CERTIFICATE

This is to certify that the project entitled **"Application of Multi Criteria Decision Making to Simulate Uncertainties in Construction Projects"** is a bonafide work of **Katrekar Shweta Sushil (16CEM06)** 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)"

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APPROVAL SHEET

This dissertation report entitled "Application of Multi Criteria Decision Making to Simulate Uncertainties in Construction Projects" by Katrekar Shweta Sushil (16CEM06) is approved for the degree of "Civil Engineering with Specialization in Construction Engineering and Management"

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DECLARATION

I declare that this written submission represents my ideas in my 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 the 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

Uncertainty certainly affects the performance of a construction project. It can be generalized as the difference between result and outcomes from usually expected values. The values can be considered to be time, quality and economy of the project depending upon the project needs. In construction project management, the effects of unidentified risks and uncertainties obstruct the project time, quality as well as its economy and upset the project management and thus its development. Identifying the uncertainty and quantitatively analysing the impact on the project performance can notably enhance the exactness, validity and reliability of a project plan. This study describes a methodology to systemize, model, and diminish uncertainty. In essence, Multi criteria decision making model is developed, which is useful for analysing uncertainties even with insufficient information or vague records. The study presents uncertainty assessment methodology based on multi criteria decision making, which is an effective integrated project management tool to deal with a subjective conclusion; that is used to configure a large number of uncertainties. It included a questionnaire survey; based on the data obtained, the probability of factors causing uncertainties were quantified using importance index and multi criteria decision making. The study is to suggest a decision support tool to quantify the probability of uncertainties in construction projects by using importance index incorporated with multi criteria decision making. Using this theory an uncertainty assessment model was suggested. The developed model can be utilized by the construction practitioners like contractors, consultants and clients while critical decision making.

Keywords: Multi Criteria Decision-Making (MCDM); Simulation; Uncertainties; Uncertainty assessment.

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ABBREVIATION NOTATION AND NOMENCLATURE

MATLAB	Matrix Laboratory
MCDM	Multi Criteria Decision Making
WSM	Weighted Sum Model
WPM	Weighted Product Model
PERT	Program Evaluation and Review Technique
VAR	Value Addition Rate
P.I.	Probability Index
I.I.	Impact Index
IMP.I.	Importance Index
PLC	Project Life Cycle
ERFs	Economic Risk Factors

Chapter 1

Introduction

1.1 General

Probability models are prevalent in uncertainty quantification and assessment. They have become the fundamental basis for informed decision-making related to uncertainty and risk in many areas. However, a probability model built upon classic set theory may not be able to describe some of it in a meaningful and practical way (Francis, 2016). Lack of experience data entangled cause-and-effect relationships and indefinite data make it difficult to assess the degree of exposure to certain risk types using only traditional probability models. Sometimes, even with a credible quantitative risk model calibrated to experience data, the cause of the uncertainty and its characteristics may be incompletely understood. Kahraman (2015) stated other models such as fuzzy logic, hidden Markov and decision tree models and artificial neural and Bayesian networks, overtly consider the underlying cause-and-effect relationships and recognize the unknown complexity. These newer models might do a better job in understanding and assessing certain uncertainties. By identifying uncertainty and risk management properly, operative risks can be significantly mitigated, despite the lack of consensus on which quantitative models should be used. Therefore, it may be useful to build and implement more suitable operational risk models with newer approaches. Unlike the probability model, the integrated model management and simulation software for complex systems recognize the uncertainty of truth precisely; it can also easily include the information described in the languages. These models are better suited to incorporating various expert statements into situations where there is insufficient and unclear information (Shang and Hossen, 2013). They provide a framework in which knowledge and experience. Expert information can together assess uncertainty and identify key issues. By approximating and inferring conclusions about unclear knowledge and data, these MATLAB models can be used for modeling risks that are not fully understood.

1.2 Uncertainties in construction industry

The developing countries are alleged developing because they are yet to develop the stock of their infrastructure. To develop the stock of infrastructure, the construction industries are pivotal and are the conduits. The challenges of sustainable development in developing countries are the challenges of development of the stock of infrastructure, (Okema, 2000). Subsequently, the challenges of development of the stock of infrastructure are the challenges facing the construction industries. The effective development of infrastructure through constructions are issues of growing concern, satisfaction and study. One of the measures to optimize construction productivities can be risk and uncertainty that the project goes due to fluctuating and emerging situations over the project lifecycles. An effective and deliberate approach towards uncertainty management is essential so as to avoid construction projects running out of control, also to optimize the project productivity and intensify business positions. During the project performance, schedule may be subject to uncertainty which can lead to significant modifications. The presence of an uncertainty of seasonal type affects some of the activities that comprise the project performance and leads to re-schedule. Chapman and Ward (2003) establish different areas where uncertainty can arise throughout the project life cycle variability associated with estimates, uncertainty about the forecast basis, uncertainty about design and logistics, uncertainty about objectives and priorities, uncertainty about fundamental relationships between project parties. Jaafari (2001) also includes a list of variable risks that are typically found on large projects promotion risk, market risk-volume, market risk-price, political risks, technical risks. This list is responsible of the Environmental risk i.e. probability that a given project will have adverse environmental impacts beyond its permitted limits and increased liabilities. As an example from (Chapman and Ward, 2004), a major construction project of North Sea oil can be affected by the condition of the sea especially during November and December. Through risk analysis, the project manager could decide to use equipment more suitable to such adverse weather conditions to reduce the risk. Using Monte Carlo simulation and sensitivity analysis, information about how the activities contribute to the overall risk project can be achieved which results to prioritize activities. Uncertainty is closely associated with uncertainty management, which is the process of integrating risk management and value management approaches of construction process, (Smith 2003). The researchers commonly tend to underestimate the influence of suitability and precision of the evaluation data as well as the reliability of methods and means of their application.

The great variety of alternatives and criteria complicate the systemizing of data and decision making. The project is designed to meet the challenges and challenges of the construction industry. There is no straight forward definition of risk and uncertainty while many scholars look at it from different perspectives. It is generally agreed that, in risk and uncertainty, the result or activities are likely to depart from anticipations. It is considered that the effect of the deviation from expectation could be value-neutral, value-negative or value-positive. In the construction industry project management, these values are in the form of time, quality and economy of the project. Therefore, in construction project management, it is the effect of risks and uncertainties on project time, quality and economy that is the subject of management and management development. Okema (2000) in dealing with risks and uncertainties management as challenges faced by the construction industry in developing countries in project management, the focus should be on:

- Identification of the various risks and uncertainties that the project faces.
- Categorization and Quantification of risks and uncertainties that the project faces.
- Risk and uncertainty sensitivity analysis for the project.
- Project risks and uncertainties allocation and distributions to those with better capacity and mechanism to handle each categorization. Sometimes, some people handle it in superstitious manners either through fortune-tellers or witchdoctors or traditions for example sacrifices of some kind for certain type of projects. Risks and uncertainties allocation and distribution should be done through the terms and conditions of contracts.
- Project risks and uncertainties response and mitigation by the responsible people or parties to whom they were allocated and distributed. So that when the threats occur partially or wholly, the project implementation is protected from their consequences or compensated for the consequences.

The fundamental bottom line of principles of management is that risks and uncertainties are not entirely negative but also holds significant opportunities that their proper management could be very much rewarding. It is this double edge notion of risks and uncertainties that is the benefit of the management challenge in Construction Industry. This is also the only managerial attitude that makes the management approach comprehensive, relevant and optimal.

1.3 Management of Uncertainties

An uncertainty problem is the foremost that influence the project's execution constraints. It can be anticipated with some prospect intensity but it is better to foresee possible optimistic and pessimistic "what if" scenarios with detail solving solutions and "stop threat" means for effective construction project management, (Chandurkar and Rajan, 2006). The study describes the ambiguities and circumstances in the realization of the construction project. There is no autonomy in uncertainty. It is not an object that can be identified and identified as a virus that invades living beings in our project. Given that naturally complex conditions stem from indefinite, it is an inseparable part of many projects. It is only an expression of inequality and the manifestation of morality. This means that our security mechanism is based on a better understanding of the way in which parts of the project function, and not on uncertainty. Give two things this is a clear idea of where our slums are and how "normal" it is. The first element indicates possible sources of uncertainty. In the course of management of uncertainty, uncertainties affect internal reliability within a specific process in the construction project being analyzed. Typically scrap, rework and queues for overworked resources are prime candidates affecting this classification. The uncertainty results from poor reliability from suppliers, including the various artifacts, products and services supplied by vendors and so on. Demand uncertainty is associated with specific customers in relation to order schedule variability and transparency of information flow. Unexplained and late changes to orders and project specification such as those documented (Eckert et al., 2006) are generally activated by the demand side. Finally, control uncertainty affects the ability to transform project requirements into targets and clients' needs. The latter activates, sequences and adjusts the flow of produces irrespective of physical form. The goal is to manage the tasks for maximum total effectiveness and reliability. The sources of uncertainty are interrelated; some sources of uncertainty may affect one element only but with others there can be a ripple effect propagating throughout the process. Depending on the project scope, types of uncertainties may differ among investments although uncertainties can be somewhat managed into selective stages:

Uncertainty identification- The first step is usually informal and can be performed in various ways, depending on the organization and the project team. It means that the identification of uncertainties relies mostly on past experience that should be used in upcoming projects. In order to find the probable uncertainties, an allocation needs to be done. This can be decided and arranged by the organization. In this case, no method is better than another since the only purpose is to establish the possible uncertainties in a project. Risks and other threats can be hard to eliminate but when they are identified, it is easier to take actions and take control over them. If the causes of the uncertainties have been identified and allocated before any problems occur, the uncertainty management will be more effective. The process is not only solving problems in advance but also being organized for possible drawbacks that can occur surprisingly. Handling probable threats is not only a way to lessen losses within the project but also a way to transfer risks into prospects which can lead to economical profitability, environmental and other advantages (Winch, 2002). The purpose of identifying uncertainties is to obtain a list with probable uncertainties to be managed in a project. In order to find all probable uncertainties which might influence a specific project, different techniques can be applied. It is important to use a method that the project team is most familiar with and the project will benefit from. The aim is to highlight the likely complications for the project team to be aware of them.

Uncertainty analysis- Uncertainty analysis is the second stage where collected data about the possible uncertainties are analysed. Uncertainty analysis can be described as short-listing risks with the highest impact on the project, out of all threats mentioned in the identification phase (Cooper et al., 2005). In the analysis of the identified uncertainties, two categories of methods qualitative and quantitative can be developed. The qualitative methods are most applicable when uncertainties can be placed somewhere on a descriptive scale from high to low level. The quantitative methods are used to determine the probability and impact of the uncertainties identified and are based on numeric estimations (Winch, 2002). In addition, there is also one approach called semi-quantitative analysis, which combines numerical values from quantitative analysis and description of factors causing uncertainties, the qualitative method (Cooper et al., 2005). Within the quantitative and qualitative categories, a number of methods which use different norms can be found, and it may be difficult to choose an appropriate uncertainty assessment model for a specific project. The methods should be chosen depending on the type of risk, project scope as well as on the specific method's requirements and criteria. Regardless of the method chosen, the desired outcome of such assessment should be reliable. Perry (1986) mentions that the selection of the right technique often depends on past experience, expertise, and nowadays it also depends on the available computer software.

Uncertainty response- This third step indicates what action should be taken towards the identified uncertainties and threats. The response strategy and approach chosen depend on the kind of risks concerned (Winch, 2002). Other requirements are that the risk needs to have a supervisor to monitor the development of the response, which will be agreed by the actors involved in this risk management process. Winch (2002) claims that the lower impact the risk has, the better it can be managed. Most common strategies for uncertainty response are: avoidance, reduction, transfer and retention (Potts, 2008). Beyond those types of responses, (Winch, 2002) describes that sometimes it is difficult to take a decision based on too little information. This may be avoided by waiting until the appropriate information is available in order to deal with the risk. This way of proceeding is called "Delay the decision" but this approach is not appropriate in all situations, especially when handling critical uncertainties which needs to be managed earlier in the process.

Monitoring Uncertainties- This final step is vital since all information about the identified uncertainties is collected and monitored (Winch, 2002). The continuous supervision helps to discover new uncertainties, keep track of identified risks and eliminate past uncertainties from the risk assessment. The assumptions for monitoring and controlling are to supervise the status of the uncertainties and take corrective actions if needed.

1.4 Multi criteria decision making

Decision Making is the act of selecting among two or more courses of action. However, there may not always be a 'correct' decision between the available choices. There may have been a better choice that is not been considered, or the correct information may not be available at the time. Multiple-criteria assessment problems consist of a finite number of alternatives, overtly known in the beginning of the solution process. In Multiple-criteria design problems the alternatives are not clearly known. An alternative (solution) can be found by solving a mathematical model. The number of alternatives is either infinite or not countable, when some variables are continuous or typically very large if countable when all variables are discrete. But both category of problems is considered as a sub-division of Multi Criteria Decision Making problems. MCDM is well-known acronyms for multiple-criteria decision-making which is concerned with configuring and resolving decision and planning complications involving multiple criteria. The purpose is to support decision makers facing such problems. Typically, there does not exist a unique optimal solution for such problems and it is necessary to use decision maker's preferences to differentiate between solutions, (Majumder, 2015). The MCDM process follows a common working principle as described below:

1. Selection of Criteria-
   Coherent with the decision

Independent of each other

Represented in same scale

Measurable

Not Unrelated with the alternatives

2. Selection of Alternatives-

   Available

   Comparable

   Real not Ideal

   Practical/Feasible

3. Selection of the Weighing Methods to Represent Importance-

   The weight determination methods can be either compensatory or outrankable.

   Example of Compensatory Method: Analytical Hierarchy Process (AHP), Fuzzy Multi-Criteria Decision-Making Process (FDM) etc.

   Example of Out-ranking Method: Elimination and Choice Expressing Reality (ELECTRE), Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHUS)

4. Method of Aggregation-

   Can be a Product

   Can be an Average

   Can be a Function

The result of this aggregation will actually separate the best alternative from the available options. The Multi criterion Decision-Making (MCDM) gaining is important as potential tools for analysing complex real problems due to their inherent ability to judge different alternatives (Choice, strategy, policy, scenario) about the criteria for choosing the best / right option, these options may be explaining more in Figure 1.1.

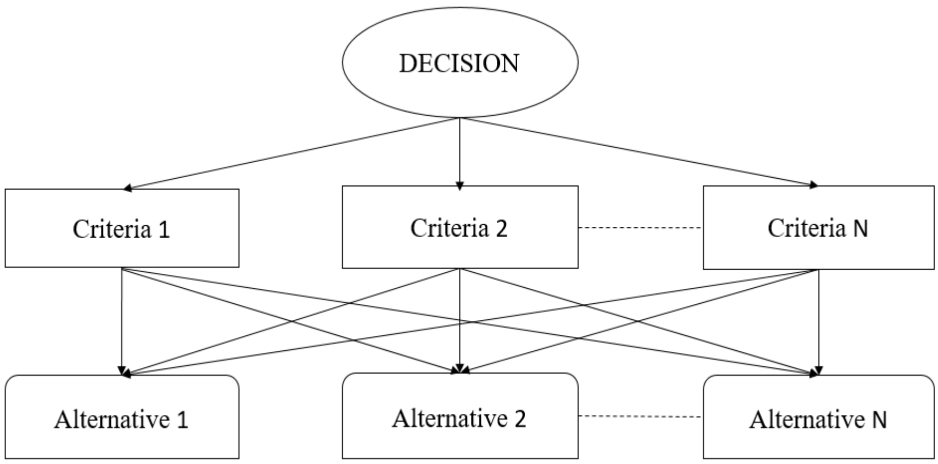

Figure 1.1 Multi criteria decision making (MCDM) Tree

Figure 1.1 explains that to reach upon a certain decision, breakdown of various criteria is to be done. These criteria possess every probable risk arising after the decision is finally taken. Further there are alternatives which acts as the precautions and the substitute measures to be selected after the decision is prepared. This entire arrangement collectively can be termed as multi criteria decision making (MCDM) tree. Multi-criteria analysis is completely different measurement standards, some unique such inequality, and conflict between the existence of multiple standards of functions, and as a unit of decision-making (MCDM) analysis, and the existence of different alternatives. This is to deal with the uncertainty of the collective decision-making process is not available to extend MCDM to different testing methods and practical justification against the need for more advanced methods for MCDM is an attempt to review the different methods. This amount model (WSM) is the oldest and perhaps the most widely used. Saghafian (2005) the WSM product will likely be a change that can be considered a model (WPM) has been proposed to overcome some of its weaknesses. The later stage of development, step-by-step process analysis (AHP) analysis, and has recently become popular. The recent revision than the original approach assumes consistently coming into the AHP. A few other methods widely used are ELECTRE and TOPSIS methods. Some of the steps involved in MCDM methodology can be summarized as:

1. Defining the problem and fixing the criteria.
2. Appropriate data collection.
3. Establishment of feasible/efficient alternatives.
4. Formulation of payoff matrix (alternative versus criteria array).
5. Selection of appropriate method to solve the problem.
6. Incorporation of decision-maker’s preference structure.
7. Choosing one or more of the best/suitable alternative (s) for further analysis.

The MCMD methods can be further classified into four groups, i.e., distance, outranking, priority/utility, and mixed category.

1.5 Problem Statement

Uncertainty management is one of the foremost problems in construction. Most of the solutions are more or less solving this problem but it must meet the demands of all project participants. The uncertainty is usually estimated in the initial stage of the construction project whereas it has to be into continuing process with solutions during the whole project life cycle. There is little evidence of application of risks and uncertainties management in construction in developing countries and yet it is apparent how they influence the course of construction projects and poses immense challenges.

1.6 Motivation of the study

The motivation of the study to reduce the challenges of the Construction Industry and improve the role and contribution of the industry, to sustainable development of developing countries, it is great potential to focus more, than ever before, on the concept of risk and uncertainty. This should be covered through both theoretical and practical approaches at operational, strategic and development level. This shall promote construction project from running out of control and optimize the deliveries of projects through strengthening business activities. The theoretical approach should be able to support the development of knowledge in the areas of risks and uncertainties, while the practical approach should be able to spread the benefits of the knowledge to bear results through various skills and techniques.

1.7 Aim and objectives of study

The following aim and objectives were benchmarked for this research:

(1) To Identify and categorize various factors causing uncertainties in construction projects.

(2) To calculate probabilities of various factors causing uncertainties in construction projects using Importance index method and hence arrive at the most important cause.

(3) To apply Multi criteria decision making model for determining uncertainty considering uncertain factors characterized by construction projects. This objective includes sub-objectives which are as follows:

a. Determine uncertain factors & alternatives to overcome factors causing uncertainties,

b. Construct decision model,

c. Determine the weights by using Importance index method findings, and

d. Carry out model operations to construct and scrutinize uncertain factors and making the wise decision of selecting appropriate alternatives.

Chapter 2

Literature Review

2.1 General

There have been several studies on the risk and uncertainties techniques. An extensive review of project risk assessment and management was conducted during the initial phase of the research effort. Past studies show that real estate companies are at risk for other companies due to their complexity. Typically, the construction project requires the skills and interests of many different people and coordinates a wide range of differentiated but interdependent activities. This complexity improves the unique features of the project and many other external uncertainties. In addition, the lack of specialized literature generally focuses on the practices, results or development of risk assessment and management techniques for Indian construction projects. The review of the literature includes books, articles, articles and Internet products at risk. Construction risk management and analysis techniques to effectively support this document.

2.2 Uncertainty Management

Construction projects are open to an uncertain nature due to its massive size, difficulty in design technology and association of external factors. These uncertainties can lead to numerous changes in project opportunity during the course of project implementation. Unless the changes are well controlled, the time, cost and quality targets of the project may never be achieved, Prasanta (2002). The ability to analyse situations and to make good decisions is a very important aspect of any managerial work. The decision-making process involves several tasks: planning, generating a set of alternatives, setting priorities, choosing a best policy after finding a set of alternatives, allocating resources, determining requirements, predicting outcomes, designing systems, measuring performance, insuring the insuring the stability of a system, optimizing, and resolving conflict, Saaty and Kearns (1991). The issue of insecurity is the main factor influencing the implementation parameters of the project. It can be expected with some possibility, but it is better to envisage possible optimistic and pessimistic scenarios "if" with detailed solutions and "stopping the threat" means effective management of the construction projects. Therefore, this article presents different types of risks that cannot be separated from the uncertainty of the construction industry. The contribution is ready to describe the reasons for the uncertainties and situations during the execution of the construction project. This study identifies the uncertainty and the nature of the risk, Smith (2003), Brauers (1986) and a detailed description of the risk management stages for construction projects as a decision-making process for an informed construction project.

According to Chapman and Harwood (2006), uncertainty in projects may be interpreted as two concepts: variability (a measurable factor can take on a range of possible values) and ambiguity (uncertainty of meaning or uncertainty about the event itself with a lack of clarity over some aspect of its existence). Atkinson et al. (2006), mention three key areas of uncertainty as uncertainty associated with estimating, uncertainty associated with project parties, and uncertainty associated with stages of the project life cycle. They believe that uncertainty is particularly predominant at the early stages of a project. Perminova et al. (2008), define uncertainty as “a context for risks as events having a negative impact on the project’s outcomes, or opportunities, as events that have beneficial impact on project performance”.

A detailed description of the sources of uncertainty presented with the effect each project participant may encounter in the execution of the construction project, Chapman and Ward, (2002). When defining the causes and resources, it is possible to propose proposals to reduce uncertainty in the technological and economic issues of construction 790. Its purpose is to explain the process of risk management and related life-cycle construction projects, Snyder (2005) with suggestions on how and when and what measures can be taken to support project decision-making, part of Cano and Cruz (2002). The complexity in construction engineering often results in hesitation on the part of the decision maker in selecting specific alternatives. Fuzzy risk assessment provides a promising tool to quantify risk ratings where the risk impacts are vague and defined by independent conclusions rather than independent statistics. It is also a suitable technique to deal with the out of control factors: site, labour, equipment, climate, unforeseen circumstances, time dependence situations, and regulations, Malek (2000). Sou-Sen et al. (2001), proposed optimal construction time-cost trade-off method developed concerning the effects of both uncertain activity duration and time-cost trade-off are taken into account in this method. Fuzzy set theory is used to model the uncertainties of activity durations. The method provides an insight into the optimal balance of time and cost under different risk levels defined by decision makers, Sou and Chung (2001).

2.3 Defining Uncertainty and Risk

In recent years' scientists describe uncertainty as associated with uncertainty management Smith (2000) which is the process of integrating risk management and value management approaches of the construction process, Smith (2003). Theoretically, uncertainty can be defined as a lack of certainty involving variability and/or ambiguity (Brauers, 1986). Likewise, management and management seem to be uncertain about the threats discovered that risk management opportunities will stem from causes and generate uncertainty, which is out of danger and risk and opportunity, Chapman and Ward (2002). In situations of uncertainty, parameters are uncertain, but it is known about probabilities. Although the unknown cause is the mass of the parameters monitored by the probability distribution is known manufacturers, Snyder (2005). The discrimination between risk and uncertainty is whether it is usually possible to determine the future the inevitability of a certain amount of the known values, Brauerei (1986). Pillar (2002), mathematics found between uncertainty and risk differences are important, but in this article, let these clauses come to each other as they describe the uncertainty in the management of construction projects. Parts or even entire construction project can be treated as the same to accomplished similar construction projects, Ustinovicius and Migilinskas (2005), Gabbar and Aoyama. (2004). However, these assumptions are not always correct and their bias degree is quite high in comparison to actually obtained parameters after the construction project implementation, Ustinovicius and Popov (2005), Popovas, et al. (2004). It is because every construction project is unique, Leinonen and Kähkönen (2003) and every project include a high degree of uncertainty. The uncertainty in undertaking a construction project comes from many sources and often involves many participants in the project, Ustinovicius and Popov (2005), Popovas and Mikalauskas (2004). Mazur et al. (2009), describe project risk through the interrelated categories: uncertainty, risk and loss. Uncertainty is characterized by incomplete and/or unreliable source of information about the project and probabilistic character of future events and can be described and analysed by mathematical concepts and tools. Then, project risk occurs as the result of uncertainty about the future events, which in turn causes to loss (damage). Meyer et al. (2002), proposed four categories of uncertainty in project as they relate to project management techniques, which are variation, foreseen uncertainty, unforeseen uncertainty and chaos and suggested recommendations for each category.

In an effort to escape your project, fighting some important participants. Risk management argues that this uncertainty is steadily increasing the ability to achieve project goals, Wang (2001). To emphasize specific scholars, the underlying cause the fact that we should not change this approach is that people are more likely to control and reduce fear, Ustinovicius and Migilinskas (2005). Hyun-Ho et al., (2004) developed a risk assessment methodology for underground construction projects. The main tool of this methodology is risk analysis software. The risk analysis software is built upon an uncertainty model based on fuzzy concept. The fuzzy-based uncertainty model is designed to consider the uncertainty range that represents the degree of uncertainties involved in both probabilistic parameter estimates and subjective judgments. Moreover, they concluded that the proposed risk assessment methodology will provide rational and practical solutions to the insurance companies and contractors with its flexible and easy to- follow procedure and tools, and robust uncertainty modelling capability. Yousef Alsulaiman, et al. (2014), carried out to understand the recent application of risk management in water and power projects in South Africa. The effect of poor operation of risk management was studied. The study surmised that lack of knowledge and experience and lack of training and awareness of risk management were the reasons of failure in achieving project intentions. El-Shehaby et al (2014), identified and analyzed risks associated with construction of offshore Oil & Gas Projects, the study involved classification of various risk factors and identifying the effects of projects risks on project duration and costs. Charlson, and Oduoza, (2014) identified legal risks for SMEs in the Construction Industry which needs to be investigated further. Pawar et al (2015), studied projects Contract Document as a risk managing tool for allocating risks to the stakeholders. The stakeholders like owners, consultants and contractors may have conflicting interests. The study reviews severity of important risks and considers the suitable control measures from Client and Contractors point of view; based on study of literature, contract documents and interviews of owners & contractors of infrastructure projects of Pune region. Boateng, P, (2015) studied a systemic approach is for arriving at a systemic approach for modelling economic risks in Megaproject Construction and identified Economic Risk Factors (ERFs) through interviews, questionnaires and non-participant observation and also prioritized the ERFs using Analytical Network Process (ANP) and shortlisted certain ERFs for the purpose of modelling within a System Dynamics framework. It estimated the mean impact of economic risks on Edinburgh Trams to be about 22% based on the measured economic impact on the project.

2.4 Multi criteria decision making (MCDM)

Real-life decision-making difficulties are usually too complex and ill-controlled to be considered through the examination of a single condition that will lead to the optimum decision. In fact, such a unidimensional methodology is just a simplification of the actual nature of the problem at hand, and it can lead to impracticable decisions. A more pleasing approach would be the concurrent consideration of all relevant factors that are related to the problem. Multi criteria Decision Making (MCDM) constitutes an advanced field of operations research that is devoted to the development and implementation of decision support tools and methodologies to confront complex decision problems involving multiple criteria, goals, or objectives of conflicting nature, Zopounidis and Doumpos (2002). Probabilistic methods evaluate the degree of compliance within various constraints, including duration, cost, and quality and their allied uncertainties. Independent processing is therefore required. The program evaluation and review technique (PERT), Malcolm et al. (1959) was an initial step toward applying uncertainties to activity duration. Activities use the beta probability curve to estimate the most expected duration and variance. The project variance is the sum of the critical path activity variances. Martinez and Ioannou (1997), mentioned that despite the probabilistic aspect of PERT, activity duration was still optimistic. PERT is also incapable to make a correlation between intervals. Moreover, errors can occur in cases of multiple crests or irregular distributions. Murray (1963), MacCrimmon and Ryavec (1964), and Grubbs (1962) have proposed substitutes to the PERT method. Different extensions emerged, taking cost and consistency into account. Other scholars, such as Halpin and Riggs (1992), Pritsker (1995) and Lu and AbouRizk (2000), advised applying simulation to the PERT network. Daji and Reiar (1993), developed the back-forward uncertainty estimation (BFUE). This technique introduces uncertainties to the duration of non-critical activities. To calculate the total duration of the project, this method takes into account the likelihood that any path will become critical. BFUE is based on the fact that noncritical paths may, (during the process) become subcritical or critical depending on how the margins of activities are used. Han et al. (2007), proposed a value addition rate (VAR), a time-scaled metric to capture the activities that consume time or resources without increasing value. Generally, these network-based scheduling skills consider only a single activity structure.

The developing range of MCDM techniques has provoked a number of reviews in recent years, which have drawn attention to the strengths and weaknesses of these techniques in solving environmental decision-making problems, Hajkowicz et al. (2000). Although MCDM was established as a technique to address uncertainty at different stages of decision making, its cumulative complexity in integrating and evaluating stakeholders' views, opinions and concerns has raised some concerns about its transparency to the end user, Hajkowicz and Collins (2007). Subsequently, non-experts, i.e. some decision makers and stakeholders, might consider some of the advanced MCDM techniques as an answer-constructing 'black box', Lai et al. (2008); i.e. the mathematical sophistication of some of the MCDM techniques to reduce potential uncertainties needs to be used carefully and weighted against any adverse clouding of transparency. Whereas, it is important to understand that, like all other environmental decision-making techniques, uncertainties can patent themselves in MCDM analyses. By providing trials to evaluate the impact of uncertainties at each stage of the analysis, however, MCDM techniques can recognise uncertainties allied with decision-makers' fondness and knowledge, as well as uncertainties in using different techniques. While there have been many empirical studies of the application of MCDM in environmental decision making, studies on how uncertainty analysis in MCDM can deal with potential uncertainties at each stage of this decision-making procedure are rare. Chileshe and Kikwasi (2013), tried to investigate the perception of construction professionals on the barriers to RAMP (Risk Assessment and Management Practices) in Tanzania. The author perceives that this study would provide insights on the barriers to implementation of RAMP across construction sector of Tanzania, involving more stakeholders such as clients, consultants in additional to the contractors.

The chronographic model premeditated the active time-scaled dependencies that permit continuous probabilistic simulations based on the core variation of the production frequency, Francis et al. (2013). Various sensitivity metrics- criticality, crucially & schedule sensitivity index was used to prioritize each one of the activities of the project depending on its short date; the relative importance of project tasks must consider a combined version of these 3 sensitivity measures, Fernando (2014). The application of a discrete–event simulation-based method which was applied in the decision-support for manufacturing control to develop the decision-support in the execution of a construction project where the effects of the deviation from the short-term schedule can be easily and quickly analysed, Andras et al (2015). Chenarani (2017), based Monte Carlo a discrete event simulation method is employed for project simulation. The required project and risk data for simulation represents dependency structure matrix (DSM). A simulation program is developed and implemented in a small turbojet engine preliminary design project. The results of research can improve the effectiveness of decision-making process by project manager where choosing appropriate method for reducing risk effects under uncertainty conditions is required. Modelling and simulating uncertainties technique remains attractive for planners by providing greater flexibility in planning complex projects, which helps to produce more realistic schedules while increasing the precision & accuracy, Francis (2017). Madanayake and Ruwanpura (2012), describes the development of a multi-criteria prediction model that has the ability to model phenomena with significant uncertainty in inputs and multiple criteria such as project cost variation, the environmental impact, the impact on schedule and the impact on construction productivity. This simulation tool can be used by the design team at an early stage of the design process to optimise the benefits and minimise the negative impacts of LEED implementation in a new construction project. Marzouk and Mohamed (2018), developed a framework stands capable to rank and assess different evacuation plans and/or design alternatives depending on several criteria, unlike other systems that evaluate buildings safety using the egress time as the individual criterion; case study was presented to illustrate the practicality of the proposed system. The building's spatial characteristics as well as the occupants' data (e.g., approximate numbers, percentages of the disabled, and behavioral data such as: movement speeds and pre-evacuation times) are identified to study their potential impact on the evacuation. Decisions on the choice of building materials turn out to be more intimidating because of the many available sustainable materials, and the interaction between their sustainable criteria. Nwodo, M., Anumba, C., & Asadi, S. (2018), provided a review of this problem and explored the current trends and opportunities for solving the problem. It proposed a more comprehensive framework for the integration of a decision support system (DSS) for materials selection into building information modeling (BIM). The unique component of the proposed framework is a holistic integration of cost, energy, carbon, and mechanical strength. Due to lack of related research on the trend of developing green building, problems appear when investors try to make the best decision about their green investment; Zhang, et al (2018), proposed a method for green building investment decision making to help investors make choice wisely. Analytic hierarchy process (AHP) and complex proportional assessment of Alternatives-Grey (COPRAS-G) methods are adopted in the research with a case study to illustrate its work mechanism and feasibility in reality. Also, the research provides an effective and accurate decision-making method to assist the investment in green buildings.

2.5 Summary

As a conclusion from the literature review, it has been found that problems in risk and uncertainties management were derived from a narrow perspective. Uncertainty management is one of the foremost snags in construction. Most of the solutions are abound with solving this problem but it must see demands of all project contestants. The uncertainty is always evaluated at the beginning of the construction project but it must be continuing process with solutions during the whole project life cycle. The uncertainty of weighting values and response were considered through individual interviews. The complication of the problem created the need to account for any sum of uncertainties or inexact data that arose during the simulations and ranking trials. A weighting sum method was also applied concurrently to the problem to compare and contrast the results and to give insight on any significant impacts on the resulting rankings. The multi criteria decision making (MCDM) 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 uncertainty analysis can be reduced to a large extent. Project managers can predict the overall uncertain factors of the project before starting the implementation. The multi criteria decision making (MCDM) analysis provides a systematic, efficient and more natural way to analyse the associated risks and uncertainties.

Chapter 3

Methods and Methodology

3.1 General

It has examined the concern over uncertainty and risk problem from the outlook of the construction industry. The researchers of the risk management are focused on the identification of random components, determination of the probability of their phenomenon and their clash over the construction project. At the completion of each phase, there is a decision point where uncertainties and risk assessment take place. Based on it, an appropriate decision is made regarding further actions or proceeding to the next phase. Modeling and simulation tools make the complex part of the world simpler to understand, define, an image. These tools require certain aspects from the real world and utilize various modeling tools for its purpose. The most suitable model should be allotted that particular required parameter to make optimum utilization of the tool. Multi criteria decision making (MCDM) deal with making decisions in the existence of several and usually inconsistent criteria. This type of decision-making is used where indeterminate and incomplete data are to be found for the solution. It is one of the most desired drawbacks handled by the researchers. Following research methodology is adopted to carry out the research work:

a. A decision-making model will be developed to mitigate uncertainties in construction projects.
b. Categorizing the factors as per the construction aspects of project cost, quality and time will be carried out.
c. Probability index, impact index and importance index so as to quantify the uncertain factors or uncertainty in construction project will be estimated.

d. Multi criteria decision making technique in MATLAB will be applied on results obtained from importance index and impact index.

The following Figure 3.1 elaborates the pattern of work conducted to simulate uncertainties in construction project.

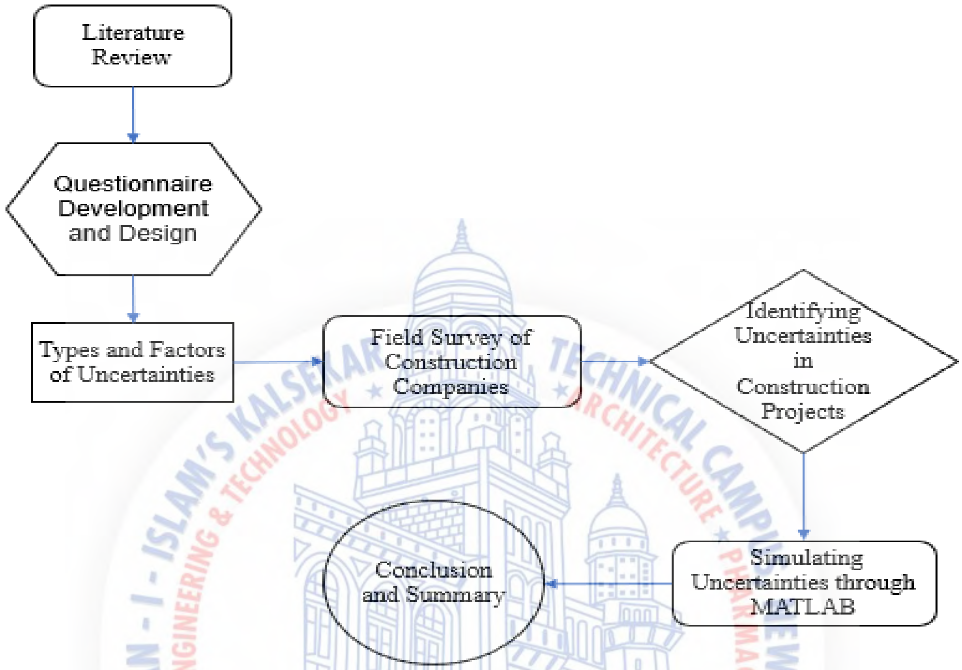

Figure 3.1 Process flow chart

Figure 3.1 particularizes the stages to accomplish the research; which focuses on the developing survey for collecting data, categorizing the identified types and factors of uncertainties, conducting field survey for better understanding of real uncertainties faced at the time of construction site, analyzing these uncertainties and resolve it with simulating technique.

3.2 Analysis of Uncertainties in Construction Project

The uncertainty analysis is the second stage in the process where collected data about the potential risk are analysed. Uncertainty analysis can be described as short-listing risks with the highest impact on the project, out of all threats mentioned in the identification phase. In the breakdown of the identified risk, two categories of methods qualitative and quantitative are developed. The qualitative methods are more relevant when factors can be placed over a vivid scale from high to low level. This can be used to determine the probability and impact of the uncertainties identified which are based on tentative numeric estimations. Generally, organizations tend to use a qualitative approach since it is more convenient to describe the uncertainty than to quantify them. Limitations of qualitative methods are in the accuracy of the data needed to provide a reliable study. In order to analyse uncertainty few criterions as accuracy, quality, reliability, and integrity of the information and understanding the risk are essential.

3.3 Uncertainty Assessment

Uncertainty assessment is an evaluation of something hypothetical defined as “vague”, which has to be explicated as “high”, or “low”, or “tolerable”. Such an assessment, whether qualitative or quantified, requires analyst’s judgment, expert knowledge, and experience. Quantification of risk in scalar values focuses on uncertainties for various reasons together with difficulties in defining the possibility and significance severity and the mathematics of relating them. An online questionnaire was sent out as a follow up to the interviews. The aim was to focus on the general identified uncertainties, in order to put in a probability and impact matrix. Further investigation analysis shows that there are top 15 factors causing uncertainty and affecting the projects in the construction industry. These factors are considered an important field of study for improvement and stabilization of the construction industry. The respondents were then asked to evaluate the probability of the uncertainty occurrence as well as the impact on time, cost and quality. The following Table 3.1. shows those 15 factors causing uncertainty with respect to cost, time and quality in construction projects.

Table 3.1 Major Factors of Uncertainty

Sr. No.	Attributes	Particulars
1.		Planning
2.		Funding approval
3.	Cost	Cost estimation
4.		Budget controls
5.		Other technical
6.		Planning
7.		Project management
8.	Time	Scheduling
9.		Constructability
10.		Documentation
11.		Environmental
12.		Engineering
13.	Quality	Civil, Structural, Systems
14.		Construction management
15.		Legal matters

3.4 Questionnaire Development

Questionnaires are extremely critical components of the research process because they identify which information is important and the participants about the discussed problem. The design of the questionnaire requires very careful consideration. One should aim at formulating the question such that no misinterpretation is possible. To do this, the following points should be taken into consideration in designing the questionnaire:

1. Proper introduction of the questionnaire explaining the purpose of the study and emphasizing the confidentiality of responses.
2. The question must give the information required.
3. The question be brief and clear.
4. The question must be presented in the best sequence possible, preferably from simplest to most complex.

The questionnaire survey as google form was sent via email and SMS to a sample of engineers involved in project management. Out of 72 reach-outs around 58 responses were received. The questionnaire contained some questions grouped into separate sections: (i) background information about the company; (ii) identification of critical uncertainty and their impact by ranking; (iii) company strategies to handle identified uncertainties; and (iv) awareness about the availability of current risk analysis and response techniques and suggestions made accordingly. Based on all the assembled information, quantitative analysis was implemented. The response rate for completed questionnaires is shown in Figure 3.2.

Figure 3.2 Response Breakdown

As realised in the entire questionnaire survey as per participated among contractors, consultants and clients of construction projects from various sectors which possessed 40% of contractors, 38% of clients and 22% of clients; which is why the research inclines more towards contractor's perspective.

3.5 Rating Uncertainties

Importance Index (IMP INDEX) technique was adopted for this research; in this technique, for each cause/factor, two questions should be asked: What is the rate of occurrence for this cause? And what is the impact of this cause? Both rates of occurrence and impact were categorized on a five to one-point scale. The rate of occurrence is categorized as follows: very high, high, moderate, low, very low (on a 5-1point scale). Likewise, the degree of severity was written off as follows: extreme, great, moderate and little (on 4 to 1 point scale) Gajewska and Ropel (2011). Probability index: A formula is used to rate causes of uncertainty based on the rate of occurrence as identified by the participants.

$$\text{Probability Index (P.I.)} = \sum a\,(n/N) * 100/5 \quad (1)$$

Where a is the constant stating weighting given to each reply (ranges from 1 for very low up to 5 for very high), n is the frequency of the replies, and N is the total number of replies.

Impact index: A formula is used to rate the impact of the cause on factors as indicated by the participants.

$$\text{Impact Index (I.I.)} = \sum a\,(n/N) * 100/5 \quad (2)$$

Where a is the constant stating weighting given to each reply (ranges from 1 for very low up to 5 for very high), n is the frequency of the replies, and N is the total number of replies.

Importance index: The importance index of each reason is calculated as a function of both frequency and impact indices, Gajewska and Ropel (2011), as follows:

$$\text{Importance Index (IMP.I.)} = [\text{P.I. }(\%) * \text{ I.I. }(\%)]/100 \quad (3)$$

Where,

P.I. = Probability Index

I.I. = Impact Index

IMP.I. = Important Index

These grades made it possible to cross-compare the relative importance of the factors as perceived by the three groups of respondents (i.e. clients, consultants, and contractors). Each individual cause's IMP. I. perceived by all respondents should be used to assess the general and overall ratings in order to give an overall picture of the causes of uncertainties in the construction industry.

3.6 Modeling and Simulation in Construction Projects

Model and simulate dynamic system behaviour with MATLAB, Simulink and Simscape can be functioned in the construction industry as well. Modelling is a way to create a virtual representation of a real-world system that includes software and hardware. If the software workings of this model are driven by mathematical relationships, one can simulate this virtual illustration under a wide range of conditions to see how it behaves. Modelling and simulation are especially valuable for testing conditions that might be difficult to reproduce with hardware prototypes alone, especially in the early phase of the design process when hardware may not be available. Iterating between modelling and simulation can improve the quality of the system design early, thereby reducing the number of errors found later in the design process. Common representations for system models include block diagrams, schematics, and state charts. In the Model-Based Design, a system model is at the core of the development procedure, from rations development through design, implementation, and testing. The model is an executable description that constantly refines throughout the development course. After the model is developed, the simulation shows if the model performs correctly or not.

When software and hardware application necessities are included with the model, such as fixed-point and timing behaviour, the code is generated for embedded deployment and create test benches for system verification, saving time and avoiding manually coding errors.

Model-Based Design allows you to improve efficiency by:

- Using a common scheme environment through project teams
- Linking designs directly to requirements
- Integrating testing with design to constantly find and correct errors
- Refining algorithms through multi-domain simulation
- Generating embedded software code
- Developing and reusing test suites
- Generating documentation
- Reclaiming designs to organise systems across numerous processors and hardware targets

Model analysis tools comprise linearization and trimming tools that can be retrieved from MATLAB, also various tools in MATLAB and its application toolboxes certainly can. Because MATLAB and Simulink are integrated and can simulate, analyse, or revise your models in every situation.

3.7 Decision making process

Each of the phases of the project life cycle (PLC) has a certain purpose and scope of work assigned. By the completion of every phase, there is a decision point where risk evaluation takes place. Based on the risk evaluation, a suitable decision is made concerning supplementary actions or proceeding to the next phase. For project management to be operative, an assessment should be made together with all phases of the PLC. By using 'go', 'maybe' and 'no go' options in a decision-making process. A 'go' rank will constitute a green light for taking place on to the next phase whereas 'no go' will stop the project. Evaluation resulting in a 'maybe' decision will lead to a return to a previous phase or even phases for further improvements and minimizing risk. The further on in the phases the 'maybe' decision is made, which takes the development back to the preliminary stages while more complications are caused. It is probably to go back in stages within a PLC, conversely, this demoralizes decisions which were made in prior phases and leads to a waste of resources, typically both time and money. Decisions which are made at the end for each stage would be made after a careful learning of the possible risks and hindrances which may perhaps be encountered. The ultimate goal of any uncertainty-assessment system is to help decision-makers make informed risk decisions. Although estimating the risk can exposure quantitatively, what is really meaningful is the ranking of the risks. This enables decision-makers to identify the major risks and provides them with a better understanding of the relative magnitude of the risks. As long as the assumptions and approaches used for assessing risks are consistent, the ranking based on the multi criteria systems will be meaningful. In addition to uncertainty identification and assessment, MCDM may play an important role in strategic planning and may affect new business plans and strategic capital management. Decision-makers can obtain a more holistic view of the company’s risks when planning its future.

Chapter 4

Data Analysis

4.1 General

A professional project manager already knows how to translate decisions into actions by communicating, delegating, reviewing progress. etc. The hard plan is reaching the right decision and doing this in a sufficiently timely fashion for the actions to be effective. If the wait is long enough, it becomes easy to spot the right decision but only because a missed chance to take effective action. This is the benefit of perception although the lessons can be learned for next time. That doesn't help with the immediate problem. So as to manage uncertainty effectively, making and implementing effective decisions is a fundamental part of the process.

4.2 Effective Decision-making

The skill to predict how key aspects of a project will progress over time is one of the project manager's most important ability. It is responsible for a way to anticipate vulnerabilities. That is, where and when uncertainty can distress the project plan, by anticipating complications. Many anticipation strategies rely on modelling future behaviour and outcomes at key stages of the project, explored the idea of a forecasting model in terms of project driven and relationships. Identifying decision points and defining the intermediate states the project must achieve below the ultimate goal is reached. By modelling a project's most important factors-the task relationships, Key variables, Dependencies, resources, timescales, etc. the groundwork is laid for exploring what happens when we have these drivers. The model determines both the likelihood and implications of a range of scenarios.

4.3 Decision-making Model

The research focuses on effective decision-making model to mitigate project uncertainties encountered during project life cycle. One such method is executed in the search by preparing a decision matrix for analysing the best suitable option for the alternatives based on the confronted criteria or factors. Each factor will have its own weightage which will ease to identify the impact over each factor. A good forecasting model must not only identify this project driven but properly understand them as well. When the model is set up, one can run it forward to understand roughly about the project's likely future positions. These must be evaluated for their desirability which of the possible outcomes will achieve the project objectives. A decision-making procedure involves the subsequent steps to be followed:

1. Identification of the objective/goal for the decision-making process
2. Selection of the Criteria/Parameters/Factors/Decider
3. Selection of the Alternatives
4. Selection of the weighing systems to signify the importance
5. Method of Aggregation
6. Decision making based on the Aggregation results

Considering the above set of steps Table 4.1 is the decision matrix system designed for analysing the decision maker to reach desired decision.

Table 4.1 Decision matrix system

Criteria	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor N
Alternative 1							
Alternative 2							
Alternative 3							
Alternative 4							
Alternative 5							
Alternative 6							
Alternative N							

The above Table 4.1 decision matrix generated is to be filled by the decision makers to analyse the uncertainties examined at the time of the construction project. Decision matrix assists to figure out all the possible factors causing uncertainties as well as the probable alternatives to be performed to overcome the uncertainties. Recognizing them as different aspects of an underlying root problem, which reduces the number of states left to deal with. If the precise decision is made at the precise time, the project proceeds to an anticipated state. A decision may even push the project into a failure state from which recovery is impossible.

Once the matrix is organized the next is to formulate the data as input for Variable X in MATLAB workspace since the decision making is done using MATLAB software. In the interface of MATLAB, a new variable is created and named it as 'X' the variable name X must be in caps lock. Double click on the variable icon and the data from the matrix is to be copy-pasted in the cell. The following Figure 4.1 is an illustration of the interface of MATLAB workspace after the Variable X is generated. And close the variable tab.

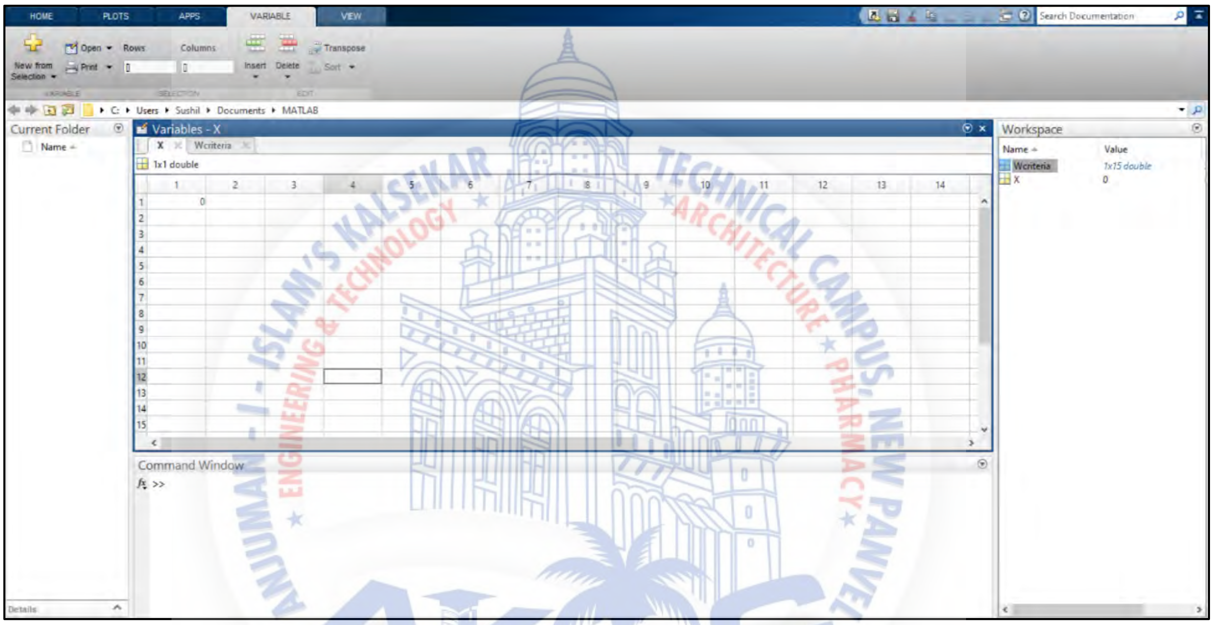

Figure 4.1 Variable X

Figure 4.1 shows Variable X successfully created, similarly another variable is to be created and name it as 'W' likewise the variable letter must be in caps lock. The values assigned for this variable will be the weightages granted to each factor as per their impacts over the affecting factors of say uncertainties.

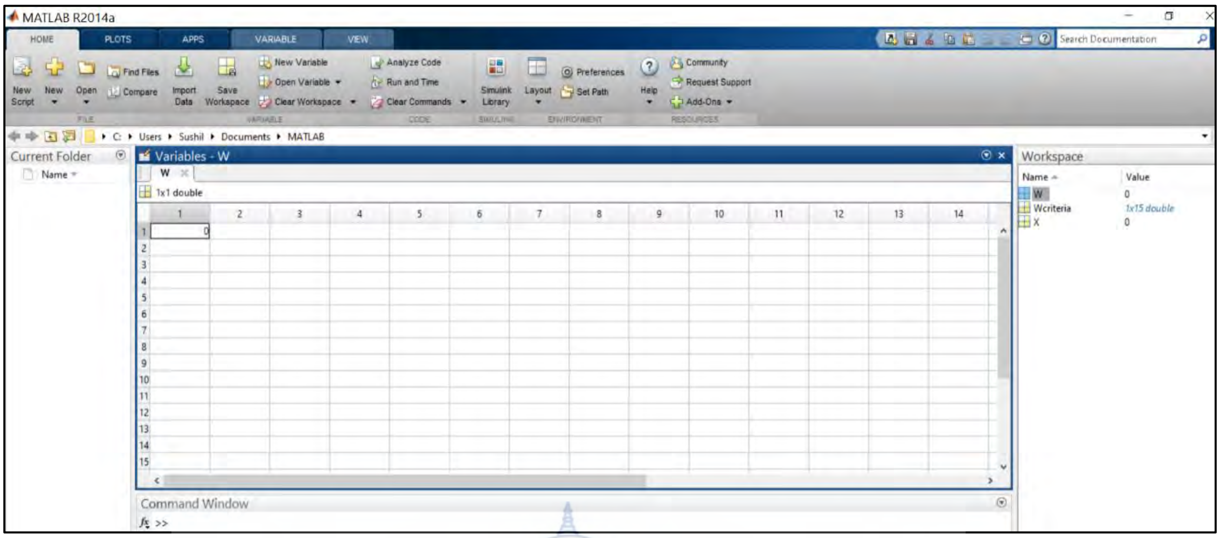

Figure 4.2 Variable W

The Figure 4.2 variable 'W' consists of weights assigned for the factors rating as per their priorities and causes of concern for the project and project life cycle. These weights decide the rating of the factors that could probably impact the success or failure of the event. The weights are to be filled up in the cell according to their ratings.

Now next it to create another variable and name it as 'W criteria' in this, the criteria are to be identified if they are beneficial or non-beneficial from the factors' perspectives. Beneficial criteria will have more weightage while non-beneficial. The criteria are assigned with values of IMP.I.%. Figure 4.3 is the illustration of how the W criteria will look alike when created in MATLAB.

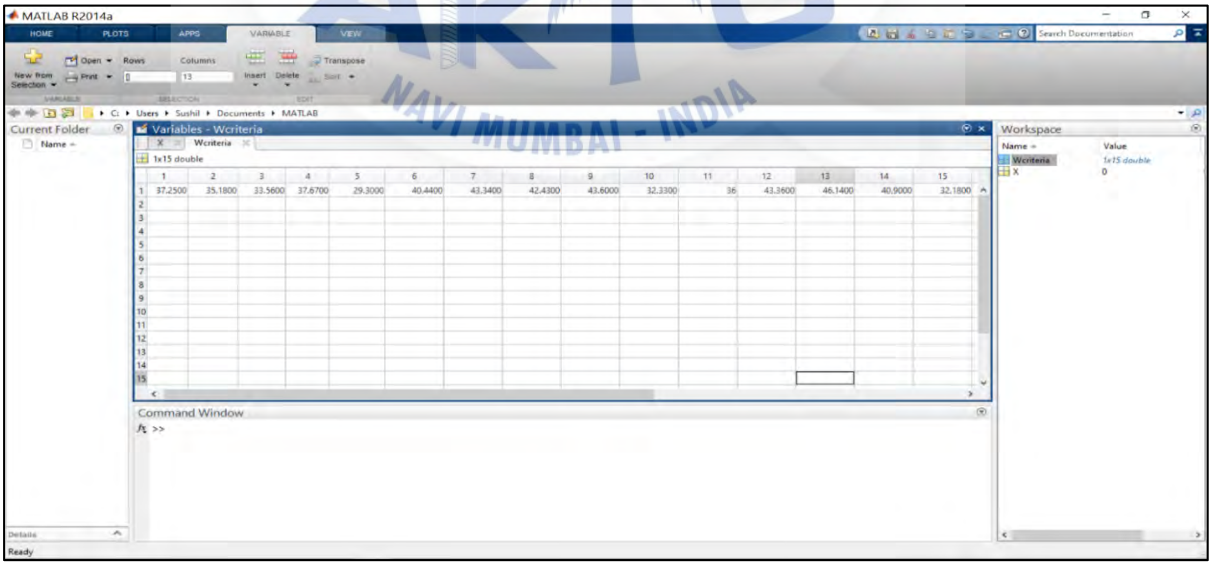

Figure 4.3 W criteria

Thus the variable W criteria are developed consisting of values of the important index. The importance index is used to rank the factors in this project. With respect to the magnitude of score rating of factors causing uncertainties. To make this model run convinced coding are to be generated. MATLAB coding for decision making plays a vital role in the successful operation of the model.

4.4 MATLAB code for decision making

Multi criteria decision making technique using MATLAB acquires coding to make the model run efficiently; the MATLAB coding involves following steps to be followed:

1. Create a new Script file in the Editor
2. Copy paste these codes in the Script file
3. Create 3 Matrix namely X, W, and Wcriteria
   - where X is the decision Matrix
   - W is the weights of the criteria
   - Wcriteria tells us that the criteria are beneficial or non-beneficial
4. Run the program.

The codes generated can be seen below:

```
Xval = length (X(:,1));
for i = 1: Xval
for j = 1: length(W)
if Wcriteria (1, j)= = 0
Y(i,j) = min (X(:,j))/X(i,j);
else
Y(i,j) = X(i,j)/max(X(:,j));
end
end
end
for i = 1:Xval
PWSM(i,1) = sum(Y(i,:).*W);
PWPM(i,1)=prod(Y(i,:).^W);
end
lamda=0.5
J=lamda*PWSM+(1-lamda)*PWPM;
Joint_generalized_criterion = num2str([J])
```

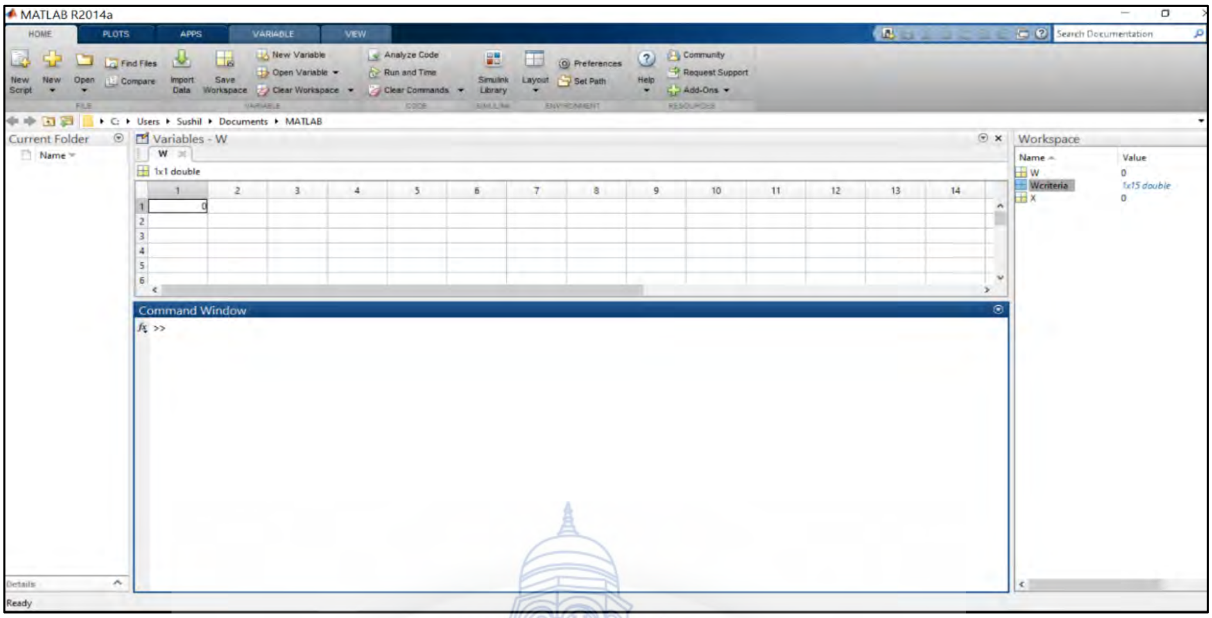

Figure 4.4 Command window

Figure 4.4 illustrates the command window where the codes are to be designed. These codes are set in the command window to generate the model. When the codes are entered the 'Enter' command is given which produce preference codes for the attributes of the decision matrix. On basis of preference codes, the alternatives can be ranked with respect to the factors inclination. The values of preference codes ultimately decide the ranks for the alternatives. The codes with the highest ranks are the alternatives of major factors for uncertainties and the codes with lowest ranks can be low/less affecting the project patterns.

Chapter 5

Results and Discussions

5.1 General

This chapter presents and discusses the results of the collected data. Also, analysis has been achieved. In order to rank the risk factors affecting the companies working in the construction industry, importance index and average risk score method were used. The comparisons of risk factors between the different companies are tabulated.

5.2 Probability Rate and Impact of Uncertain Factors

Considering the ratings received from the participants the further calculations for probability index were thus intended. Each individual factor rate was summed up to examine the average rate of factors and probability index (P.I.) to identify the probability of factors causing uncertainties in the respective construction project. The factors of uncertainties identified by the participants were from the following activities:

- Planning
- Funding approval
- Cost estimation
- Budget controls
- Other technical
- Inventory Planning
- Project management
- Scheduling
- Constructability

- Documentation
- Environmental
- Engineering
- Civil, Structural, Systems
- Construction management
- Legal matters

From appendix I results of probability frequencies were deliberated on the basis of the questionnaire survey conducted. Further probability index was calculated as mentioned in Table 5.1 as data for the research work.

Table 5.1 Probability Index

Particulars	Rating	Average	Probability Index
Planning	178	3.068965517	0.613793103
Funding approval	173	2.982758621	0.596551724
Cost estimation	169	2.913793103	0.582758621
Budget controls	179	3.086206897	0.617241379
Other technical	154	2.655172414	0.531034483
Inventory Planning	190	3.275862069	0.655172414
Project management	197	3.396551724	0.679310345
Scheduling	195	3.362068966	0.672413793
Constructability	193	3.327586207	0.665517241
Documentation	171	2.948275862	0.589655172
Environmental	172	2.965517241	0.593103448
Engineering	187	3.224137931	0.644827586
Civil, Structural, Systems	195	3.362068966	0.672413793
Construction management	182	3.137931034	0.627586207
Legal matters	164	2.827586207	0.565517241

The above Table 5.1 was hence functioned for estimating Probability Index (P.I.). Likewise, from appendix II results of impact frequencies were deliberated on the basis of the questionnaire survey conducted. The following Table 5.2 was hence functioned for estimating Impact Index (I.I.)

Table 5.2 Impact Index

Particulars	Rating	Average	Impact Index
Planning	176	3.034482759	0.606896552
Funding approval	171	2.948275862	0.589655172
Cost estimation	167	2.879310345	0.575862069
Budget controls	177	3.051724138	0.610344828
Other technical	160	2.75862069	0.551724138
Inventory Planning	179	3.086206897	0.617241379
Project management	185	3.189655172	0.637931034
Scheduling	183	3.155172414	0.631034483
Constructability	190	3.275862069	0.655172414
Documentation	159	2.74137931	0.548275862
Environmental	176	3.034482759	0.606896552
Engineering	195	3.362068966	0.672413793
Civil, Structural, Systems	199	3.431034483	0.686206897
Construction management	189	3.25862069	0.651724138
Legal matters	165	2.844827586	0.568965517

The Table 5.2, explains the impact index for each factor causing uncertainties in construction projects was estimated with due consideration of participant's rate of impact over the particular factors. These participants had individually rated the impact of the factors causing uncertainties for their projects as per their knowledge and experience.

5.3 Findings from Importance Index (IMP. I.)

Approximation of these probability index and impact index were then utilized for estimation of Important Index for the factors causing uncertainties in construction projects. The IMP.I. rating shows the Major Uncertain Factor affecting the project's cost, time and quality, as shown in below Table 5.3, the score has been calculated using ranking given by respondents. This IMP.I. indicates the probable impact on the factor causing uncertainty, higher the importance index higher is the rate of concern for uncertainties. The IMP.I. with minimal percentage are of less concern when compared. From appendix III results of probability and impact index were deliberated on the basis of the questionnaire survey conducted to calculated importance index of each aspect causing uncertainties in construction project.

Table 5.3 Importance Index

Sr. No.	Particulars	P.I.	I.I	IMP. INDEX%
1	Planning	0.61	0.61	37.25
2	Funding approval	0.60	0.59	35.18
3	Cost estimation	0.58	0.58	33.56
4	Budget controls	0.62	0.61	37.67
5	Other technical	0.53	0.55	29.30
6	Inventory Planning	0.66	0.62	40.44
7	Project management	0.68	0.64	43.34
8	Scheduling	0.67	0.63	42.43
9	Constructability	0.67	0.66	43.60
10	Documentation	0.59	0.55	32.33
11	Environmental	0.59	0.61	36.00
12	Engineering	0.64	0.67	43.36
13	Civil, Structural, Systems	0.67	0.69	46.14
14	Construction management	0.63	0.65	40.90
15	Legal matters	0.57	0.57	32.18

From the above Table 5.3 we understand, the factor Civil, Structural, Systems has maximum IMP.I. % i.e. 46.14 while the factor other technical possess least IMP.I. % as 29.30. This specifies that the factors encountered with maximum IMP.I. can be concentrated on a priority basis and vice versa. Required precautions are taken when will thus diminish the uncertainties arising while execution of construction projects. This ease the work of decision makers to decide the major important factors affecting the project and thus work on it on an immediate basis so as to avoid the complex situations in near future and optimize their outputs. The Figure 5.1 is a representation of the importance index percentage of every factor graphically.

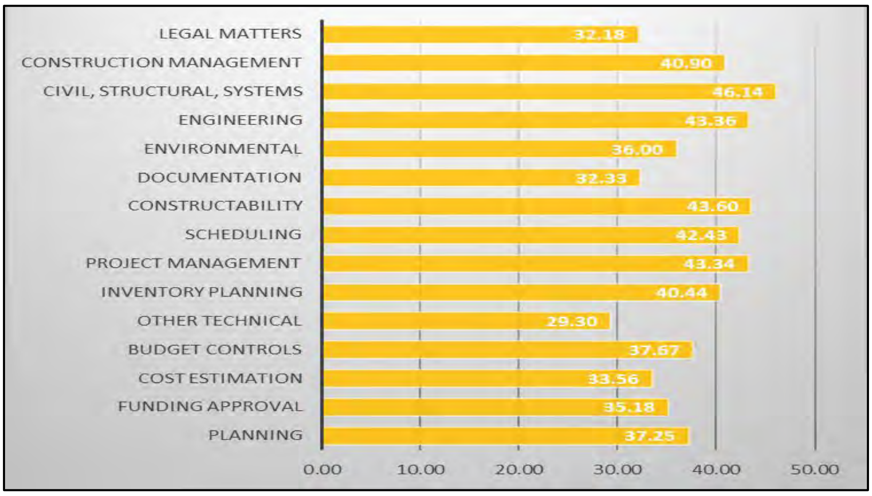

Figure.5.1 Importance Index %

The Figure 5.1 elaborates the important index % obtained from the statistical analysis that quantifies the uncertainties examined at project execution. It enables the project manager to model how events will unfold. Even a simple project has some of the other traits which dictate a sequence of events, estimates how long certain tasks will take and identifies the resources needed to accomplish the goals. More complex projects explicitly model many more key aspects of the project such as supply chain dependencies and benefits realization. As shown in Figure 5.1 the factor causing uncertainty in parameter civil, structural systems possess maximum percentile which determines the activities taking place in these parameters are of greater concern and precautionary measures are to be taken so as to overcome the hurdles caused; whereas activities of other technical parameters do not require much attention while execution. This approach takes a subjective view of probability as a measure of the degree of belief in a hypothesis. Although it is a belief that this is a step in the right direction to represent epistemic uncertainty and still it is not satisfactory. Research into modern theories of uncertainty-based information, such as possibility theory, evidence theory, fuzzy set theory, and imprecise probability theory. But, these theories are not well established when compared to probabilistic interpretation.

Knowledge-centric strategies provide the ability to visualize future stales of the project. This 'forward look' is determined by knowledge of many different variables, such as:

1. What resources are needed to create the necessary outputs?
2. Is it likely that the project objectives will change?
3. Will external inputs be available on time?
4. What levels of efficiency can the teamwork at?

5. Are there dependencies on things outside the project manager's immediate control?

They can analyse different scenarios by building forecasting models of how these key variables alter over time. The better the model, the less uncertainty there is about the future, and the better our decision-making becomes. We can think of each project driver as a kind of knowledge-node where a collection of facts, variables and constraints are at work. Many of these drivers are dependent on each other and even where there are no obvious dependencies, there may be subtle influence. Therefore, understanding how these relationship works is another kind of knowledge. Building the forecasting model can be hard. Some of the project drivers may be hidden or their relevance only become apparent later in the project. Similarly, relationship may be poorly understood even when the drivers are known. Worse still, both project drivers and relationship can change during the course of the project. For the forecasting model to be useful, the project manager must have sufficient knowledge of the drivers and relationships both now and in the future. Effective decision-making lies at the heart of managing uncertainty. If we are unable (or unwilling) to make effective decisions, then our options shrink to a single path - to let uncertainty run its course and hope that it remains quiescent. There are strategic decisions, to invest in researching a particular area of uncertainty, or to develop mitigation plans for major scenarios, or to redefine objectives to avoid problem areas. Decision without actions are pointless. Actions without decisions are reckless, taking action is just the flip-side of decision-making.

5.4 Multi-Criteria Decision Making (MCDM)

Multi criteria decision-making (MCDM) refers to making decisions in the presence of multiple and usually conflicting criteria. The decision-making is used where vague and incomplete data exist for the solution. The proposed evaluation framework is applied to a random data obtained from the conducted field survey with the purpose of understanding the process in MATLAB interface which may assist decision-makers to fulfill their responsibilities. A sample decision matrix can be seen in Table 5.4 which decides the major factors affecting the cost of the construction project.

Table 5.4 Sample Decision Matrix

Criteria	Planning	Funding Approval	Cost Estimation	Budget Controls
Planning	32	31	33	30
Design Works	34	41	35	38
Site Clearance	32	32	29	37
Execution	42	34	38	39
Project Controlling	43	41	42	40

The criteria and their values of above Table 5.4 are taken from the factors and rating determined from the analysis of the probability of uncertainties in construction projects on the basis of the responses of the participants. The values of Table 5.4 were put into the MATLAB interface and with the help of the coding, the output was generated. The following Figure 5.2 is the interface of the command window where the values are entered.

```
Command Window
>> Xval=length(X(:,1));
for i=1:Xval
for j= 1:length(W)
if Wcriteria(1,j)== 0
Y(i,j)=min(X(:,j))/X(i,j);
else
Y(i,j)=X(i,j)/max(X(:,j));
end
end
end
for i=1:Xval
PWSM(i,1)=sum(Y(i,:).*W);
PWPM(i,1)=prod(Y(i,:).^W);
end
lamda=0.5
J=lamda*PWSM+(1-lamda)*PWPM;
Joint_generalized_criterion = num2str([J])

lamda =

    0.5000

Joint_generalized_criterion =

0.75892
 0.8915
0.78273
0.92042
      1

>>
```

Figure 5.2 Command Window with Codes

From Figure 5.2 we function MCDM in MATLAB interface which provided with the certain preference scores. These scores further analysis the rate of concern of that particular activity which tends to affect the smooth functioning of the construction project. The scores even decide which activity has more or moderate rate of impact on the construction process. The following Table 5.5 is Final decision matrix that provides decision makers to take required measures while performing the activity.

Table 5.5 Final Decision Matrix

Criteria	Planning	Funding Approval	Cost Estimation	Budget Controls	Score
Planning	32	31	33	30	0.75892
Design Works	34	41	35	38	0.89150
Site Clearance	32	32	29	37	0.78273
Execution	42	34	38	39	0.92042
Project Controlling	43	41	42	40	1

In Table 5.5, the Project Controlling criteria secured the maximum score of 1, which would help decision makers to understand maximum uncertainties in construction projects may irrupt which execution of project controlling. Whereas, execution activity will also have certain uncertainties and risk causing factors but less than that of project control. When a project is in planning phase the uncertainties encountered will be least, this is decided with the least preference score 0.75892. The activities under criteria site clearance and design works will have to face moderate uncertainties while in process.

This decision framework so-called multi criteria decision making in MATLAB, can evaluate the factors and agencies causing uncertainties in the construction project and leads to various disturbances for Project Life Cycle.

5.5 Discussions

The current approach in the area of uncertainty engineering applied either numerical values of probability and impact or worked with a classical sharp jurisdiction of these values into certain sets, which for many applications not appropriate and did not correspond to the actual perception of the cause. Multi criteria decision making approach to modelling these processes minimize this shortcoming. In Multi criteria decision making technique using MATLAB, the model generated provides with preference codes which ranks the alternative with due consideration of their factors affecting optimization. The preference codes with higher value indicate the maximum affecting factors for that alternative. The preference codes with that of lower values indicate minimal affecting factors for alternatives. This procedure eases the decision makers to decide which alternatives are to be preferred and which alternative cannot be feasible; and further work over the factors which are obstructing the current situations optimization that remained unnoticed in an initial stage of the construction project. This technique nearly diminishes the factors causing uncertainty or any another aspect which tries to disturb the execution of construction project.

Chapter 6

Summary and Conclusions

6.1 Summary

In India, risk management is still a new word in the construction sector and this should be changed as soon as possible. At present, the Government of India has proposed a risk rating system that will help the developers to develop projects at a faster pace by taking quick decisions. Each rating activity will have its own methodology to rate projects. The system will assist the government to develop a scheme to mitigating risk. This will inspire more response from developers and investors for public-private partnerships projects. It could also make the bidding projects more competitive. The system will support bankers to take quick decisions for lending finances, which could lead to the financial closure of the project at a faster pace. Third party risk rating would certainly raise critical points, which are not normally raised during finalization of the project.

This study has created a list of uncertainties and it's an impact on the construction industry using survey. This study should assist management in identifying activities where there is an uncertainty of injury or loss and hence provide a basis for management decisions on the application of resources. This enables management to take objective decisions on the reduction of agencies causing uncertainties to an agreed level. The entire study is about minimizing the factors causing uncertainties in construction projects that occur in project execution in terms of time, material, quality, cost etc. This research eliminates the uncertainty by focusing on choosing appropriate alternatives over the hindrances so that the project execution can be carried out appropriately considering effective and economic construction. On basis of multi criteria decision making technique using MATLAB techniques, through a complete analysis of a better alternative over the uncertain ones was performed and based on the preference code and ratings of factors causing difficulties, the conclusion of the research work was made. The developed model can be used to sort projects based upon risks and uncertainties, which facilitate company's decision of which project can be pursued.

6.2 Conclusion of the experimental program

The ability to make the decision when dealt with uncertainty is a real challenge. The good decision is always based on the availability of good information. But there is always an uncertainty that prevail in the project which does not allow us to give an accurate data. So we need to understand from where the uncertainty raises, so that we use proper strategies to mitigate it. If we can learn how to reduce, we can make better management decision and increase the chances of project succeeding. The project manager needs to understand the exact source and root cause of the uncertainty, so that proper strategies can be employed to mitigate it. In this work various factors causing uncertainties in construction projects were identified from the experienced based data collected and literature review. These factors were analysed by calculating probability causing uncertainties in construction projects by using Importance index method. Based on ranks obtained from the importance index the most important causes of uncertainty that affects execution of construction projects were identified. A MCDM model is developed using MATLAB software as a platform to simulate uncertainties in construction projects.

6.3 Future Scope

Future studies could be performed for various specific types of construction projects, such as road and railway construction projects, mass housing projects, utility projects, bridges, dam construction projects, etc. Future research must also look in more detail at uncertainty management processes, such as risk management planning, identification, measurement, prioritization, monitoring, and control. Using different model parameters such as Simulink methods uncertainties can be precisely taken into consideration. This research sets a benchmark for future researchers in this domain and opens up a plethora of options were many other parameters constraints can be considered to develop a more powerful, user-friendly software that can analyse all the possible of uncertain factors.

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APPENDIX-I

Results for Probability and Impact Frequencies

Sr.no	Attributes	Particulars	Probability (frequency) Rating					Impact Rating				
			1	2	3	4	5	1	2	3	4	5
1	Cost	Planning	4	14	23	8	9	4	16	21	8	9
2		Funding approval	9	11	12	16	10	10	9	17	16	6
3		Cost estimation	6	14	20	12	6	6	17	18	12	5
4		Budget controls	6	9	20	14	9	7	9	22	14	6
5		Other technical	5	25	14	8	6	5	23	15	9	6
6	Time	Planning	7	8	19	10	14	10	7	19	9	13
7		Project management	5	9	14	10	20	7	13	14	10	14
8		Scheduling	3	11	16	18	10	4	12	16	16	10
9		Constructability	4	11	17	14	12	5	10	16	13	14
10		Documentation	6	16	15	14	7	8	17	19	10	4
11	Quality	Environmental	4	18	17	14	5	3	17	18	15	5
12		Engineering	5	8	21	12	12	4	7	23	12	12
13		Civil, Structural, Systems	4	11	17	12	14	4	8	18	13	15
14		Construction management	6	12	17	11	12	4	10	19	11	14
15		Legal matters	7	20	11	16	4	5	21	12	16	4

APPENDIX-II

Results for Probability and Impact Range

Sr.no	Attributes	Particulars	Probability (X) Range					Impact (X) Range				
			0.1	**0.3**	**0.5**	**0.7**	**0.9**	**0.05**	**0.1**	**0.2**	**0.4**	**0.8**
1	Cost	Planning	0.0690	0.2414	0.3966	0.1379	0.1552	0.0690	0.2759	0.3621	0.1379	0.1552
2		Funding approval	0.1552	0.1897	0.2069	0.2759	0.1724	0.1724	0.1552	0.2931	0.2759	0.1034
3		Cost estimation	0.1034	0.2414	0.3448	0.2069	0.1034	0.1034	0.2931	0.3103	0.2069	0.0862
4		Budget controls	0.1034	0.1552	0.3448	0.2414	0.1552	0.1207	0.1552	0.3793	0.2414	0.1034
5		Other technical	0.0862	0.4310	0.2414	0.1379	0.1034	0.0862	0.3966	0.2586	0.1552	0.1034
6	Time	Planning	0.1207	0.1379	0.3276	0.1724	0.2414	0.1724	0.1207	0.3276	0.1552	0.2241
7		Project management	0.0862	0.1552	0.2414	0.1724	0.3448	0.1207	0.2241	0.2414	0.1724	0.2414
8		Scheduling	0.0517	0.1897	0.2759	0.3103	0.1724	0.0690	0.2069	0.2759	0.2759	0.1724
9		Constructability	0.0690	0.1897	0.2931	0.2414	0.2069	0.0862	0.1724	0.2759	0.2241	0.2414
10		Documentation	0.1034	0.2759	0.2586	0.2414	0.1207	0.1379	0.2931	0.3276	0.1724	0.0690
11	Quality	Environmental	0.0690	0.3103	0.2931	0.2414	0.0862	0.0517	0.2931	0.3103	0.2586	0.0862
12		Engineering	0.0862	0.1379	0.3621	0.2069	0.2069	0.0690	0.1207	0.3966	0.2069	0.2069
13		Civil, Structural, Systems	0.0690	0.1897	0.2931	0.2069	0.2414	0.0690	0.1379	0.3103	0.2241	0.2586
14		Construction management	0.1034	0.2069	0.2931	0.1897	0.2069	0.0690	0.1724	0.3276	0.1897	0.2414
15		Legal matters	0.1207	0.3448	0.1897	0.2759	0.0690	0.0862	0.3621	0.2069	0.2759	0.0690

APPENDIX-III

Results for Probability and Impact Index

Sr.no	**Attributes**	**Particulars**	**Probability Index (P.I.) Rating**					**Impact Index (I.I.) Rating**				
			1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
1	Cost	Planning	0.0069	0.0724	0.1983	0.0966	0.1397	0.0034	0.0276	0.0724	0.0552	0.1241
2		Funding approval	0.0155	0.0569	0.1034	0.1931	0.1552	0.0086	0.0155	0.0586	0.1103	0.0828
3		Cost estimation	0.0103	0.0724	0.1724	0.1448	0.0931	0.0052	0.0293	0.0621	0.0828	0.0690
4		Budget controls	0.0103	0.0466	0.1724	0.1690	0.1397	0.0060	0.0155	0.0759	0.0966	0.0828
5		Other technical	0.0086	0.1293	0.1207	0.0966	0.0931	0.0043	0.0397	0.0517	0.0621	0.0828
6	Time	Planning	0.0121	0.0414	0.1638	0.1207	0.2172	0.0086	0.0121	0.0655	0.0621	0.1793
7		Project management	0.0086	0.0466	0.1207	0.1207	0.3103	0.0060	0.0224	0.0483	0.0690	0.1931
8		Scheduling	0.0052	0.0569	0.1379	0.2172	0.1552	0.0034	0.0207	0.0552	0.1103	0.1379
9		Constructability	0.0069	0.0569	0.1466	0.1690	0.1862	0.0043	0.0172	0.0552	0.0897	0.1931
10		Documentation	0.0103	0.0828	0.1293	0.1690	0.1086	0.0069	0.0293	0.0655	0.0690	0.0552
11	Quality	Environmental	0.0069	0.0931	0.1466	0.1690	0.0776	0.0026	0.0293	0.0621	0.1034	0.0690
12		Engineering	0.0086	0.0414	0.1810	0.1448	0.1862	0.0034	0.0121	0.0793	0.0828	0.1655
13		Civil, Structural, Systems	0.0069	0.0569	0.1466	0.1448	0.2172	0.0034	0.0138	0.0621	0.0897	0.2069
14		Construction management	0.0103	0.0621	0.1466	0.1328	0.1862	0.0034	0.0172	0.0655	0.0759	0.1931
15		Legal matters	0.0121	0.1034	0.0948	0.1931	0.0621	0.0043	0.0362	0.0414	0.1103	0.0552

LIST OF PUBLICATIONS

1. Katrekar S., R. B. and Khan A. (2018), “A Review on Simulating Uncertainties in Construction Projects”, International Advanced Research Journal in Science, Engineering and Technology, Vol. 5, Special Issue 3, pp. 114-117.
2. Katrekar S., R. B. and Khan A. (2018), “A Review on Simulating Uncertainties in Construction Projects”, International Conference on Advances in Civil Engineering (IC-ACE2018), Thakur College of Engineering and Technology, February 2018.
3. Katrekar S., R. B. and Mahajan G.B. (2018), “Application of Multi Criteria Decision to Simulate Uncertainties in Construction Projects”, communicated in National Conference on ", ASMMCE 2018, NIT Jalandhar, November 3rd-4th, 2018.

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