A Model for Time Overrun Quantification in Construction of Industrial Projects Based on Risk Evaluation

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Abstract: The complete of construction projects on time is considered one of the most challenges that meet construction companies since time is one of the vital criteria that control the success of projects. The construction projects involve various risk factors which have various impacts on time objective that may lead to time overrun and schedule delay. One of the serious problems that face the dealers with construction projects is the lack of practical models that used to quantify the effect of risk factors on time objective. A fuzzy model for time overrun quantification in construction projects was proposed based on risk evaluation. The developed model is mainly based on many relationships among the impacts of risk factors on time and the time overrun through several logical rules. The developed model was validated and used to demonstrate an actual case study in Egypt based on real data taken from an industrial construction project. The estimated time overrun based on the model outputs is compared with the actual construction time overrun from the case study. The results represent a new methodology for using the probability of occurrence for a certain risk factor to represent the weight of its fuzzy logical rules. In addition, the results showed that the proposed model can be used to calculate the expected time overrun, which is associated to the industrial projects, as a percent of the original time of the project.

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1. Introduction

The delay in time of construction is one of the burning issues in the field of construction projects, which has a significant effect on the projects objectives. Consequently, researchers give more attentions to overcome such problems in the future through the development of theoretical models to minimize the delay in construction time. In general, construction delay is defined as the time overrun either beyond the completion date as specified in the contract or beyond the date that the parties agreed upon for delivery of the project **(Assaf and Al-Hejji, 2006).** The delayed event is defined as a situation when both contractor and owner jointly or individually contribute to the non-completion of the project within the original or the agreed contract period **(Aibinu and Jagboro, 2002).** Delays in construction time can occur in all phases of project construction **(Acharya et al., 2006**), however all parties in construction projects agree that the major delays can be occurred during the construction phase **(Abdul-Rahman et al., 2006 and 2009).**

For various types of projects, the time overrun can be generated due to variety of risks, which are coming from planning, method of construction, the satisfaction of clients and the change of economic situation. For example, if the schedules of the project exceed more than the planned targets, client satisfaction would be compromised. Subsequently, it has a significant effect on the delay of project construction and this will be associated with harmful effect, especially in the case of developing countries. This is most likely related to the wealth measure strategy in the developing countries and completely dependent on their performance in infrastructure provision through the construction industry.

The delays in construction project can be divided into four types **(Bramble and Callahan 1987as cited in Yates and Apstein, 2006).** This includes 1) Non-excusable delays; 2) Non-compensable excusable delays; 3) Compensable excusable delays and, 4) Concurrent delays. Non-excusable delay is mainly come from the action or inaction of the contractors **(Yates and Apstein, 2006).** This delay is probably related to inadequate scheduling or mismanagement, construction mistakes, equipment breakdowns and staffing problems **(Ahmed et al. 2002).** In the event of this type of delay, the contractor does not entitle any extension of time to the project schedule. Conversely, excusable delay can be classified into two types: non-compensable excusable delay and compensable excusable delay. Non-compensable excusable delay is mainly occurred due to unforeseeable causes and out-controls both the contractor and the owner. Examples of the unexpected events that out-control both parties are: “Acts of God”, force majeure and labor and materials shortage **(Baram, 2000)**. This type of delay will be relieved the contractor from any contractually imposed liquidated damages for the period of delay as well grants an extension of time for the contractor. However, the compensation based on cost cannot be given to the contractor due to this type of delay (**Ahmed et al., 2002).**

The delay come from the owner is considered one of the compensable excusable delays since there is no any fault come from the contactor. This type of delay is most likely related to the following reasons: the owner's failure to meet the estimated time to offer the site for contractor for starting the construction, changes in works by the owner, defective design by the designer, and differing site conditions **(Yates and Apstein, 2006).** In the case of this type of delay, the contractor has a powerful to obtain time extension and compensation for any cost incurred due to the delay. Concurrent delays are common in construction projects, especially during the peak of project when multiple-responsibility tasks are being performed concurrently **(Baram, 2000).** Concurrent delays are almost occurred when two or more delayed events occur at the same time and the delayed events are caused by the client and the contractor. In the event of concurrent delays, it is quite difficult to determine who is responsible about the delay. It is probably related to both owner and contractor use the concurrent delay as a defensive tool against each other, the owner will try to protect his interest by collecting liquidated damages while the contractor will try his best to waive from his own delays in order to avoid liquidated damages **(Baram, 2000)**. Assessing concurrent delays will lead to various issues **(Ibbs et al., 2011)** and if it cannot be done between both parties, legal proceedings might be needed to resolve the issue **(Yates and Apstein, 2006).**

Risk analysis

The risk analysis is defined as estimating the probabilities needed as input data to evaluate the alternative decisions **(Lifson and Shaifer, 1982).** Risk analysis is performed to show what will happen if the project does not proceed according to the plan due to potential risks and warns the decision-maker or manager about the necessary responses to deal with risks. Furthermore, it captures all feasible options and analyses various outcomes for any decision. For assessing the impacts of risk on projects or plans, the risk analysis is grouped for two parts: quantitative and qualitative **(Flanagan and Norman 1993; Vaughan 1997; Hillson 2002; Sollenberger et al., 2007)**. They both benefit from the data produced by risk identification but the qualitative approach consumes the gathered information through direct judgment, ranking options, comparing options, and descriptive analysis. In contrast, some of the quantitative risk analysis techniques are used in performing statistical models and simulations in order to reach numerical results that show the effects of risks.

1 - Qualitative risk analysis

The identified risks can be assessed qualitatively to determine both probability and potential effect on project objectives, allowing risks to be prioritized for further attention **(Hillson, 2002).** The primary technique for this approach is mainly based on the Probability–Impact Matrix, where the probability and impacts of each risk are assessed against defined scales, and plotted on a two-dimensional grid. This approach can be used to assess both threats and opportunities, although it is hard to visualize how a single Probability–Impact Matrix can clearly show both, since the ''Impact ''scale would need to reflect both positive and negative effects.

Qualitative risk analysis includes methods for prioritizing the identified risks for further action, such as Quantitative Risk Analysis or Risk Response Planning. Organizations can improve the project's performance effectively by focusing on high-priority risks **(Sollenberger et al., 2007).** Qualitative Risk Analysis assesses the priority of the identified risks using their probability of occurrence, the corresponding impact on project objectives if the risks do occur, as well as other factors such as the time frame and risk tolerance of the project constraints of cost, schedule, scope, and quality.

2 -Quantitative risk analysis

Quantitative analysis seeks to quantify the combined effect of risk on project objectives. These involve building a model of the whole project or key elements, reflecting the identified uncertainty into the model, and analyzing the combined effect on project outcomes. The aim is to determine the overall level of risk exposure associated with a project, exposing areas of particular risk, and assisting in the development of the appropriate responses.

All of the common quantitative techniques can be used to take account of both positive and negative effects of uncertainty, since they involve estimating ranges of values for variables (such as duration, cost, resource requirement, etc.). The best case value in the range (or minimum or optimistic) should include the effect of the identified opportunities in reducing activity time or cost, whereas the worst case (maximum, pessimistic) estimates should include the effects of the identified threats.

Fuzzy set theory

As the lack of previous data and unique, non-repetitive nature of construction projects, usually probabilistic approach cannot be applied to quantify risks. **Baloi and Price (2003**) argue that as most of the risk analysis tools are based on statistical decision theory and then contractors rarely use them in practice. Furthermore, probabilities, individual knowledge, experience, intuitive judgment and rules of thumb should be structured to facilitate the risk assessment and retrieval by the others.

It is well-known that Fuzzy set theory is one of the most important tools used to deal with uncertainties that are not statistical in nature **(Klir and Yuan, 1995)**. The theory of fuzzy sets provides a natural way of dealing with problems in which the source of imprecision is the absence of sharply defined criteria of class membership rather than the presence of random variables **(Zadeh, 1965).** In the context of fuzziness we deal with the possible not only the probable. Possibility is the degree of ease with which a variable may take a value. Possibility describes whether an outcome can happen while probability describes whether it will happen. Unlike probabilistic categorization, possibility categorization allows over-lapping, fuzzy sets where the truth (or believability) of categorization is measured as a degree of membership falling between zero and one.

The proposed model

The proposed model namely Time Overrun Quantification in Industrial Projects (*TOQIP*) is introduced in this study to calculate the expected time overrun. Any construction project is subject to the effects of many risk factors. These risk factors have different probabilities of occurrence and different impacts on project time. The model is mainly based on the relationships among the impacts of many risk factors on time and time overrun. These relationships are introduced in the form of fuzzy logical rules. The time overrun value is assumed to be a result of the combined effect of the impacts of the identified risk factors on the project time. The probability of occurrence of every risk factor is assumed to be equal to the weight of the logical rules of such factor. So, the inputs in this model are the impacts for the identified risk factors represented by their impact indices. Figure (1) shows the inputs and output for the (*TOQIP*).

The output of the fuzzy risk assessment procedure is the percent of time overrun. This percent is calculated by using a scale of 1–40%, which represents the maximum percent that can be taken into consideration when engineers design the contract.

The states of linguistic variables are defined as: very low, low, medium, high and very high. The universe of discourse scale also was chosen by using the predefined membership functions to represent the inputs of the model in the range of 0 to 100 for the impact indices of the risk factors. While the outputs were chosen in the range of 0 to 40 to represent the expected time overrun. In the proposed model, all membership functions are triangular and overlap ratio, subsequently the overlap robustness are ensured. This is accomplished by parameterizing the membership functions only through their centers and the centers of the two neighboring membership functions. Figures (2) and (3) represent the membership functions for (*TOQIP*) inputs and outputs.

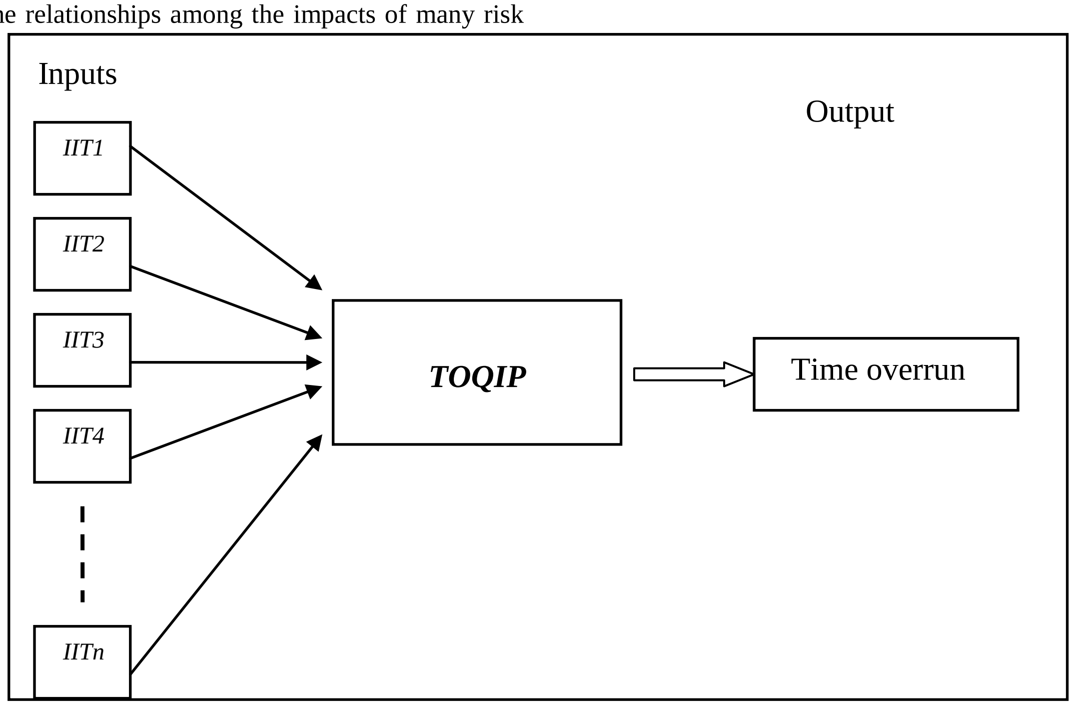

Figure (1) Inputs and output for the *TOQIP*

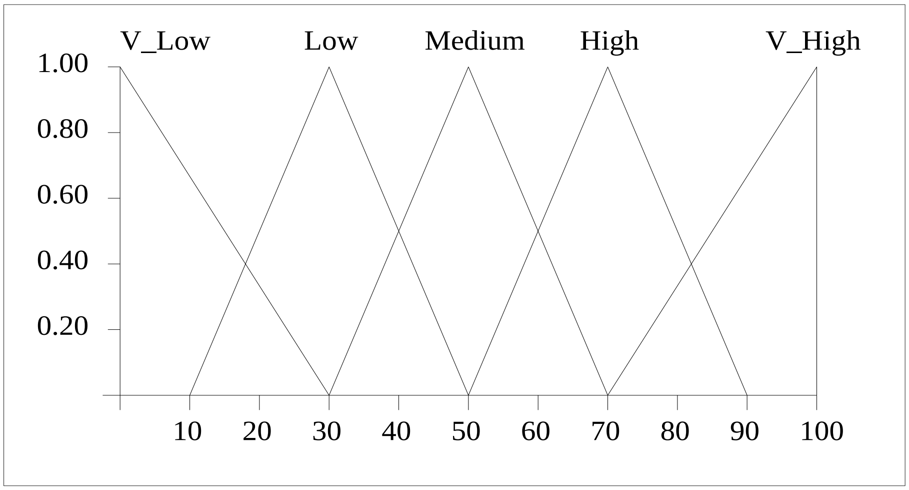

Figure (2) Input Membership functions for *TOQIP*

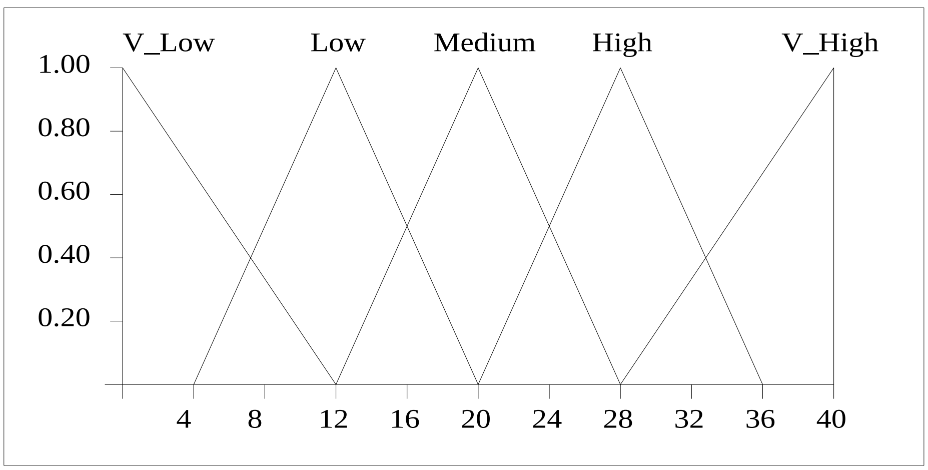

Figure (3) Output Membership functions for *TOQIP*

The corresponding fuzzy sets can be defined for the input and output Membership function as follows:
Very low = (1, 0.67, 0.33, 0, 0, 0, 0, 0, 0, 0, 0)
Low = (0, 0, 0.5, 1, 0.5, 0, 0, 0, 0, 0, 0)
Medium = (0, 0, 0, 0, 0.5, 1, 0.5, 0, 0, 0, 0)
High = (0, 0, 0, 0, 0, 0.5, 1, 0.5, 0, 0, 0)
Very high = (0, 0, 0, 0, 0, 0, 0, 0, 0.33, 0.67, 1)

Aggregation rules and rules weighting

Fuzzy logic requires the professionals to determine a set of rules in order to create the needed model to solve the defined problem. These rules are defined based on the opinions of experts in the field who know how the inputs relate to each other or how they affect on the objectives of a project. These rules are the basis of the model which will be developed and they are the building blocks of the model. Moreover, when an expert was not available, some easy and intuitive control rules could be stated by an understanding of the first principles of the system's functioning **(Chen, 2000**).

There are many logical rules proposed to represent the relationships between risk factor and time overrun. These rules reflect the extent of increasing delay in acting on the risk factors in this model. The probability of occurrence of each factor reflects the weight of the rule on the impact of the factor on the time of the project.

The rule weight can be defined as a numerical approximation of the conditional probability of the consequent class **(Ishibuchi and Yamamoto, 2005).** Rule weighting is used when the user do not want firing of all rules to have equal impact on the output. To reduce the effect of a rule, we can give it a weight less than those of other rules, thus limiting its impact. The proposed model depends on a main idea that is considering the probability of occurrence (represented by *PI*) of the risk factor which represents the weight of the rule, while the impact of the risk factor is used as the input for the model.

For every risk factor, there is a group of logical rules which used to measure the impact of risk factor on time of the project. The given risk factors with an impact on time objective *IIT* and the change in the time objective is given by *W* induced on a task and it can be represented by the following rule:

if *IIT* then *W* *Equation* (1)

For each risk factor, it is assumed an interrelationship of *IIT* and *W*

For this case, n inputs and 1 output system, we can not write rules by preparing a matrix due to the large number of inputs. An example of the proposed rules for a certain risk factor is:

If the Impact of the risk factor No (5) on Time is high then the time overrun is high

For every risk factor there will be five rules. This group of rules has the same weight for the same risk factors and equal to its probability of occurrence as proposed in the model.

Case study

The chosen case study is construction of milling factory for flour production in Minia industrial zone, Minia city, Egypt. The estimated budget cost for construction the main buildings is 6.50 Million LE (about 1.40 Million U.S. dollars). The budget cost mentioned above does not include the cost of infrastructure or machinery. The production rate of flours for this factory is 250 tons/day. The start date of this stage was 1st October 2009. Figure (4) shows the plan for manufacturing main building which represents the case study.

Model application

The author was one of the consultant group who are supervised the construction stage of the project. The most critical risk factors which affected the project time were chosen from many factors introduced by **Issa (2011),** with the help of both owner representative and contractor after completion of the project. They introduced their data in a form of probabilities of occurrence and the impacts on time in the form of two indices; namely *PI* and *IIT*. Table (1) shows the most critical risk factors and their indices for the investigated case study. These data will be used as an input in the model to estimate the time overrun of this project.

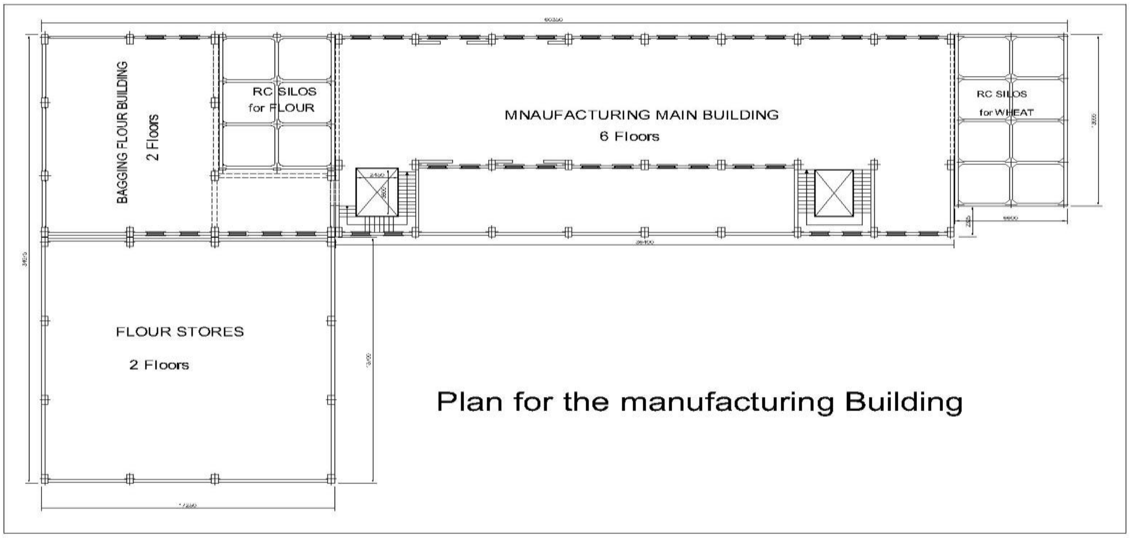

Figure (4) the Plan for manufacturing main Building of the Case Study

Table (1) the most critical risk factors that affect the case study and their indices

No	Risk Factor	*PI*	*IIT*
1	**Fluctuation default of Subcontractor**	**52.0**	**v h**
2	**Changes in the materials prices**	**53.3**	**m**
3	**Defective workmanship**	**42.5**	**h**
4	**Long lead items equipment and bulk material**	**42.4**	**h**
5	**Lack in project financing**	**38.8**	**h**
6	**Delay in materials delivering**	**36.7**	**h**
7	**Scheduling, errors and underestimation of cost**	**33.3**	**m**
8	**Client's representative problems**	**32.5**	**m**
9	**Problems resulted in interference among different subcontractor's**	**32.8**	**h**
10	**Inadequate specifications and shortage of design data**	**30.6**	**m**
11	**Inadequate and slow decision-making mechanism**	**29.4**	**m**
12	**Poor quality of local materials**	**27.0**	**h**
13	**problems among project team members**	**26.8**	**l**
14	**Familiarity of the work and Project complexity**	**23.5**	**l**
15	**Improper accommodations for workers**	**23.4**	**m**

Based on the data presented in Table 1, the numbers of crisp inputs are 15 and they were represented by the *IIT* for each risk factor while the number of rules used are 75 (15×5). For every risk factor, the weight for its rule groups (5 rules) is represented by its *PI*. For example, the risk factors No (12), its crisp input is 0.50 and the associated weight for its rules group is (0.27).

By applying the model, using the above input data, the percentage of time overrun for this project was found 24.40

Model validation

Model validation is one of the most important tasks to evaluate the efficiency of the investigated model. It is the final step in the development process. The aim of model validation is to show that the results obtained from the model are realistic. In addition, it will illustrate how the contractor or the owner can use the proposed model to estimate the expected percent of time overrun before starting the project.

The actual time overrun percent can be simply calculated as a difference between the actual duration and the planned duration of the project divided by the planned duration as presented in equation (2).

$$Actual\ Time\ Overrun\% = \frac{(Actual\ Duration - Planned\ Duration)}{Planned\ Duration} * 100 \qquad Eq.\ (2)$$

The planned duration for this project stage (construction stage) was 180 days while the actual duration was 220 days. Applying Equation (1) on this data, the actual time overrun is equal to (22.20 %).

There is a slight difference (about 10 %) between the actual and the estimated time delay when model used to calculate the percent of time overrun. The estimated percent of time overrun using the model was found 22.20 while the percent of actual time overrun was found 24.40. This slight difference confirms the possibility of using the model and the viability of its application on similar projects. The outcomes from the investigated case study reflect the validity of using the model in industrial projects in Egypt. It should be noted that this model is general and with slight modifications can be easily adapted to apply for other types of projects.

Conclusion

A fuzzy model was proposed in this research to quantify the time overrun in the industrial project construction namely *TOQIP*. The main components and functionalities of this model were presented in details in this paper. The model calculates the expected time overrun associated to the industrial projects using the impacts of many risk factors taking into consideration the probability of occurrence of risk factors to weight the relationships between the impacts of risk factors on time and time overrun. The *TOQIP* has been applied on a real completed industrial project, which executed in the period of years 2009-2010 in Minia city, Egypt. The comparison of the time overrun come from the model application to the actual time overrun shows an extent of convergence, which reflects the success of the model in quantifying the time overrun in an easy way which is very important for both contractor and owner before and during the tendering stage.

The probability of occurrence for a certain risk factor is used to represent the weight of its fuzzy logical rules. This new methodology provides a quick and efficient tool for project managers to calculate the time overrun for construction projects, by allowing the project manager to scrap useless projects without putting the least amount of effort into an analysis.

The presented case study in this paper is limited to industrial construction projects in the investigated area. However, the proposed model may be successfully applied to other types of construction projects with minor modifications.

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