



**DEVELOPMENT OF MATHEMATICAL MODEL OF  
FUZZY RISK ANALYSIS IN CONSTRUCTION  
PROJECTS**

**BY**

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## ABSTRACT

Construction projects are more subjective and risky compared to other projects due to the unique characteristics of construction activities and high level of uncertainty such as topographical factors of project, changing of weather, sort of project, the effects of economy, sub-contractor accessibility, and the impacts of politics, etc. Risk analysis and management of the project is the first key to achieve adequate level of project success. Previous few studies have been done to quantify risk analysis utilizing different methods, for example, Monte Carlo, Event Tree Analysis (ETA), Failure Mode and Effect Analysis, Risk Matrix. However, some of those methods are either limited and hard to be used or do not support the quantitative method because of the required measure of information to quantify and analyse the risk factors. Moreover, modern construction and new sophisticated design have shown significant obstacles and uncertainties to complete the project safely with success; thereby it is inevitable to search for a new approach to deal with uncertainties. The fuzzy system has the ability to convert the natural verbal human thoughts to computational comprehensive intervals, deliver the accurate reasoning process, and deal with inexact and vague information. Thus, this leads to an absolute result, fewer failures, and a lower tolerance for risk in construction projects. This research defines the critical factors in construction project success, namely the iron triangle time-cost-quality in the projects, reviews some techniques and methods in engineering construction projects, conducts an original contribution to develop a quantitative risk analysis method using fuzzy logic and validate the result in software Matlab. This research also describes the stages of the fuzzy risk analysis model which is developed to assess the risks related to construction projects and their uncertainties based on evaluations of the criteria of project success which represents the iron triangle: cost, time and quality. The method is verified on a real project which demonstrates the results of comparison and proves the advantages of using fuzzy logic as risk analysis method. Ultimately, by using this model we can prioritize and rank all risk factors cited in the construction project; besides that we can easily manage them in the best appropriate way. To sum up, using fuzzy risk analysis eases the risk of management process and affects positively the decision made by the experts to monitor and control the project and meet the satisfaction of stakeholders. As a result, the project will reach the ultimate degree of success.

## ملخص البحث

مشاريع البناء هي أكثر ذاتية ومحفوفة بالمخاطر مقارنة مع مشاريع أخرى بسبب الخصائص الفريدة لأنشطة البناء وارتفاع مستوى عدم اليقين مثل العوامل الطبوغرافية للمشروع، والتغير في الطقس، ونوع المشاريع، والآثار الاقتصادية، وتوفر المقاولون، والآثار السياسية... الخ. تحليل وإدارة المخاطر للمشاريع هو المفتاح الأول لتحقيق مستوى مطمئن لنجاح المشروع. في العقود القليلة الماضية تم تطبيق عدة دراسات لتحديد وتحليل المخاطر باستخدام أساليب مختلفة، على سبيل المثال، مونت كارلو، التحليل التخطيطي كالشجرة، وضع الفشل وتحليل التأثير، مصفوفة المخاطر. ومع ذلك، فإن بعض تلك الأساليب إما محدودة ويصعب استخدامها أو هي لا تدعم طريقة التقدير الكمي للخطر بسبب المتطلبات الخاصة للمعلومات لتحديد وتحليل عوامل الخطر. وبالإضافة إلى البناء الحديث والتصميم المتطور الجديد، قد أظهرت عقبات وشكوك كبيرة لإنجاز المشروع في أمان والنجاح؛ وبالتالي فإنه لا مفر من البحث عن نهج جديد للتعامل مع حالات عدم اليقين لإنجاز المشاريع. إن نظام فازي لديه القدرة على تحويل الأفكار الطبيعية والبشرية اللفظية إلى مجالات حسابية شاملة، وتقديم عملية التفكير الدقيقة، والتعامل مع المعلومات غير الدقيقة والغامضة. وبالتالي هذا يؤدي إلى نتيجة مطلقة، أقلها الفشل، وتقليل الخطر في مشاريع البناء. يحدد هذا البحث معايير النجاح المسمى المثلث الحديدي (الوقت - التكاليف - الجودة) في المشاريع ويستعرض بعض التقنيات والأساليب في هندسة البناء والمساهمة في تطوير الأسلوب الكمي لتحليل المخاطر باستخدام منطق فازي وتأكيد النتيجة باستعمال برنامج المطلب. يصف هذا البحث أيضا مراحل نموذج فازي لتحليل المخاطر التي تم تطويره لتقييم المخاطر المرتبطة مع مشاريع البناء وعدم اليقين على أساس تقييم معايير نجاح المشروع الذي يمثل المثلث الحديدي: التكلفة والوقت والجودة. وفي النهاية يمكننا باستخدام هذا النموذج من تحديد الأولويات وترتيب جميع عوامل الخطر المذكورة في مشروع البناء. إلى جانب ذلك يمكننا سهولة إدارتهم بأفضل الطريقة المناسبة.

## APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion; it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science (Built Environment).

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## DECLARATION

I hereby declare that this thesis is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

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*To My Beloved Mother, Father, Brothers and Sisters*

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# **CHAPTER ONE**

## **INTRODUCTION**

### **1.1 INTRODUCTION**

The construction project is plagued by many risk factors such as poor working conditions, the significant frequency of accidents and conflict in management team which have influenced negatively on the project success. Risk analysis on the project is the first key to achieve adequate level of security on one hand and to realize the project success on the other hand. In the presence of many criteria may affect the success of project such as: cost, time, performance, and quality, safety and environmental. Risk analysis and management and their consequences can be defined using a descriptive linguistic variable. This study focused on developing a mathematical fuzzy risk analysis method and doing the assessment for the extracted risk factors from a project by using one of the most accurate and effect approach fuzzy approximation and composition and validate the result in Matlab as well.

### **1.2 BACKGROUND OF THE STUDY**

In recent years, intensive research and development have been carried out in the area of risk analysis and management, considerably recognized as one of the most critical procedures and potential areas in project management field. There is a significant relationship between management support for risk analysis and reported project success. (Voetsch et al, 2004). Risk analysis construction is one of the most highlighted fields in risk management as the nature of the project carries uncertainty. Thus, the construction project has become the first issue of most countries across the world. Furthermore, it is a major hazardous industry in which fatal and non-fatal

occupational injuries occur most frequently (Imhyoung et al, 2009) due to its unique nature (Tam et al, 2004). It is specialized by continual changes, use of many different resources, poor working conditions, no steady employment, tough environment (eg noise, vibration, dust hand of cargo and direct exposure to weather )(Pinto et al, 2011). In addition, there is another important technique called risk analysis which is an advantageous ways dealing with both qualitative and quantitative risk data due to its capability of capturing vague and possible data in an effective and efficient manner and which may help professionals and engineers to improve their analysis and management system of the construction project. (Debasish Majumder et al, 2013).

On the other hand, the nature of construction project has forced, in the risk analysis process, generous uncertainties and subjectivities, which have hampered the applicability of numerous risk evaluation strategies. They are used generally as a part of construction project and require excellent information, the traditional method which has been used for example: Fault Tree Analysis (FTA), Event Tree Analysis (ETA), Probability and impact grids, Sensitivity Analysis, Estimation of System Reliability, and Failure Mode and Effect Analysis (Ahmed et al., 2007). Much of the time, the utilization of traditional risk analysis methods might not provide attractive results because of fragmented risk information or the abnormal state of uncertainty included in the risk information accessible .Moreover, the traditional methods cannot deal and aggregate effectively the different impacts of many criteria such as cost impact, time impact, safety impact, and quality impact in construction project (Abdelgawad, 2008). Thus, it is compulsory to create new risk analysis approaches to evaluate the risks in construction project where traditional methods couldn't be productively and efficiently used (Nieto-Morote, 2011).

All these methods have showed some weakness to identify and quantify the uncertainty aspects and risks in construction. A formalised risk analysis process is still a rarity within many construction organisations, and the groundwork needs to be laid to enable risk management to become an accepted part of construction process. Moreover, the prototype is focus about the practical concerns of the construction through applying an accurate approach for further development to satisfy the needs of construction project safety and success (Qian Shi, 2014).

Fuzzy approach is introduced to enable quantitative risk assessment descriptions to be modelled mathematically and may set the relationships between different categories of project, risk factors and there consequences which are represented on cause and effect. In this research, there is a scheme for identifying and analysing the uncertainty through risk analysis techniques and their practical application. In addition, the recommendation of remedial actions in a consistent way would be proposed.

### **1.3 PROBLEM STATEMENT**

Most of the constructions projects are megaprojects and they have experienced frequent cost overruns, poor working conditions and significant major disasters. Construction projects have struggled with the use of risk Management (Zwikael, O. and Ahn, 2010). Global risk management on megaprojects; such as analysis risk factors on constructions project, received the highest attention from researchers (Marta Gangoellls, 2010).

However, the effectiveness of risk management as an analysis of project risk planning across construction projects Industries has fluctuated and still very doubtful, in recent years, due to the new and sophisticated designs. Moreover, the increasing

complexity and dynamism of construction projects have imposed substantial uncertainties and subjectivities in the risk analysis process. (Marta Gangoellés, 2010, Nieto-Morote, 2011). There are many traditional methods to address risk analysis and management, but few have been adapted and validated for use in the construction project. Every new project, even identical ones such as residential developments and office buildings has new constraints and barriers (Abel Pinto et al, 2011).

Many researches and practical techniques have been applied to manage all these uncertainties (constraints and barriers) and their consequences. Nevertheless, there is a gap about the effectiveness of risk analysis techniques and their practical application management as well as to assess the magnitude of risks in a meaningful way. This uncertainty can be due to a lack of knowledge or experience, unavailability of data, or improper historical analysis. Any construction project bears a set of risk factors which affect it in different ways, including time, cost, safety, and quality. All these factors are important, but they vary in terms of consequences and the impacts depending on the situation or the perspectives of different parties. This leads to look forward the best approach which may deal with inherent uncertainty on construction project.

Finding an effective approach is quite important to distinguish the uncertainty inherent in construction project, as well as they clarify the potential risk at workplaces in different categories of project. Furthermore, one of the main steps, in a risk analysis and management procedure is to calculate and quantify hazardous and risks in a meaningful and comprehensive way. Thus, various ways are involved in gaining the best practice. In this research, many valuable approaches are reviewed and a contribution in using the Fuzzy Logic methods for construction risk analysis and management as tools for identifying, assessing, and managing risk and uncertainty on

construction projects. The methods are enabling to convert risk assessment descriptions from linguistic variable to be modelled mathematically.

#### **1.4 RESEARCH QUESTIONS**

The identification of the problems above has left the research area with several raised questions:

- i. What are the factors which may control or affect construction project success?
- ii. What are the effective mechanisms in current practice of risk analysis on construction management project?
- iii. How may uncertainty and risk influence on the construction project success?
- iv. How can the risk analysis approach ‘‘fuzzy logic’’ define and deal with the risk factors in different categories of construction project?

#### **1.5 RESEARCH OBJECTIVES**

These are the aims which could to be the contributions of this study:

1. To define the critical factors in construction project success and the effective risk analysis approaches.
2. To develop a systematic quantification Fuzzy Logic method in risk analysis for construction project.
3. To verify the method on a project and to demonstrate the results of their comparison.

4. To prove the advantages of using fuzzy logic as risk analysis method by testing the model on real project.

## **1.6 SCOPE AND LIMITATION OF THE STUDY**

The scopes of this study are identified and evaluate the construction project risks analysis. The study's key is based on information obtained during the literature review regarding project risk analysis utilization in the construction project. The scope is that the construction project managers and experts recognize and perceive using risk management analytical tools as beneficial and important to improving the overall effectiveness of the successful project delivery. Additionally; the analyses are carried out based on practical ways and experts' views.

Although this research has some kind of limitation, when it was conducted on one project in Kuala Lumpur Malaysia in order to test our model. The results and conclusions can be applied to any construction project has the same characteristics in other parts of Malaysia.

## **1.7 SIGNIFICANCE OF STUDY**

The risk analysis using FUZZY is considered the best approach for process risk management for megaproject, this study was successfully applied in construction project, and it could be extended to cover other field of industries such as oil and gas.

The finding of this research will contribute to the improvement of performance in dealing with risk management in project. Moreover, the thesis will assist the policy of management towards the different category of project. In addition it may identify the benefits that include the ability to better manage project process and success regarding to various factors criteria such as schedule, cost and quality in the future, the

ability to better manage risks, the ability to make risks explicit, increased confidence in project construction safety and success.

Finally, the results of this study will benefit companies, organizations, and agencies, public and private, in the construction industry that are interested in reducing losses and increasing profitability on construction projects.

## **1.8 RESEARCH ORGANIZATION**

Generally, this study focus on risk analysis and management in the construction by identifying risk factors that could potentially affect any construction project, quantifying all risks, and paving the way for mitigation strategies to strengthen project success. This thesis was carried out: to improve the process of risk analysis in construction project through the enhancement of the quantification process using fuzzy sets techniques.

The research is elaborated in the following chapters to achieve the objectives of this study:

- Chapter 01 includes identifying the objectives and scope of work involved.
- Chapter 02 is an overview of the literature. It basically focuses on a comprehensive review to define the critical criteria in construction project success and the effective risk analysis approaches applied for construction projects. This chapter also explained the background of Risk analysis and Management construction project, including a review on the works which had utilised fuzzy set and arithmetic applications in quantification risk analysis.
- Chapter 03 clarifies the framework and methodology which has been used to conduct this research.

- Chapter 04 focuses on the Development of Fuzzy Quantification method and illustrates the development of a quantifying strategy to aggregate the risk severity of different risk factors affecting a project using the validation in Matlab. The concept of fuzzy synthetic is used in this part of analysis. An analytical method is applied to compute a number for ranking and prioritizing the risk factors.
- Chapter 05 verify the method on a project and to demonstrate the results of their comparison. An actual existing risk analysis case was examined. The fuzzy analysis approach which was developed in this research was utilized to reproduce the results. By this exercise, we enable to find how meaningful the consequences. Through this project, we approved the advantages of this approach for conducting a complete risk analysis in real construction project.
- Chapter 06 is an overall recommendation to enhance current practice and conclusions. It is a summary of all chapters and provides a summary of the major findings of the research. In addition, a conclusion derived from this thesis with some recommendations for further research.

## **CHAPTER TWO**

### **LITERATURE REVIEW**

#### **2.1 INTRODUCTION**

This chapter on literature review is divided into 4 main parts, the first part review the concept of the project and determine the success factors of the project. It starts with defining and highlighting issues concerning the implement on the projects. These issues are with regards to project, project management, project lifecycle and the concept of critical criteria in project time, cost and quality. The second part focuses on the comprehensive process of risk management and the different steps of risk management in construction project. The third part explains the perspective on risk and risk analysis and presents a review about previous risk analysis using different methods in construction project. Finally, the last part explains the characteristics of fuzzy logic which represents the paving of the model proposed.

#### **2.2 PROJECT OVERVIEW**

Any project process relies on the overall planning, coordination, and control of a project from beginning to completion. The project success is aimed at meeting a client's requirement in order to produce a functionally and financially viable project.

##### **2.2.1 Definition of Project and Construction Project**

Gaddis (1959) was among the first to provide with a descriptive definition of a project as it goes beyond the boundaries of a project being a static task. He defines a project as 'an organization unit dedicated to the attainment of a goal - generally the successful completion of a development product on time, within budget, and in conformance