A Framework for Risk Assessment in Egyptian Real Estate Projects using Fuzzy Approach

By

Ahmed Magdi Ibrahim Aboshady

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE
In
STRUCTURAL ENGINEERING

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"This thesis is dedicated to my family."
Abstract

The Egyptian Real Estate Market has witnessed a high level of recessions in selling real estate units because of its current political, economic, and social situations. Therefore, developers of Egyptian Real Estate have a strong demand to assess risks encountered in their projects in order to be able to compute the bidding price of a real estate project in different uncertain scenarios. This research presents a fuzzy risk management framework that enables developers of Egyptian Real Estate to assess critical risk events in their projects. The framework consists of three components: 1) Fuzzy Expert System (FES), 2) Fuzzy consensus-based model, and 3) Fuzzy Fault and event tree analysis model. The Fuzzy Expert System (FES) is developed to determine the importance weight factor for each expert, participating in the risk evaluation process, based on experts' qualifications. The Fuzzy consensus–based model is applied to aggregate experts' opinions in evaluating risks in a linguistic framework. The Fuzzy Fault and Event tree model is used to support decision-makers by identifying the critical root causes of the identified risks and hence develop a mitigation strategy to respond to the risks. In order to determine risk categories relevant to real estate development projects, Literature review and experts interviews have been conducted to identify risk events. A Fuzzy Consensus Measurement approach integrates experts' opinion in a linguistic framework by computing a consensus weight factor for experts based on the proximity of their opinions on a linguistic scale. A Fuzzy Expert System (FES) computes the importance weight factor for each expert, representing expert quality. Experts' opinions are integrated using both the importance weight factor and the consensus weight factor of experts. Based on the aggregated opinions of experts, a Three-Dimensional Matrix Ranking Approach and preset experts rules are used to prioritize different risk factors according to their importance to real estate development projects. After detecting critical risk events, a fault and event trees analysis is conducted to calculate the probability of failure of critical risk events as well as the probability of failure of mitigation strategies. Moreover, the event tree analysis computes the cost of success of the mitigation strategy. A Case Study is presented to evaluate the results obtained from the framework.
Chapter 1

Introduction

1.1 General

Risk management is a vital process in planning Real Estate Development Projects, which have a great consequence on the Construction Industry as a whole. Due to the uncertain characteristics of the Construction Industry, risk management has a great consequence on the Construction Industry, such as the case of Residential Building Construction. The Real Estate industry plays a crucial role in raising the national income and solving social problems of a developing country. For example, the Indian Real Estate sector contributes to 6% GDP in 2011 (Sahni 2012). The Indian Real Estate market grows annually with 14%. The Indian Real Estate Sector is ranked in the third place and it is expected to be in the first place in 2030. The foreign investment in Indian Real Estate Sector reached 15 US$ billion this year. Also, it is expected to reach 102 US$ billion after ten years from now. The Lebanon Real Estate Industry contributes to the Lebanese economy with 6.7% in 2011 (Bank Audi 2012). Risk management is a vital process in planning Real Estate Development Projects, which have a great consequence on the Construction Industry due to its uncertain characteristics. The Real Estate Industry plays a crucial role in raising the national income and solving social problems. In 2011, Real Estate Construction contributed less than 5% to the US Gross Domestic Product (GDP). This figure is less than the peak of 2006, which is 8.9% of the GDP (Approximately $1.195 trillion). Real estate Construction is labor intensive. As such, any decline in Housing Construction contributes to the recession's high unemployment rate (Amadeo 2012). The Real Estate Construction Industry contributes to the Egyptian Government Budget with 2.83 percent from the Egyptian national income (Alexandria Bank Research Paper 2012). Therefore; there is a strong need to enhance this sector.

1.2 Problem Statement

Risk management is a crucial process to the success of any business. The importance of risk management becomes even greater in an industry that embraces many uncertainties, such as the Construction Industry, especially in a developing country such as the case of Egypt. In order to evaluate risks, several stages were suggested by PMI (2008) in the planning stage. Stage one involves the project risk planning and identification process. Regab (2003) considered the risk identification stage as the most important stage in the risk management process since if a risk is not identified, it cannot be controlled, transferred, nor managed (Orabi 2003). The second step in evaluating risks is the qualitative risk assessment process.
Qualitative risk analysis assesses the criticality of the identified risks and develops prioritized lists of these risks for further quantitative analysis or direct mitigation. The third step is to conduct quantitative risk assessment, which is a detailed process of numerically estimating the probability and impact of the identified risks on project objectives (Zabaal 2007). The fourth step is risk response planning whose main aim is to take a course of action in order to eliminate risks from a project or, at least, reduce their potential negative implications. This can be achieved either through an immediate response during the project execution or through developing a contingency plan (Orabi 2003). The final step is risk control, which is beyond the focus of this thesis. Real Estate Developers want to ensure the quality of experts participating in the decision-making process of aggregating their opinions to make sure that their opinions are not flawed. This is why there is a high demand to determine the importance weights of experts in deciding on their qualifications prior to assessing risks. Most often, Real Estate project teams have difficulty in evaluating risks encountered in their projects, while Real Estate construction firms depend on expert judgment in assessing these risk factors. This is the reason why there is a need to develop a framework to aggregate expert opinions in prioritizing risks that can motivate expert judgment and deal with the vagueness and imprecise nature of expert opinions, linguistically. The framework should be capable of assessing the quality of experts in the decision-making process and it has to enable experts to prioritize the risks, based on their probability of occurrence, impact, and level of detection. Finally, construction firms should be able to calculate the bidding price of a Real Estate project in different scenarios when the probability of occurrence of a risk event is uncertain. Therefore, the Expected Monetary Value (EMV) of each risk event should be calculated and should be sufficient to accommodate the consequences of risk events. Based on the above, this thesis proposes an integrated Risk Management Framework, which combines Fuzzy Expert System (FES), Fuzzy Consensus Measurement Model, and Event and Fault Tree analysis to assess risks in Building Construction and Real Estate Projects to perform the above tasks.

1.3 Research Objectives

The main objective of this thesis is to propose an integrated Risk Management framework that identifies, qualifies, quantifies, and mitigates risk factors affecting Egyptian Real Estate Projects. The framework provides project teams with a useful tool that incorporates consensus of the project team members in performing risk criticality analysis of the Real Estate project. To achieve the main objectives, the following sub-objectives are satisfied:
1- To propose a flexible methodology based on expert judgment and fuzzy consensus aggregation that help projects teams gather data and reach agreement on the criticality of the risk factors affecting their projects.

2- To classify the quality of experts in the risk management process by defining an importance weight factor for each expert which is used to weigh his or her response during aggregation, based on his or her key quality attributes.

3- To incorporate a fuzzy consensus measure in the decision-making process of assessing risks that allows experts to reach an adequate consensus level when deciding on the risk factors that affect Real Estate projects.

4- To use the Three Dimensional Matrix Ranking Approach to prioritize risk events, using preset expert rules.

5- To incorporate the use of fuzzy logic in the risk analysis process, fault trees and event trees that extends the fuzzy set applications in the construction domain.

6- To support the decision-makers in identifying the critical root causes of the risk event by conducting fuzzy importance analysis on fault trees.

7- To calculate the Expected Monetary Value (EMV) of the consequence of the risk event, using event trees, which help in determining the actual cost of the mitigation strategy if the risk event occurs.

8- To validate the results obtained from the Framework through conducting a comparative Case Study.

1.4 Research Limitations

The thesis is focused on a middle class Egyptian Real Estate Development Projects which ranges from 6to 350 millions EGP. Also, the Case study is limited to governmental related risk events in this thesis. The risk events analyzed in the case study were seven risk events, which contain more than twenty five percent of the total number of risk events (twenty seven risk events) so that Pareto principle, which states that roughly 80% of the effects come from 20% of the causes, is sustained.

1.5 Research Methodology

The framework consists of three models: Fuzzy Expert System Model (FES), Fuzzy Consensus Measurement Model, and Fault and Event Tree Model (see Figure 1.1).
1.5.1 Fuzzy Expert System Development

The Fuzzy Expert System (FES) is composed of three stages: (1) data collection and variables’ development; (2) fuzzy expert system (FES) model development; and (3) validation and sensitivity analysis. Stage one involves defining the input and output variables of the FES model, developing the scales that are used to define these variables, and defining the linguistic terms describing each of these variables, using expert judgment. Step two of stage one involves constructing the membership functions of the input, and output variables, using the modified horizontal approach with interpolation technique. Step three of stage one involves deciding on the influence of the input variables on the output variable, which assists on developing the rule base of the FES. In this step, data are collected from experts, using a survey-based questionnaire. The second stage involves the FES model development, which includes the creation of the fuzzy expert system (FES) model that is implemented using FuzzyTECH®. FuzzyTECH® software motivates the creation of the knowledge base of the fuzzy-if-then rules, automatically, based on the influence of the input variables on the output variables. The final stage involves the validation and sensitivity analysis to test the quality of the FES model.

1.5.2 Fuzzy Consensus Measurement Model Development

The Fuzzy Consensus Measurement Model is composed of seven steps. The first step is to identify critical risk events that may generally exist in Real Estate Projects. The second step is to create a fuzzy linguistic scale; through which Real Estate Project teams can rank different risk factors affecting Real Estate Development Projects, according to probability of occurrence, impact, and level of detection, linguistically. The third step is to collect project teams' opinions regarding risk factors affecting Real Estate Projects using the linguistic terms that are created in step two. The fourth step is to apply the Fuzzy Expert System (FES) to calculate an importance weight for each expert participating in the risk assessment process. The fifth step is to apply a distance measurement algorithm to aggregate experts' opinions by combining each expert's importance weight factor with his or her consensus weight factor, and determining the final linguistic value representing experts' opinions. The sixth step is to apply the three dimensional ranking approach that utilizes specific ranking rules in order to produce a prioritized list of qualified risk events. The seventh step is to conduct a Case Study and validation with experts, using a three-step Delphi Approach.

1.5.3 Fuzzy Fault and Event Tree Model Development

The third model in the Fuzzy Risk Management Framework is the Fuzzy Fault and Event Tree Model which is composed of six stages. The first stage is data collection, which is concerned with collecting
root causes for each critical risk event and establishing linguistic terms to assess the probability of occurrence of each critical risk event. The second stage involves conducting Qualitative Fuzzy Fault Tree Analysis for critical risk events. The objective of stage two is to use the result of stage (1) to assess the fuzzy probability of occurrence of basic events and to identify the minimal cut sets (MCS). The third stage in the model involves conducting Quantitative Fuzzy Fault Tree Analysis and Fuzzy Importance analysis. The main objective of conducting the quantitative fault tree analysis is to compute the fuzzy probability of occurrence for the top event. This is achieved through assessing the fuzzy probability of occurrence of basic events, linguistically. The fourth stage is to conduct Fuzzy Fault Tree Analysis for each mitigation strategy.

Figure 1.1: Schematic Diagram of the Proposed Framework
Each identified mitigation strategy is then analyzed by considering the failure of mitigation to be the top event, and repeating steps for stages of data collection, qualitative and quantitative fuzzy fault tree. The fifth step involves conducting Fuzzy Event Tree Analysis to provide a crisp value of the Expected Monetary Value (EMV) of the risk event. The steps of Fuzzy Event Tree Analysis can be summarized as follows:

1. Define the linguistic terms representing the impact of each risk event.
2. Use the fuzzy probability of the critical risk events, and the fuzzy probability of each mitigation strategy according to the findings from the fuzzy fault tree analysis to define the fuzzy probability of success of each mitigation strategy.
3. Construct the Fuzzy Event Tree based on the findings of step 2.
4. Assess the consequence of each path.
5. Determine the overall probability (OP) of each path by multiplying the fuzzy probability of all the events located on the same path.
6. Multiply the OP of each path with the estimated consequence of each path to calculate the Expected Risk Magnitude (ERM) of each path.
7. Use the fuzzy arithmetic operation on fuzzy numbers to compute the Expected Monetary Value (EMV).
8. Use the mean of maximum (MOM) method to provide a crisp value of the Expected Monetary Value (EMV) of the risk event.

The sixth step is to perform a comparative Case Study in Egypt and validate the results obtained from the model by comparing the Actual Selling Price of a Real Estate Building per square meter now with the Proposed Price of the obtained from the model and compute the percentage of error between the two prices.

1.6 Thesis Organization

Chapter 2: Provides review of literature of previous research studies conducted on Fuzzy Logic, Fuzzy consensus approaches, and Fuzzy Fault tree and Event tree.

Chapter 3: Demonstrates the methodology and application of the Fuzzy Expert System (FES) to define an importance weight factor for each expert which is used to weight his or her response during aggregation.

Chapter 4: Explains the methodology and application of the Fuzzy Consensus Measurement Model.

Chapter 5: Discusses a methodology to integrate Fuzzy logic, Fault trees and Event trees to support risk analysis in Real Estate Projects.
Chapter 6: Represents a Case Study, and validation of the Framework.
Chapter 7: Describes the conclusions of this research, the contribution, the research findings, and recommendation for future research.
Chapter 2

Literature Review

2.1 General

The Success parameters for any project are in the proper time completion within specific budget and with properly achieved performance. Construction Projects frequently fail to achieve their goals and objectives. This is due to the fact that contractors fail to quantify risks encountered in their projects. Amendments occurred in the project environment are considered the most important obstacle that threaten the success of the project. The amount of uncertainty encountered in most Construction Project is an essential element in deciding whether the project will be executed in a specific time (schedule) and will achieve profit. Schedule delay and cost overrun are key elements that raise disputes and claims among various parties in the project and may lead to the failure of Construction Projects. Therefore, it is essential to quantify risks encountered in Construction Projects. The role of project management is to assist in turning uncertain events into certain outcomes and promises. If this is the case, then the primary process associated with project management should be that of risk management. This chapter presents an overview of the risk management process, the definitions of risks, risk versus uncertainty, and risks in Real Estate Development Projects. Moreover, this chapter presents an overview of methods of Experts' Qualifications, different types of membership functions methods, overview of different methods used for consensus. Furthermore, this chapter presents an overview of different methods existed in literature to qualify and quantify risk events.

2.2 Risk Management Process

Risk management is a vital process in planning Real Estate Development Projects, which have a great consequence on the Construction Industry as a whole. Due to the uncertainty characteristics of the Construction Industry, risk management has a great consequence on the Construction Industry, such as the case of Residential Building Construction. However, there are many obstacles that threaten performing qualitative risk analysis. First, it involves experts' judgment, which may be considered inaccurate in performing risk analysis if experts were not qualified to do so. Second, unavailability of historical information which are used to assist in risk assessment is another obstacle. Third, the risk management process in general involves vagueness, which may require a specific mechanism that deals with imprecision in the knowledge elicitation process. Therefore, these obstacles should be overcome in order to efficiently produce a prioritized list of qualified identified risks. The third step is to conduct
quantitative risk assessment, which is a detailed process of numerically estimating the probability and impact of the identified risks on project objectives. Quantitative analysis is based on simultaneous evaluation of the impact of all identified and qualified risks (Zabaal 2007). There are many problems that may threaten performing quantitative risk analysis. The first is the lack of sufficient data. The second is the inability to establish probability distributions to represent the uncertainty of a risk event. The third is the difficulty to understand the probability concepts. Therefore, these issues should be settled in order to perform quantitative risk analysis. The fourth step is risk response planning whose main aim is to take a course of action in order to eliminate risks from a project or, at least, reduce their potential negative implications. This can be achieved either through an immediate response to the project or through a retarded response (Contingency plan) (Orabi 2003).

2.2.1 Risk Definition

Risk can be defined in several ways. Moskowitz and Bunn (1987) asserted that risk has many interpretations and its definition can vary from one situation to another. Al–Bahar and Grandall (1990) defined risk as "the exposure to the chance of events adversely or favorably affecting project objectives as a consequence of uncertainty." Chapmen (1998) defined risk as "the exposure to the possibility of economic and financial loss, or delay as a consequence of uncertainty associated with pursuing a particular course of action." Blair et al. (2007) defined risks as "the potential for loss as a result of a system failure." Baloli and price (2003) argued that risk can be classified as "The likelihood of a determinal event occurring in the project." Jannadi and Almisher (2003) defined risk as "measure of the probability, severing, and exposure of all hazards of an activity." Molenaar (2005) defined risk events as "potential adverse events that negatively affect the defined project resulting in negative impacts to cost, schedule, safety, performance, or other characteristics but don't include the minor variance inherent in base costs." Also, he considered the negative side of the risk event as a "threat". Moreover, he defined opportunity events as "Potential beneficial events that positively affect the project resulting in improvements to cost, schedule, safety, performance, or other characteristic but are greater than the minor variance inherent in normal costs." Cooper et al. (2005) provides a definition for risk in a project as "The chance of something happening that will have an impact upon objectives."

2.2.2 Risk versus Uncertainty