions/acceleration. Early release of competitive product.
Quality Management	Performance failure, or environmental impact.	Poor attitude to quality. Substandard design/materials/workmanship. Inadequate quality assurance program.
Scope	Changes in scope to meet project objectives.	Inadequacy of planning, or planning lead time. Poor definition of scope breakdown, or work packages. Inconsistent, incomplete or unclear definition of quality requirements. Inadequate scope control during implementation.

PMBOK (Version 2008) defines risk classification as a provider of a structure that ensures a comprehensive process of systematically identifying risks to a consistent level of detail and contributes to the effectiveness and quality of the risks process identification. Risk classification is an important step in the risk assessment process, as it attempts to structure the diverse risks that may affect a project. There are many approaches in literature for construction risk classification. Perry and Hayes (1985) give an extensive list of factors assembled from several sources, and classified in terms of risks retainable by contractors, consultants and clients.

Abdou (1996) classified construction risks into three groups, i.e. construction finance, construction time and construction design. Shen (1997) identified eight major risks accounting for project delay and ranked them based on a questionnaire survey with industry practitioners. Tah and Carr (2000) classified project risks by using the hierarchical risk breakdown structure (HRBS) and classified them into internal and external risks. Chapman (2001) grouped risks into four subsets: environment, industry, client and project. Shen (2001) categorized them into six groups in accordance with the nature of the risks, i.e. financial, legal, management, market, policy and political. Chen *et al*. (2004) proposed 15 risks concern with project cost and divided them into three groups: resource factors, management factors and parent factors. Assaf and Al-Hejji (2006) mentioned the risk factors as the delay factors in construction projects. Dikmen *et al*. (2007) used influence diagrams to define the factors which have influence on project risks. Zeng *et al*. (2007) classified risk factors as human, site, material and equipment factors.

4.4 Risk Breakdown

By summarizing and merging some of the above risk factors, following Fig: 3.1 hierarchical risk breakdown structure for construction projects is proposed. Construction project risk is divided into five categories. External, operation, project management, engineering, financial. There are seven number of sub risks under external risks (i.e. four sub risks under external and three under costumer) namely weather, market, low culture and government, costumer, risk altitude, experience and tricky decision. There are ten sub risks under operation (i.e. four sub risks under operation, six sub risks under contractor) namely safety, unavailability of resources, unforeseen site conditions, contractor, experience, manpower, cash flow, training, communication. There are six sub risks under project management namely technical and managerial complexity, planning and controlling, project team selection, decision making, communication and unavailability of resources. There are five sub risks under engineering namely construction method vagueness, scheduling, design errors and changes, productivity, documents not issued on time. There are five sub risks under financial namely delayed payment to contractors, contractor's financial conditions, inflation, funding, financial assessment.

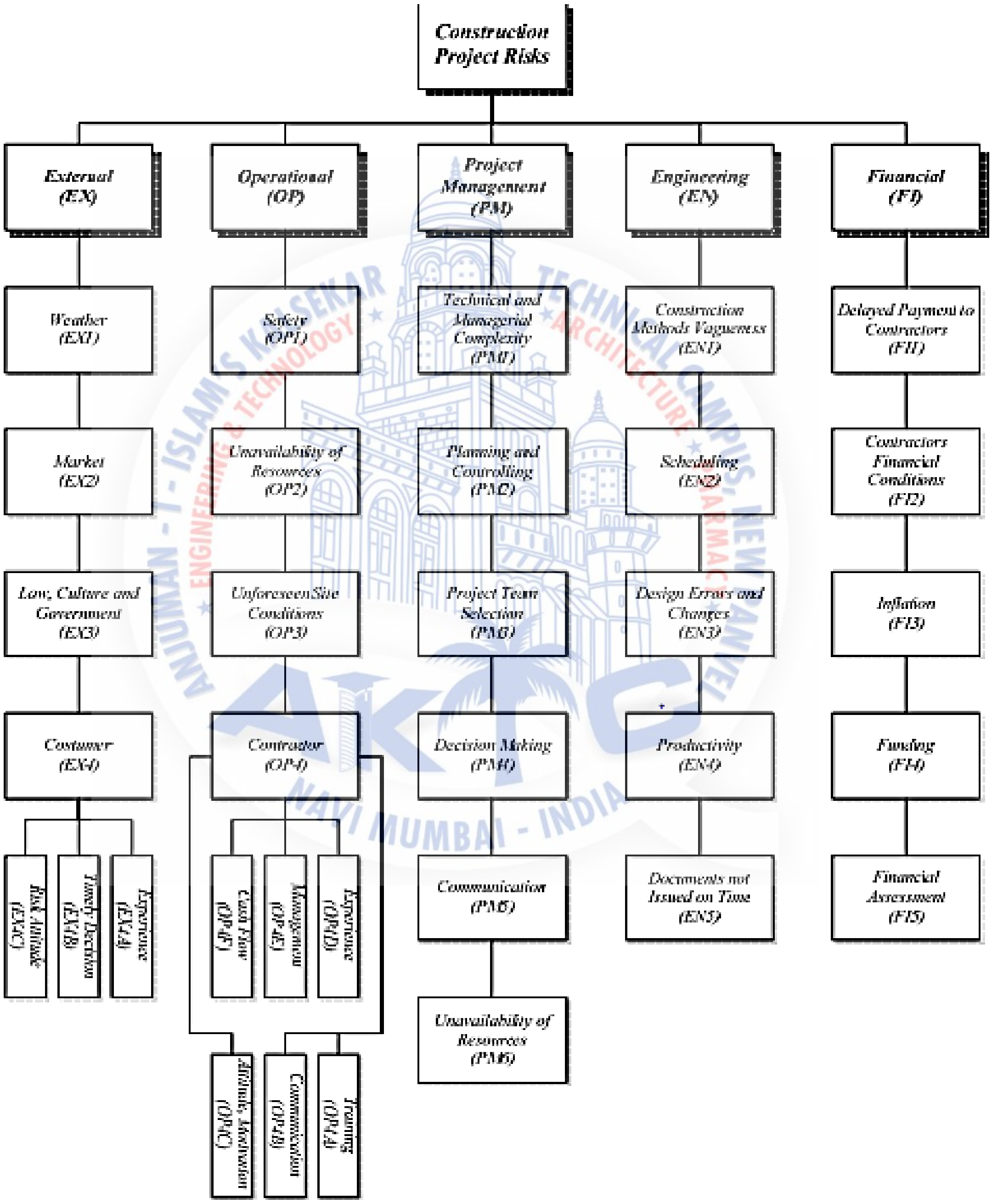


Figure 4.1 Risk breakdown structure

4.5 Basics of fuzzy set theory and fuzzy logic

In classical set theory, an individual object is either a member or a non-member of a set. However, in reality, due to insufficient knowledge or imprecise data, it is not always clear whether an object belongs to a set or not. In contrast, fuzzy sets interpret uncertainty in an approximate way. Conceptually, fuzzy set theory allows an object belonging to multiple exclusive sets in the reasoning framework. For each set, there is a degree of truth that an object belongs to a fuzzy set. Take Risk X as an example. Assume there are three levels of the Risk: low, average and high, which can be considered as three sets. Based on classical set theory, the full set is composed of these three exclusive sets. Once the Risk X is known, the level of the risk is determined. Figure 4.1 shows an example of classical sets for Risk X. With a value of 3.5, it is 100 percent true that the Risk X is high.

Risk X

Figure 4.2 Classical Set Example: Risk X (Shang and Hossen, 2013)

Figure 4.2 shows an example of fuzzy sets for Risk X. Each set has its own membership function, which determines the degree of truth that an element belongs to the set. For example, with a value of 3.5, it is 60 percent true that the risk is high and 22 percent true that it is average. It is false that the risk is low. In fuzzy logic theory, the degrees of truth for all sets do not necessarily add up to one for a specific object.

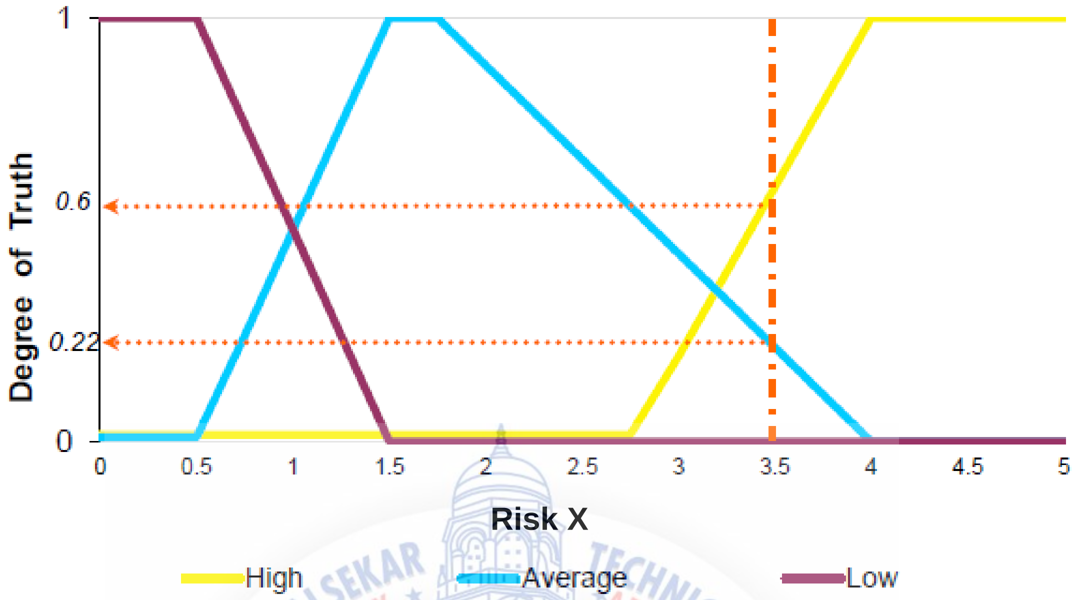


Figure 4.3 Fuzzy Set Example (Shang and Hossen, 2013)

4.6 Membership Function

The difference between traditional set and fuzzy set theory lies in the degree of membership which elements may possess in a set. Traditional set theory dictates that an element is either a member of a set or it is not; it's membership values are defined as 1 or 0. In fuzzy set theory this membership value can take any real value from 0 to 1 and this value defines the degree of membership of a given set.

A membership function is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1. The only condition a membership function must really satisfy is that it must very between 0 and 1. There are so many membership functions which can be used. Some of them are Triangular, Trapezoidal, Gaussian, Generalized Bell, Z Curves, etc.

In this example, the membership functions for the three sets are specified as below.

$$\mu^{High}(x) = \begin{matrix} 0 & x \leq 2.75 \\ (x - 2.75)/1.25 & 2.75 < \boldsymbol{x} \leq 4 \\ 1 & x > 4 \end{matrix}$$

$$\mu^{Average}(x) = \begin{matrix} 0 & x \leq 0.5 \\ (x - 0.5)/1 & 0.5 < x \leq 1.5 \\ 1 & 1.5 < x \leq 1.75 \end{matrix}$$

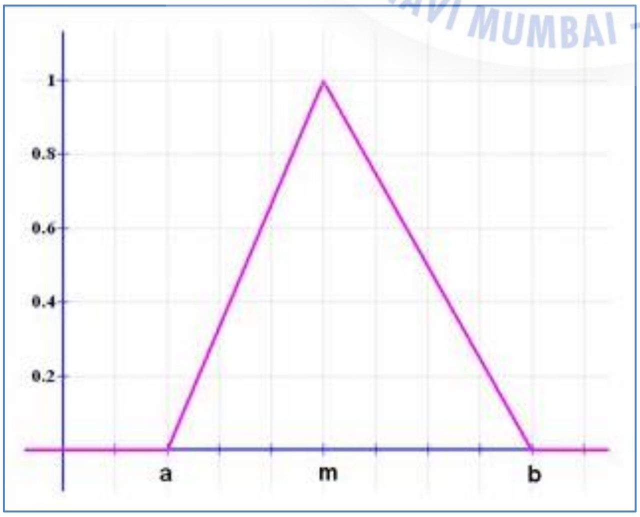
$$
\begin{array}{cc}
(4 - x)/2.25 & 1.75 < x \leq 4 \\
0 & x > 4
\end{array}
$$

$$
\mu^{Low}(x) = \begin{array}{cc}
1 & x \leq 0.5 \\
(1.5 - x)/1 & 0.5 < x \leq 1.5 \\
0 & x > 5
\end{array}
$$

A key feature of fuzzy sets is that there are no hard rules about how their membership functions are defined. Both the mathematical form of the function and the parameters depend on the input from the experts. As long as the membership functions are consistent, on a comparative basis, the conclusion based on fuzzy sets is still meaningful. For example, the degree of truth for a risk X of value 4 belonging to fuzzy set “High” should be no less than that for a value of 3. And only one of the membership functions may be strictly increasing for a certain range of risk X. It may be conflicting if the degree of truth for a value of 4 belonging to fuzzy set “High” is greater than that for a value of 3 while the degree of truth for a value of 4 belonging to fuzzy set “Average” is greater than that for a value of 3 at the same time.

Figure 4.3, Figure 4.4, Figure 4.5 shows the triangular, trapezoidal and Gaussian membership function respectively.

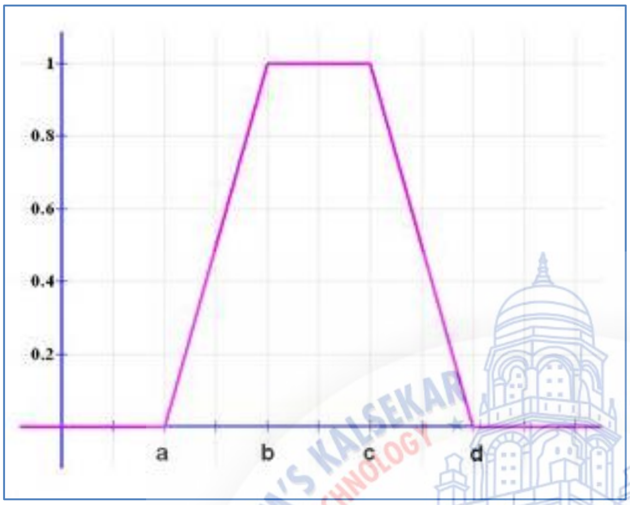
Triangular function: defined by a lower limit a, an upper limit b, and a value m, where a < m



$$
\mu_A(x) = \begin{array}{cc}
0 & x \leq a \\
\dfrac{(x-a)}{(m-a)} & a < x \leq m \\
\dfrac{(b-x)}{(b-m)} & a < x \leq m \\
0 & x \geq b
\end{array}
$$

Figure 4.4 Triangular function (Shang and hossen 2013)

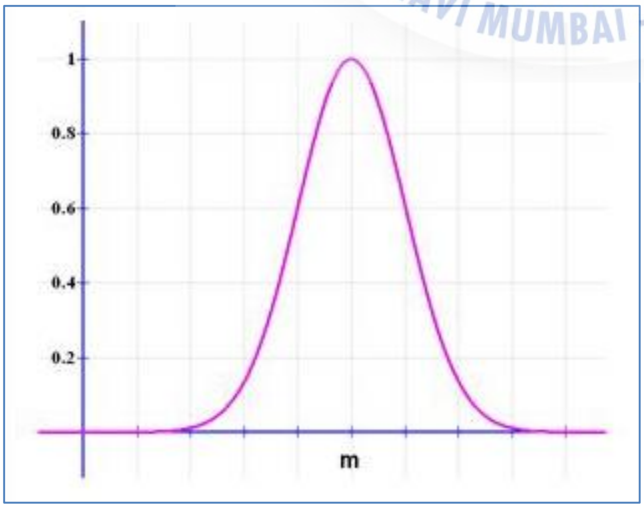
Trapezoidal function: defined by a lower limit a, an upper limit d, a lower support limit b, and an upper support limit c, where a < b < c < d.



$$\mu_A(x) = \begin{cases} 0 & (x < a) \text{ or } (x > d) \\ \dfrac{(x-a)}{(b-a)} & a \le x \le b \\ 1 & b \le x \le c \\ \dfrac{(d-x)}{(d-c)} & c \le x \le d \end{cases}$$

Figure 4.5 Trapezoidal function (Shang and hossen 2013)

Gaussian function: defined by a central value m and a standard deviation k > 0. The smaller k is, the narrower the "bell" is.



$$\mu_A(x) = e^{-(x-m)^2}/2k^2$$

Figure 4.6 Trapezoidal function (Shang and hossen 2013)

4.7 Fuzzy Sets Operation:

As in classical set theory, fuzzy sets have their own operations such as union, intersection and complement. Different from the operation on classical sets, the operations on fuzzy sets are based on the membership function. Figure 4.6 shows the operation on classical sets. Figure 4.7 shows one possible type of operation on fuzzy sets.

Figure 4.7 Operations on Classical Sets

	$A \cup B$	$A \cap B$	A'
	$\{x, y, z\}$	$\{y\}$	$\{z\}$
x	$1 \cup 0 = 1$	$1 \cap 0 = 0$	$1 - 1 = 0$
y	$1 \cup 1 = 1$	$1 \cap 1 = 1$	$1 - 1 = 0$
z	$0 \cup 1 = 1$	$0 \cap 1 = 0$	$1 - 0 = 1$

$Where$

$1 : \in$ $\quad e.g. x \in A$

$0 : \notin$ $\quad e.g. x \notin A$

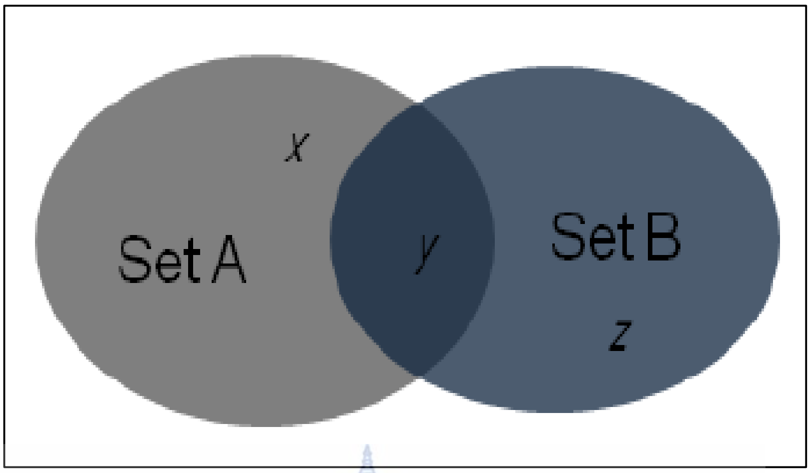


Figure 4.8 Operation on Fuzzy sets

$$\mu_A(x) = 0.5 \quad \mu_B(x) = 0.1$$
$$\mu_A(y) = 0.6 \quad \mu_B(y) = 0.4$$
$$\mu_A(z) = 0.1 \quad \mu_B(z) = 0.7$$

	$A \cup B = \max(\mu_A, \mu_B)$	$A \cup B = \max(\mu_A, \mu_B)$	$A' = 1 - \mu_A$
x	0.5	0.1	0.5
y	0.6	0.4	0.4
z	0.7	0.1	0.9

In this example, a max-min rule is used. The degree of truth that an element belongs to the union of some fuzzy sets is the maximum of the degrees of truth that the element belongs to each of the fuzzy sets. The degree of truth that an element belongs to the intersection of some fuzzy sets is the minimum of the degrees of truth that the element belongs to each of the fuzzy sets. The degree of truth that an element belongs to the complement of a fuzzy set is one deducted by the degree of truth that the element belongs to the fuzzy set.

4.8 Inference Rules and Fuzzy Hedges

With logical operations on fuzzy sets, inference rules can be built to establish the relationship among different variables. One type of fuzzy inference rule is called the max-min inference rule. It is the max-min rule shown in Figure 4.8 applied to inference.

1. *If A and B, then C.*

The maximum degree of truth for C is the lesser of the degree of truth for A and that for B.

2. *If A or B, then C.*

The maximum degree of truth for C is the greater of the degree of truth for A and that for B.

3. *If not A, then C.*

The maximum degree of truth for C is one deducted by the degree of truth for A.

For example, when assessing the risk of unavailability of materials, late delivery and availability of vendor are the two associated risks. A possible inference rule is given below.

If the late delivery risk is small and availability of vendor risk is low, the risk of unavailability of materials in the near future is high.

The risk of late delivery is 2 percent with a degree of truth μ small (2 percent) of 0.6. The risk of availability of vendor index value is 65 with a degree of truth μ low (65) of 0.72. Using the intersection operation on fuzzy sets as the minimum of the two degrees of truth μ small (2 percent) and μlow (65), the maximum degree of truth that there is a high risk of economic downturn is 0.6. The resulting fuzzy set membership function is truncated at the true value of 0.6 from the top, as shown in Figure 4.8.

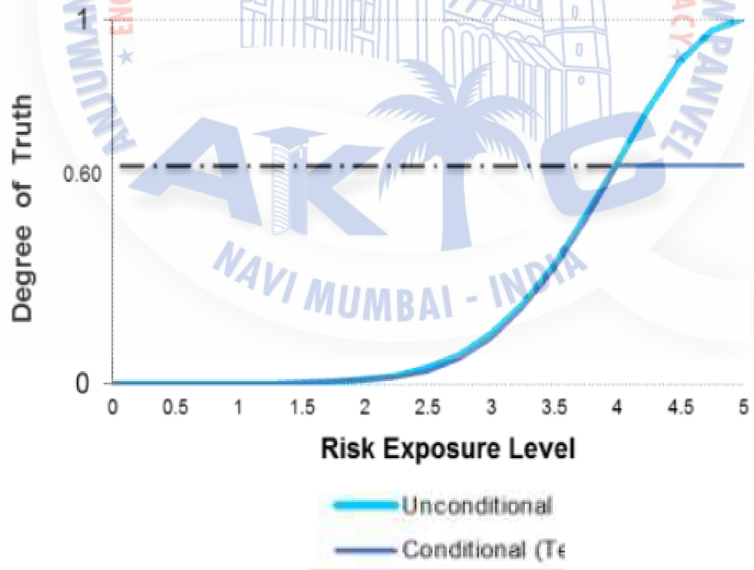


Figure 4.9 Fuzzy Inference Rules (shang and Hossen 2013)

4.8.1 Natural language representation

The risk assessment process requires an assessment of the probability or likelihood of the risk and impact. The assessment of the level of risk is a complex subject shrouded in uncertainty and vagueness. Risk severity should be considered in terms that are as close as possible to the corporate objectives at the time of assessment. A simple approach that is advocated by some risk experts is to multiply the severity of the consequence by the likelihood of their occurrence, as the likelihood of the occurrence automatically includes the exposure. Consequently, the key attributes of risks and risk factors are likelihood and severity. Table 4.1 shows customizable standard terms for quantifying likelihood.

Table 4.2 Customizable standard terms for quantifying likelihood

Likelihood	Description
Very very likely	Expected to occur with absolute certainty
Very likely	Expected to occur
Likely	Very likely to occur
Medium	Likely to occur
Unlikely	Unlikely to occur
Very Unlikely	Very Unlikely to occur
Very Very Unlikely	Almost no possibility of occuring

4.9 Defuzzification

Defuzzification is the process of estimating the value of the dependent variable based on the resulting fuzzy set after applying the fuzzy inference rule. Translating the membership degree of fuzzy sets into a particular choice or real value. A process that converts fuzzy terms to conventional expressions quantified by real-valued functions. Three typical defuzzification methods are described below.

1. Average method: The average numerical value of the dependent variable in the output fuzzy set.

2. Average of maximum method: The average numerical value of the dependent variable with the maximum degree of truth in the output fuzzy set.

3. Centroid method: The weighted average numerical value of the dependent variable in the output fuzzy set. The weight is the degree of truth.

Different methods are appropriate in different situations.

4.10 Reasons for using fuzzy risk analysis

PMBOK Guide defines risk as a measure of the probability and consequence of not achieving a defined project goal. Risk has two primary components for a given event: · A probability of occurrence of that event. Impact (consequence) of the event occurring consequently the risk for each event can be defined as a function of probability and consequence (impact); that is: (PMBOK Guide) Probability theory cannot deal with important aspects of project uncertainty and cannot explain some important aspects of observed project management practice. Following are some limitations of probability theory:

- Probability theory is based on assumption of randomness whereas project deal with consciously planned human actions that are generally not random.
- Uniqueness of project reduces the relevant and reliability of statistical aggregates derived from probability based analysis.
- Probability theory assumes future states are known and definable; however uncertainty and ignorance are inevitable on projects.

The laws of probability apply if certain assumptions are met, including: (Pender, 2001) Knowledge of probable future states:

- Rationality
- Frictionless transactions
- Random events
- Repeatability
- Comparability
- Optimization goal
- Project parameters and outcomes have shades of grey.

Imprecise statements cannot be interpreted within the framework of probability theory because of its assumption of crisp inputs and outputs. The theory of fuzzy sets provides a framework and offers a calculus to address these fuzzy statements. (Zadeh L.A., 1965) states the theory of fuzzy sets as follows:

Fuzzy Logic provides a natural way of dealing with problems in which the sources of imprecision are the absence of sharply defined criteria of class membership rather than the presence of random variables.

The primary reasons for using fuzzy logic risk analysis model are:

- The modelling of vague input is successfully done with the use of membership functions.
- The inherent ability of fuzzy logic systems to explain its reasoning ensures that the modelling process is understood and could also be intuitively verified.
- The parallel nature in which rules are activated in a fuzzy system ensures that all factors are considered in a harmonized manner.

The results of fuzzy systems can naturally be scaled to be comparable with each other, with the use of the scaling membership functions. Fuzzy logic`s use of linguistic sets and rules ensures that the terminology of the user interface and modelling structure can be tailored toward the specific environments. Techniques for risk analysis can be either qualitative or quantitative depending on the information available and the level of detail that is required (Bennett *et al.* 1996). Statistical approach is the main idea for quantitative techniques. Some tools for this technique are Monte Carlo Simulation (White, 1995), Fault and Event Tree Analysis (Bennett *et al.* 1996, White, 1995), Sensitivity Analysis (White, 1995), Annual Loss Expectancy (Rainer, *et al.* 1991), Risk Exposure (Boehm, 1989), Failure Mode and Effective Analysis (White, 1995) etc.

Qualitative techniques rely more on judgment than on statistical calculations such as Scenario Analysis (Rainer *et al* 1991), Fuzzy Set Theory (Rainer, *et al.* 1991). Quantitative techniques can involve significant additional expenses and is only warranted in the rare instance where the assumptions of probability theory apply. Among these techniques, the application of fuzzy set theory to risk analysis seems appropriate; as such analysis is highly subjective and related to inexact and vague information (Ngai and Wat, 2005). In construction research area one of the applications of fuzzy risk analysis is to outline an approach to the assessment of the construction project risk by linguistic analysis.

4.11 Benefits of Fuzzy Logic

The use of fuzzy logic clearly enables a human being to interface easier with an automated system than in the conventional case. This is because human beings more or less have a natural tendency towards uncertainty. Advantages therefore may result in all cases where human beings are involved with systems, be it as a designer or as a user. When a human being is seen as a user, a more natural system interface can be obtained in fuzzy systems. This is because the system can directly communicate with the user via natural language terms.

In the design of systems that are less soft, fuzzy logic can be of assistance because of the fact that in the design of such systems often human knowledge can or must be used. One can think of expert knowledge from humans that already are able to perform tasks that must be automated, like for instance train control, mortgage analysis or target tracking. One can also think of fuzzy knowledge of expert system designers. Mostly, the tasks that can be performed with fuzzy logic can also be done in a non-fuzzy way. The key idea of using fuzzy logic however is that precision is expensive while not always necessary. People for instance are quite good at performing several decision tasks using only non-precise data and generating non precise actions. One of the key reasons why fuzzy logic works well is the fact that many systems do not require very critical tuning. In other words, when parameters are set sub-optimal, the performance will not degrade very much (Shang and Hossen, 2013)

Summarizing, the following benefits can be named:

1. Fuzzy Logic describes systems in terms of a combination of numbers and linguistics (symbols). This has advantages over pure mathematical (numerical) approaches or pure symbolic approaches because very often system knowledge is available in such a combination.
2. Problems for which an exact mathematically precise description is lacking or is only available for very restricted conditions can often be tackled by fuzzy logic, provided a fuzzy model is present.
3. Fuzzy logic sometimes uses only approximate data so simple sensors can be used.
4. The algorithms can be described with little data so little memory is required.
5. The algorithms are often quite understandable.
6. Fuzzy algorithms are often robust, in the sense that they are not very sensitive to changing environments and erroneous or forgotten rules.

7. The reasoning process is often simple, compared to computationally precise systems, so computing power is saved, this is a very interesting feature, especially in real time systems.
8. Fuzzy methods usually have a shorter development time than conventional methods. Although the above named advantages are very promising, one must be aware that fuzzy logic does not fit to every problem. The following remarks must be made:
9. Fuzzy logic amounts to function approximation in the case of Crisp-Input/Crisp-Output systems. This means that in many cases, using fuzzy logic is just a different way of performing interposition in the light of the fact that system knowledge is often available as a combination of numbers (quantitative) and linguistics (quantitative or qualitative) this approach may even be advantageous.
10. In areas that have good mathematical descriptions and solutions, the use of fuzzy logic most often may be sensible when computing power (i.e. time and memory) restrictions are too severe for a complete mathematical implementation.
11. The results obtained in successful fuzzy application, that are given in literature can be reached with a conventional approach as well, possibly taking longer development time and possibly with the use of different interpolation methods. Careful analysis of comparison examples, 'proving' the superiority of fuzzy logic often shows that they compare the fuzzy approach with a very simple, non-optimized conventional approach.
12. Proof of characteristics of fuzzy systems is difficult or impossible in most cases because of lacking mathematical descriptions; especially in the area of stability of control systems this is an important research item.

4.12 Summary

This chapter gives us the brief and clear idea of Fuzzy logic and its use, characteristic's, definition, applications and the overview of the Fuzzy logic to be used further in this work (risk assessment). It also focused on the needs and benefits of the fuzzy logic in the risk assessment and as well as various stake holders connected to the construction project.

Chapter 5

Results and Discussions

5.1 General

Every project in the construction industry includes some sort of risk. These risks can be detrimental to the company, and therefore they must be identified and assessed to determine the impact they may have on the company. In Indian construction industry there is low knowledge about risk assessment. The major reasons for this condition being high cost of software, low demand from clients and lack of skilled or trained employees. The problems, which often occur in terms of the risk analysis are methodology adopted. Most of the methods that are adopted have manual algorithms calculations and it can be very tedious.

The proposed methodology develops a decision making model by using fuzzy logic. The advantage of the fuzzy model is the ability to transform the input variables, The Number of Sub-Risks (NSR) and The Total Value of Sub-Risks (TVSR) to linguistic variables, which helps in the evaluation of the Total Value of Project Risk (TVPR) which is the output variable. With this approach it is possible to simulate the risk value and uncertainty that are always associated with real projects.

The scheme of the model, rule block, attributes and their membership functions are mentioned. The use of fuzzy logic is a particular advantage in decision-making processes where description by algorithms is extremely difficult and criteria are multiplied.

The developed expert decision-making fuzzy model system consists of two input variables with five attributes. The input variables are No. of Sub-Risk (NSR) and Total Value of Sub-Risk (TVSR). The five attributes are Very High (VH), High (H), Medium (M), Low (L), Very Low (VL). And the output variable is Total Value of Project Risk (TVPR) with the same attributes as above. Table 5.1**.** Shows the likelihood of each attribute.

Table 5.1 Customizable standard terms for quantifying likelihood

Likelihood	Description
Very High	Expected To Occur With An Absolute Certainty
High	Expected To Occur
Medium	Likely To Occur
Low	Unlikely To Occur
Very Low	Almost No Possibilty Of Occurenece

Membership function: In fuzzy set theory this membership value can take any real value from 0 to 1 and this value defines the degree of membership of a given set. A membership function is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1.

The only condition a membership function must really satisfy is that it must very between 0 and 1. There are so many membership functions which can e used. Some of them are Triangular, Trapezoidal, Gaussian, Generalized Bell, Z Curves, etc

In this work, the membership functions of the linguistic terms are characterized by Trapezoidal fuzzy numbers. Figure 5.1. Shows the membership function of input variable NSR. This membership fuction names trapmf (trapezoidal-shaped). Syntax of the function is following: y = trapmf(x,[a b c d]). Description of the trapezoidal curve is a function of a vector, x, and depends on four scalar parameters a, b, c, d, as given by:

The parameters a and d locate the "feet" of the trapezoid and the parameters b and c locate the "shoulders". Figure 5.1 denotes trapmf trapezoidal-shaped membership functions. As can be seen from the chart, the function has a value between 0 and 1, which also characterises how much it belongs to a certain fuzzy set.

Figure 5.1 shows the input variable NSR with five attributes (membership functions): *VH – very high, H – high, M – middle, L – low and VL – very low*. Membership function used is of type (*trapmf)* and range [0; 100] to create fuzzy model. The parameters of membership functions are adjusted balanced for each of the variables. The membership function *VH – very high* has the parameters: [–22.5 –2.5 2.5 22.5]. The membership function *H – high* has the parameters: [2.5 22.5 27.5 47.5]. The membership function *M – middle* has the parameters: [27.5 47.5 52.5 72.5]. The membership function *L – low* has the parameters: [52.5 72.5 77.5 97.5]. The membership function *VL – very* low has the parameters: [77.5 97.5 102.5 122.5]. Similarly, the other input variable TVSR and output variable TVPR has the same five attributes and membership function.

Figure 5.1 shows the range of the input variable 1 i.e. number of sub risks is from 0 to 100. And the membership function used is trapezoidal membership function. The parameters of the input variable 1 corresponding to the likelihood (VH) of the risk are shown in the figure.

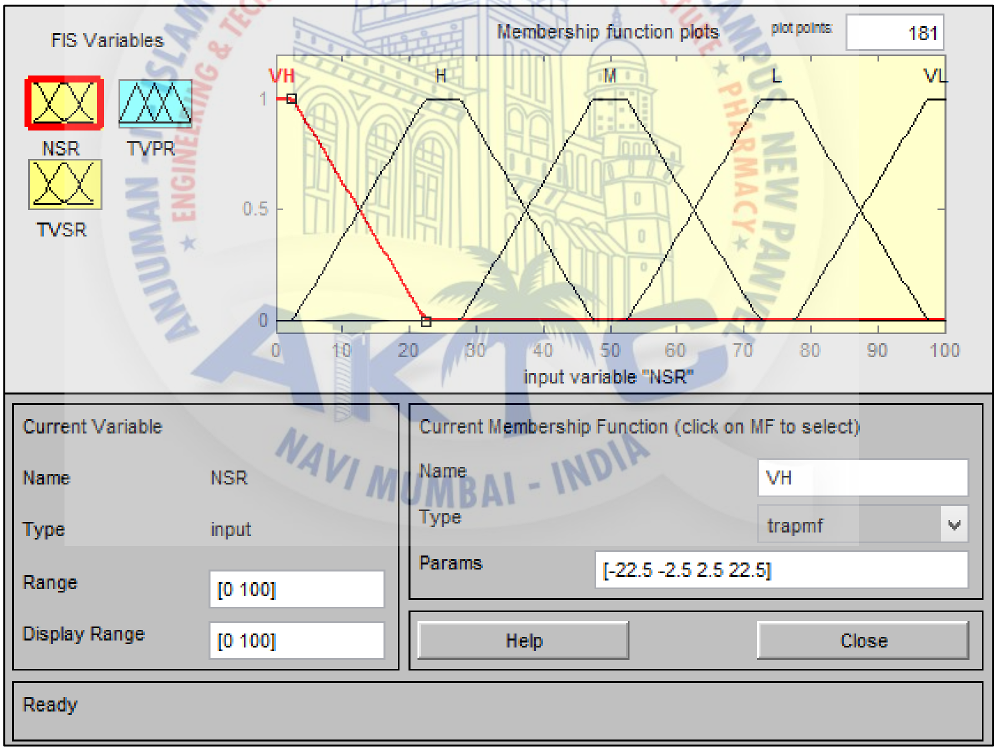


Figure 5.1 Membership Function of input variable1 (NSR)

Figure 5.2 shows the range of the input variable 2 i.e. total value of sub risks is from 0 to 100. And the membership function used is trapezoidal membership function. The parameters of the input variable 2 corresponding to the likelihood (VH) of the risk are shown in the figure.

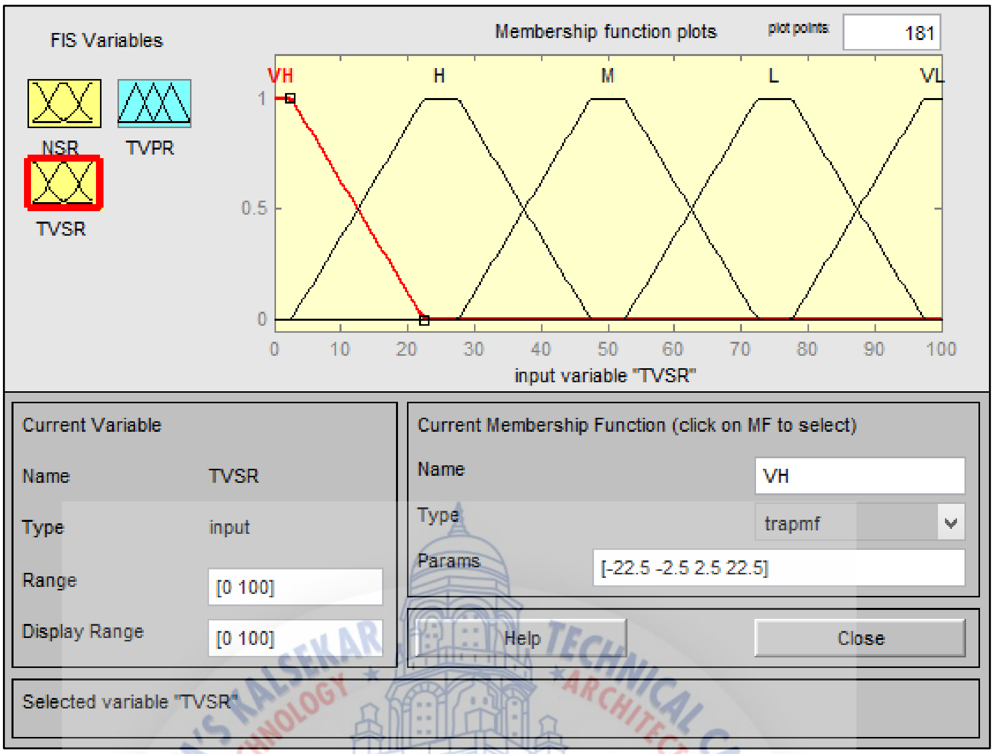


Figure 5.2 Membership Function of input variable2 (TVSR)

Figure 5.3 shows the range of the output variable i.e. total value of project risk is from 0 to 100. And the membership function used is trapezoidal membership function. The parameters of the input variable 2 corresponding to the likelihood (M) of the risk are shown in the figure.

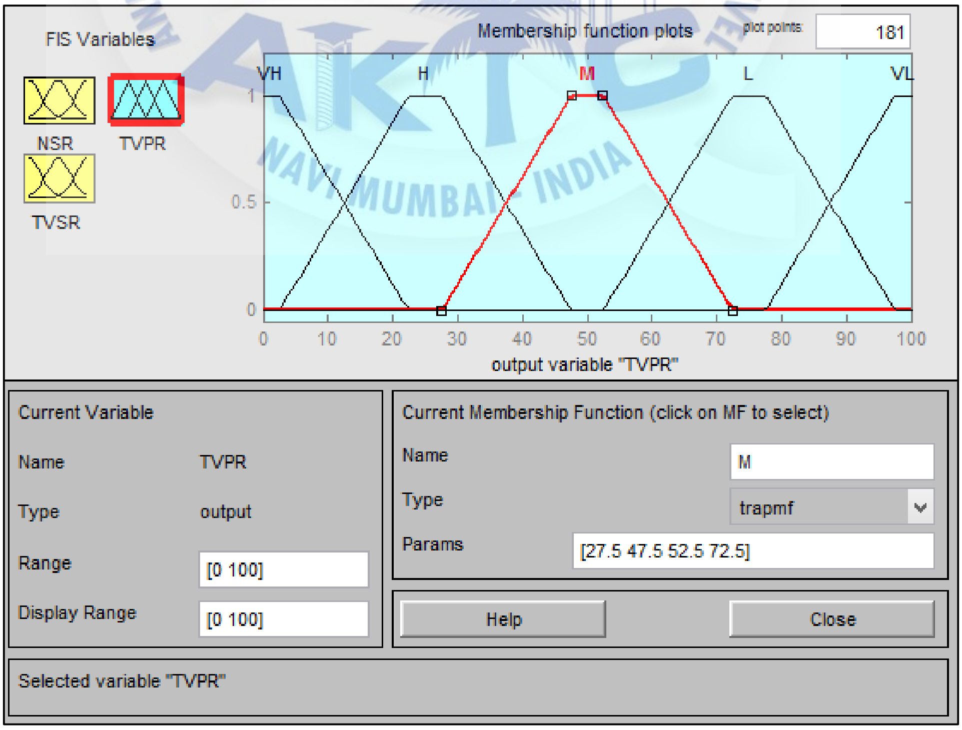


Figure 5.3 Membership Function of output variable (TVPR)

5.2 Fuzzy inference

Table 5.2 shows different rule combinations used in this case. For example, if NSR and TVSR which are given numbers having combination (1,1), (1,2), (1,3), (1,4), (2,1), (2,2), (2,3), (3,1) have very high (VH) risk attribute.

(1,1) – means, if NSR is very high and TVSR is very high, TVPR is also very high.

(2,1) – means if NSR is high and TVSR is very high, TVPR is very high.

(3,1) – means if NSR is medium and TVSR is very high, TVPR is very high.

Similarly, other rule combinations are interpreted.

Table 5.2 Rule combinations

NSR	TVSR	NSR	TVSR	NSR	TVSR	NSR	TVSR	NSR	TVSR
1	1	2	1	3	1	4	1	5	1
TVPR=VH		TVPR=VH		TVPR=VH		TVPR=H		TVPR=M	
1	2	2	2	3	2	4	2	5	2
TVPR=VH		TVPR=VH		TVPR=H		TVPR=M		TVPR=L	
1	3	2	3	3	3	4	3	5	3
TVPR=VH		TVPR=H		TVPR=M		TVPR=M		TVPR=VL	
1	4	2	4	3	4	4	4	5	4
TVPR=H		TVPR=M		TVPR=M		TVPR=VL		TVPR=VL	
1	5	2	5	3	5	4	5	5	5
TVPR=M		TVPR=M		TVPR=VL		TVPR=VL		TVPR=VL	

Figure 5.4 shows the rule box with 25 rules and degree of support that set up the relationship between the input and output variables. The module allows you to set rules and work with them. Rule number one is a situation where:

<If> = NSR = VH <And> TVSR = VH <Then>TVPR = VH.

Interpretation of the rules is as follows: If the Number of Sub-Risk (NSR) is very high (VH) and the Total Value of Sub-Risks (TVSR) is very high (VH), then the Total Value of Project Risk (TVPR) is evaluated to be very high (VH).

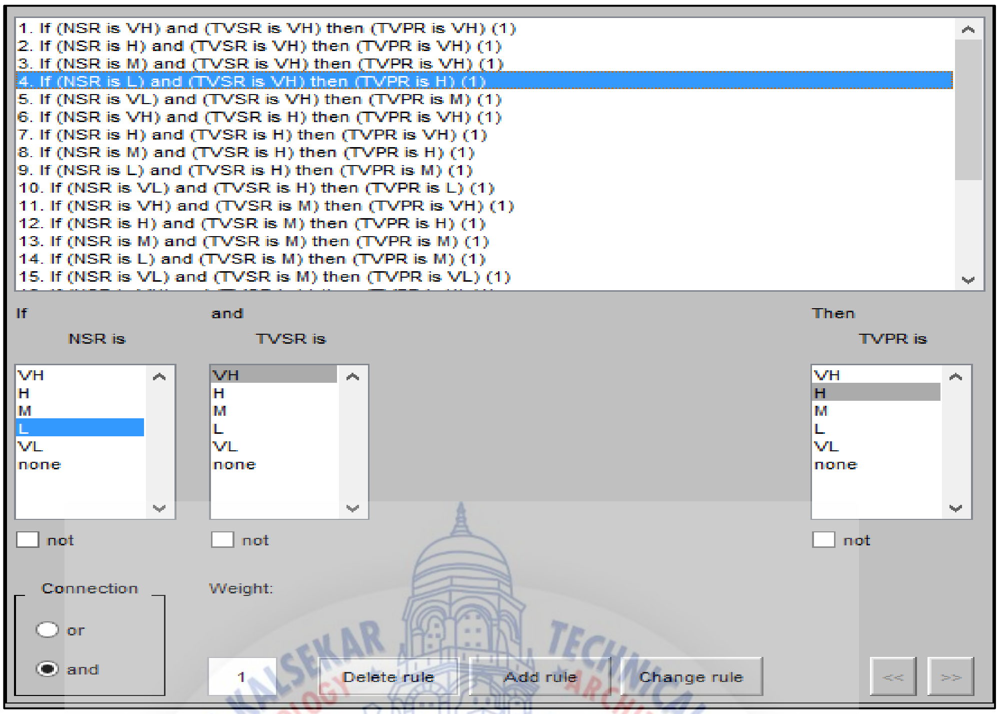


Figure 5.4 Rule Block

5.3 Defuzzification

Transfers the results of fuzzy inference (numerical values) on output variables by linguistic values. It describes results verbally. The system with fuzzy logic works as an automatic system. The user must enter input data only. The output is received by generating an executable file called M-file in the MATLAB software. When the M-file is run the output is generated.

This project presents the use of fuzzy logic at evaluation of total project risk base on RIPRAN method. The Fuzzy Logic Toolbox of the MATLAB software was used for the creating of the decision making model. At first is it necessary to design the variables, their attributes and their membership functions. The developed expert decision-making fuzzy model system consists of two input variables with five attributes, one rule block and one output variable also with five attributes. The inputs are represented by two variables: The Number of Sub-Risk (NSR) and The Total Value of Sub-Risks (TVSR). Both input variables are very important indicators based on RIPRAN method. The output from the rule block and the output variable is The Total Value of Project Risk (TVPR).

5.4 Discussions

After the model is created, it must be tuned (to set up the inputs on known values, evaluate the results and change the rules or weights, if necessary). The tuning and validation of the fuzzy model must be realized on real data of the project. The parameters of the model must be adjusted on the basis of the real data for each of the variables. If the validation shows, that the model provides relatively accurate results, can be used in practice. For implementation of fuzzy model in MATLAB software was created executable file called "M-file". This file contains the following sequence of commands. This file is used to enter the input values (NSR, TVSR) and As soon as you enter the input values the software calculates the output variable TVPR and shows whether the total value of project risk is very high, high, medium, low and very low.

The first line in Figure 5.5 loads a variable *BTVPR*. There are the parameters of fuzzy model in this file. The second line loads the input variables: *The Number of Sub-Risk (NSR)*; *The Total Value of Sub-Risks (TVSR)*. The third line implements an evaluation with command *evalfis*. Inputs are variable *DataBTVPR* and parameters of fuzzy model *BTVPR*. The value of the output is the variable *EvaluationBTVPR*.

```
BTVPR = readfis('rules');
dataBTVPR = input('enter the input data in the form (the number of Sub-risk; the total value of sub risks): ');
evaluationBTVPR= evalfis( dataBTVPR, BTVPR)
if evaluationBTVPR<20 'very high value of total project risk'
elseif evaluationBTVPR<40 'high value of total project risk'
elseif evaluationBTVPR<60 'middle value of total project risk'
elseif evaluationBTVPR<80 'low value of total project risk'
else 'very low value of total project risk'
end
fuzzy(BTVPR)
mfedit(BTVPR)
ruledit(BTVPR)
surfview(BTVPR)
ruleview(BTVPR)
```

ommand Window

```
>> mfile
enter the input data in the form (the number of Sub-risk; the total value of sub risks): [0;0]

evaluationBTVPR =

    7.2885


ans =

very high value of total project risk
```

Figure 5.5 M-file

The fourth to ninth line implements own evaluation. When the value of the output variable is evaluated less than 20, then the output linguistic value is *Very high value of the total project* *risk*. When the value of the output variable is evaluated in the interval from 20 to 40, then the output linguistic value is *High value of the total project risk*. When the value of the output variable is evaluated in the interval from 40 to 60, then the output linguistic value is *Middle value of the total project risk*.

When the value of the output variable is evaluated in the interval from 60 to 80, then the output linguistic value is *Low value of the total project risk*. When the value of the output variable is evaluated more than 80, then the output linguistic value is *Very low value of the total project risk*. Command *fuzzy(BTVPR)* displays and allows set-up work fuzzy model (line 10). Command *mfedit(BTVPR)* displays and allows edit membership functions of input and output variables (line 11). Command *ruleedit(BTVPR)* displays and allows edit fuzzy rules (line 12). Command *surfview(BTVPR)* displays graphical viewing dependency input and output variables (line 13). Command *ruleview(BTVPR)* displays and allows testing and simulation output variable to input variables (line 14). If the M-file is run the request to enter inputs [*The Number of Sub-Risk* and *The Total Value of Sub-Risks*] is displayed. After enter inputs e.g.: *The Number of Sub-Risk* = 0 and *The Total Value of Sub-Risks* = 0 in form [0;0], the result is received TVPR = *Very high value of the total project risk*. Table 5.3 shows the relationship between severity and the range of output variable

Table 5.3 Customizable standard terms for severity quantification

Severity	Range Of Output Variable
Very High	<20
High	20-40
Medium	40-60
Low	60-80
Very Low	>80

Figure 5.6 shows correlation between inputs and output variables. Concretely this picture shows graphically correlation between two input variable NSR, TVSR and output variable TVPR. It is a functional dependence TVPR = f (NSR, TVSR). Point with coordinates [0; 0] represents the situation where the input variable NSR is very high and the input variable TVSR is very high, then the output variable TVPR is evaluated as very high. Point with coordinates [100; 100] represents the situation where the input variable NSR is very low and the input variable TVSR is very low, then the output variable TVPR is evaluated as very low. Graphical display of dependencies of input and output variables allows you to check the set parameters of fuzzy model.

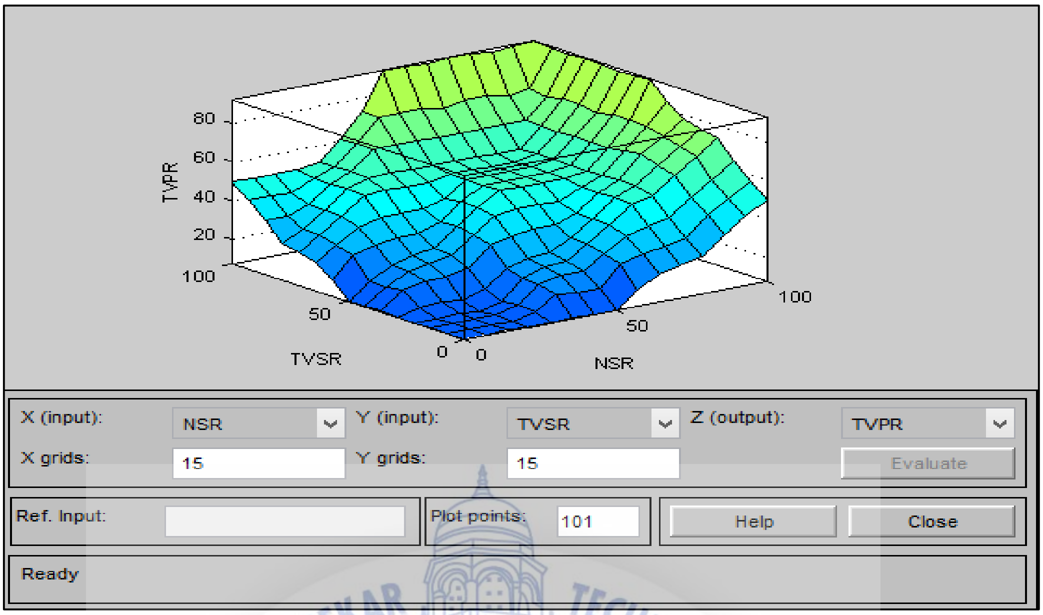


Figure 5.6 Correlation between variables

Figure 5.7 is used to view the entire implication process from beginning to end. You can move around the line indices that correspond to the inputs and then watch the system readjust and compute the new output. ruleview(fileName) depicts the fuzzy inference diagram for the fuzzy inference system stored in file fileName. Specify fileName as a character vector or string with or without the (.fis) extension.

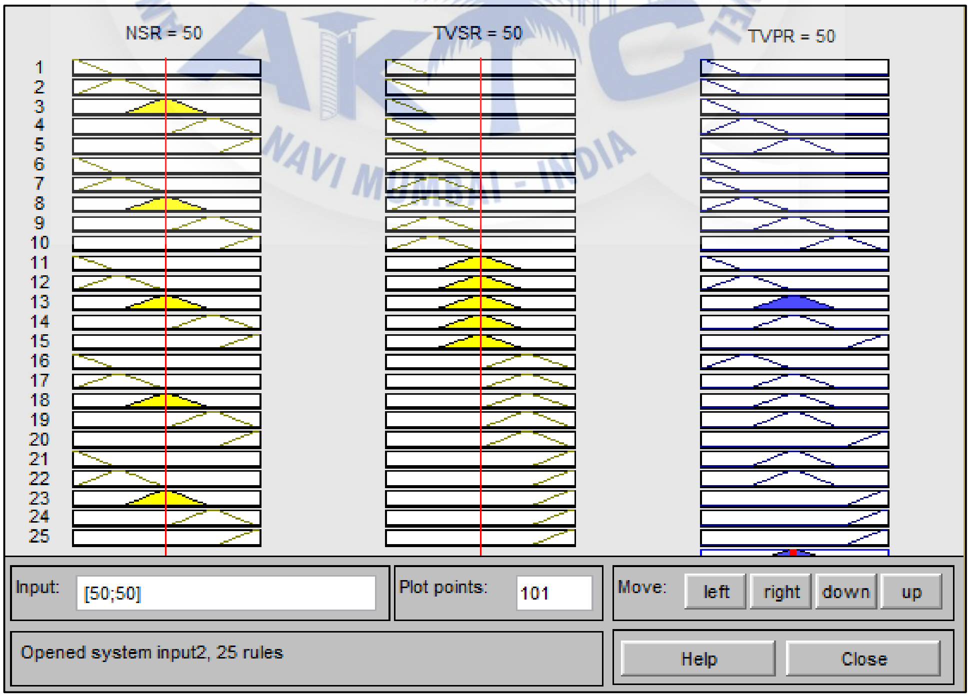


Figure 5.7 Rule Viewer

5.5 Summary

The current approach in the area of risk engineering applied either numerical values of probability and impact, or worked with classical sharp jurisdiction of these values into certain sets, which for many applications not appropriate and did not correspond to the actual perception of risk. Fuzzy approach to modelling these processes minimizes this shortcoming. The advantage of the fuzzy model is the ability to transform the input variables The Number of Sub-Risks (NSR) and The Total Value of Sub-Risks (TVSR) to linguistic variables, as well as linguistic evaluation of the Total Value of Project Risk (TVPR) - output variable.

Chapter 6

Summary and Conclusions

6.1 Summary

In view of today's multidisciplinary and international project environment, characterized by a large number of risk in the project, the fuzzy approach is one way of incorporating uncertainty into project practice. The advantage of fuzzy sets over classical set theory lies in their ability to record inexact (vague) concepts that project managers use in their natural language in the design and implementation of projects. The individual characteristics associated with the given process of project management are, it's true, relatively countable in project practice, though generally only with a wide scatter, i.e. they are more or less guesswork anyway. The approach to date, in the area of risk engineering for example, has either applied numerical values of probability and impact directly or worked with the classical strict membership of these values to certain sets which was unsuitable for a number of applications and failed to correspond to the true risk perception. The fuzzy approach to the modelling of these processes minimizes this shortcoming. The proposed model provides project managers and others with a tool for the "measurement" of risks (assessment of project risks). A significant general advantage of the application of the technique of modelling in project management is the possibility of subsequent experimentation with the model, in the form of simulation for example. This makes further information about the possible variant development of projects available and can provide warning signals to support future decision-making.

6.2 Conclusion

Project risk management is a necessary and critical task of the project manager and project team. The expert fuzzy decision-making model of evaluation of total project risk is only one of possible options how to use fuzzy logic for support of decision-making. This work presented a new expert fuzzy model, based on the RIPRAN method, specifically on the phase: risk assessment. This phase evaluates the total project risk based on two constraints: the number of sub-risks and the total value of sub risk. For creating of model is used fuzzy set theory and fuzzy logic. The advantage of fuzzy sets in comparison with the classical set theory is its ability to record inaccurate (vague) concepts that project managers use natural language in the design and implementation of projects. The advantage of this fuzzy model is the ability to transform the input variables The Number of Sub-Risks (NSR) and The Total Value of Sub-Risk (TVSR) to linguistic variables, as well linguistic evaluated The Total Value Project Risk (TVPR) – output variable. With this approach it is possible to simulate an uncertainty that is always associated with projects. After the fuzzy model is constructed, it is necessary to tune it (to set up the inputs on known values, evaluate the results and to change the rules or weights, if necessary) when the model was built. If the fuzzy model is tuned, it is possible to use it in practice. To implement the fuzzy model in MATLAB an executable file called M-File is created. M-file is used to enter the input values and automatically evaluate the total risk of the project. The fuzzy model has a lot of benefits for users (project managers and others). Some of them are: speed up the decision-making in risk management, automatization and standardization of risk analysis process, effective project management etc.

6.3 Scope of Future Work

Although the computations involved in the model of the fuzzy risk analysis are tedious if performed manually, it is an easy task and the time for risk analysis can be significantly reduced. It becomes easier if a software is used. Construction project managers can predict the overall risk of the project before starting the implementation. The proposed fuzzy risk analysis provides an effective, systematic and more natural way to analyse the associated risks. Evaluators can just adjust the parameters of the input and output variable and run the M-file to get the total value project risk. There are some limitations in this work. For example, the membership functions were distributed by trapezoidal fuzzy numbers. Various membership functions need to be estimated to be as realistic as possible

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