Using the fault tree for analysis the schedule delay factors

Yasser Abdel Shafy Gamal¹, Mostafa Abd Elrazek²
¹ High Institute of Engineering Technology, EL-MINA Lecture of structural engineering, Civil Department, El Mina
² High Institute of Engineering Technology, EL-MINA. Lecture of properties and strength of materials, Civil Department
E-mail: Yasser.gamal2310@mheit.edu.eg, dr.mostafa.abd.k@mheit.edu.eg

Abstract. The delaying in the construction projects is one of the magnifying problems facing the construction industry in Egypt, and still a lot of researchers interest to find the main reasons for these problems and suggest the solution for mitigate or avoid the problem, a lot of contractors in Egypt suffer from the liquated damages due to the delaying problems, although there are a lot of researchers find out the delaying factors problems, but we need to get the root cause analysis of the delaying factors, in our research, the investigation find out the most critical delaying factors and categorized the factors in modeling by using factor analysis methodology into 7 factors modelling and hence using the root cause analysis to link the reasons with each other, Fault tree is one of a valuable tool can be used to link with the reasons of delaying which will be used in our research and help us to investigate deeply with the roots of the problems which is our target in the research and in the final the major problems leads to most of the problems are the delaying of the supplies (code of Factor DF5) with mean 4.2039 and RII = 0.84078, A lot of change Orders (code of Factor DF14) with mean 4.1845 and RII = 0.8369, no of delaying factors in our research are 22 factors which considering as an important delaying factors in the construction industry in Egypt, the survey pilot contains no of 103 questionnaires to rank the delaying factors by statistical analysis.

1. Introduction

In the construction industry, the completion of the project on the specified time is considered as one of the important constraint for succeeding the project, not only the budget, quality but also the time, avoiding the penalty and liquated damages by ending of the project on the specified time can't be achieved without investigation on the reasons of delaying, Chan and Kumaraswamy 1997 considered the completion of the project on contract time is a signal for efficiency, a lot of features in the construction industry had been investigated such as extension time on the project, environmental conditions, the conflict in interesting between the stakeholders and the dynamic effect of the project team, there are some of the features created the obstacles in completion the project on specified time on the contract. The delaying in the construction industry is an inevitable problem facing almost construction projects,
Diverse researchers have investigated the reasons, and the research has been conducted by the survey pilot method to analyze the opinion of the questionnaires about the reasons of the delaying. Understanding the reasons of problems is the root of the solution, a little research interest about analyzing the root cause of the delaying so that it considers as an essential tool will be used in the research to link between different sources of delaying, the personal experience contributes in determination the importance of the delaying factors which is depends on the participants, delaying of the construction projects deduced from series of events, the events can be divided into minor and major events according to its impacts on the scheduling, the objective of research to determine the leading cause of delaying by using fault tree diagram as a tool for determining the causes of delaying which assists to link between different cause, fault tree analysis can be used to determine the delay cause and identify the relationship between the causes.

The succeeding of the construction project depends on ending the project on time within cost and with satisfaction of the stakeholders, the main problem of almost projects is delaying the project and over time than the time of the project according to the contract, indeed the time of completion of the project before or after depends on the uncertainties of risk [1], Assaf, S.A. and Al-Hejji, S. [2] deduced that about 70% of constructions projects suffer from delaying and nearly 76% of the contractors and 56% of consultants have deduced that the percentage of increasing of time in the construction projects is in range between 10 to 30% from the original duration which lead to increasing the cost by 50%, about 50% of the construction projects in the United Arab Emirates suffers from the delaying [3], the delaying of the construction project is considered as the major problem caused the negative impact on the construction industry [4], indeed the delaying of construction projects which means the time beyond the contract durations can considered as costly situation, in another meaning the delaying of the construction project interprets as the extension of time to end the scope of works in the contract [5], Different factors can effects on the delaying of the project and a lot of researchers interest to clarify the problems which differ from country to another [6-7-8], poor site management can effect on the extension of the duration of the project [9], the cause of delaying in US (United State) has been investigated by Bordoli and Baldwin [10] and they clarified the climate, the labor are the main factors in delaying and the subcontractors were demonstrated the leading causes of delaying are poor risk management, unforeseen condition, slow making of decision.

2. Literature Review:

The following the duration of project in the schedule plan is sign of succeeding the project, the completion of the project on specified time in the contract means successful project, using different tools in the project management to control the construction project duration, the professional-managerial using the management tools to achieve the objective of the project, the completion of the project on the specified time is one of the objective of the project, in the project management, using the resources labor, equipment, materials and methodology [11] to manage the project and end in specific time, due to the absence of the active management the delaying of the project and cost overruns have been happen.

There are different methods can be used to determine the causes of the delaying and to prevent the occurring of delaying. Using the root cause analysis as tool to achieve the previous objectives, Using the root cause analysis in discovering the cause of delaying in the construction projects, it is more effective tool to figure out the problem and solving their, and it contributes to finding out the primary causes of problem, the fault tree analysis is a kind of root cause analysis methods, it can be used to visualize the delaying factor and their relationships between causes, the fault tree analysis directs to identify the primary cause of delaying that lead to most of delaying events, RCA (Root Cause Analysis) used in the analysis of reasons of failure in the construction project [14].

The analysis of Fault tree can be assisted to help for understanding the reasons for the delaying to compose procedures to mitigate or avoid the delaying.
Fault Tree Analysis is a diagrammatic tool can be used based on the probability of occurrence or non-occurrence of the event [15&16].

Fault tree analysis is an appropriate tool to use for the delay factor analysis, especially to link the causes to each other. To execute the Fault tree analysis, it can be done in steps, in the beginning, determine the main event at the top, in our research the top problem is the delaying of the construction projects, it can be considered as a critical problem, and in the second step link the top event to other events by the logic gate ( OR, And ), the process can be created until all the basic cause of delaying in the construction projects, Fault Tree analysis can be qualitative or quantitative or both, the type of analysis depends on the available information, the big objective of using FTA in the delay analysis is to enable to get the prioritization causes for delaying in the construction projects.

3. The collection of data

In the starting of the research, the gathering of the data is one of the crucial steps to get the input for the research so that there are two steps to get the data of the delaying factors, the first step: interviews with various project managers in random construction projects and selecting different delaying factors, the second step: omitted the similarity delaying factors from the survey and focus only the different causes to avoid the similarity in the factors which can occur from the interview of the project manager, in the final no of the delaying factors in our research become 22 factors as shown in Table (1)

| Ser | Item                                                                 | Code |
|-----|----------------------------------------------------------------------|------|
| 1   | Delaying of issue the license and agreement to construct the project | DF 1 |
| 2   | Lack of communication between different department inside the organization | DF 2 |
| 3   | Effects of absence of work authorization system | DF 3 |
| 4   | Absence of the communication requirement inside the organization | DF 4 |
| 5   | The delaying in the procurement process | DF 5 |
| 6   | The delaying of the supplies | DF 6 |
| 7   | the delaying of payment request for vendors and subcontractors | DF 7 |
| 8   | The delaying of the fee of the labor and incentives | DF 8 |
| 9   | Absence of justice in distribution the fees between the labors | DF 9 |
| 10  | Poor performance management of the subcontractors | DF 10 |
| 11  | Slow making decision | DF 11 |
| 12  | Hesitated and change in the decision making | DF 12 |
| 13  | careless the risk management factors in the projects | DF 13 |
| 14  | A lot of change Orders | DF 14 |
| 15  | Lack of Skilled workers | DF 15 |
| 16  | Absence of Inflation and the change in the prices of the materials, equipment and wages | DF 16 |
| 17  | the poor management | DF 17 |
| 18  | the weakness of the technical performance | DF 18 |
| 19  | the absence of communication outside the organization | DF 19 |
| 20  | Delaying of the deliverables at the working stages | DF 20 |
| 21  | the effects of type of leadership on the time and cost of the project | DF 21 |
| 22  | The effects of type of organization (centralized , decentralized ) | DF 22 |

The questionnaires collected from different types of construction to get credibility and confidence in the results of analysis, there are around 103 questionnaires from construction projects with diversity in the construction types, Fig 1 indicates the types of construction work in the projects, these projects comprise 61.17% residential projects, 7.77% infrastructure projects, 2.91% Electromechanical construction projects, 28.16% roads projects
The degree of education of the respondents are diverse from bachelor’s degree to a doctoral degree. Fig 2 illustrates the degree of education for the respondents, the respondent ’s degrees are bachelor’s degree (82.52%), (12.62%) the Master’s degree and 4.85% Doctoral Degree.

The no of experience years for the respondents is illustrated in Fig (3) which clarify that no of respondents with experience between 10-20 years is 93 responders with percentage 90.29%, the experience between 21-30 are 5 responders with percentage 4.85% and in the final no of responders with experience more than 40 years are 2 with experience 2.91%.
The age as a factor effects on the opinion of the respondents. Fig (4) illustrates the age of respondents which indicate that the difference between the age of respondents, as shown in Fig (4), it can illustrate that no of respondents between 23 Years to 40 Years are 93 responders, from 41 Years to 50 Years are 3 responders, from 51 Years to 60 Years are 3 responders and more than 60 Years are 4 responders.

![Age Frequency Chart](image1)

Fig (4)

In the other side, the type of respondents are 93.2% male and 6.8% female as shown in Fig (5).

![Type Frequency Chart](image2)

Fig (5)

4. objectives of the Research

The study has an objective to get the most impact factor effects on the delaying of the project and understanding the relationship between the causes of delayed by using a fault tree as tools for root cause analysis and to achieve the objective there are different steps have been followed to achieve the target of research and also create modeling for the delaying factors by using the factor analysis, and these can assist in managing the prevention the reasons of delaying in the construction projects.
5. Data analysis and results

The methodology of research can be illustrated in the flow chart which indicated in Fig (6), in the flow chart, it can be obviously the road map of research to get the objectives, in the beginning, First step: starting with identification of the study case (Delay of the construction project), second step: collection of data from different responders, third step: omitted the similarity delaying factors from the survey pilot, fourth step: Questionnaires survey. Fifth step: categorized the delay factors; sixth step: Analysis the delay factor by using relative importance index seven steps: using Fault Tree analysis as tools of root cause analysis.

Fig (6) Flow chart of methodology of research

5.1 Alpha Cronbach

To get the reliability and internal consistency, using Cronbach's alpha as the suitable statistical method to evaluate the reliability and confidence of the questionnaires [12], the range of acceptance degree of credibility of alpha Cronbach are above 0.6 [13], in the research by calculation submitted from using SPSS the percentage of alpha Cronbach is 0.827 which means the highest value in credibility

Relative Importance Index:

The relative importance index is used to identify the ranking of the delaying factors and is considered as a statistical method used as analytical tools to get the ranking of delaying factors; the Relative importance index depends upon the Five Likert Scale. In the five Likert Scale: from one to five express with different cases (one: Strong Disagree, two: Disagree, three: Neutral, four: Agree, Five: Strongly Agree.

\[
RII = \frac{\sum w}{A \cdot N}
\]

Where:
RII is Relative importance index.
W is Weighting is given to each other by the respondents (ranging from 1 to 5).
A is the highest weight (i.e. 5 in this case).
N is Total number of respondents.

The importance level of relative importance index can be categorized with different levels, Table (2) indicates the level of importance according to the value of the relative importance index.
RII values & Level of importance

| RII | Level of importance |
|-----|---------------------|
| 0.0 ≤ RII ≤ 0.14 | Strongly unimportant |
| 0.15 ≤ RII ≤ 0.29 | Very unimportant |
| 0.30 ≤ RII ≤ 0.44 | Unimportant |
| 0.45 ≤ RII ≤ 0.59 | Moderately important |
| 0.74 ≤ RII ≤ 0.89 | Very important |
| 0.90 ≤ RII ≤ 1 | Strongly important |

From the current study the main delay factors effects on the extension of time of the construction project are the delaying of the supplies (Code of Factor NF5) with mean 4.2039 and RII = 0.840 (Level of importance = very important). A lot of change Orders (code of Factor NF 14) with mean 4.1845 RII = 0.8369 (Level of importance = very important), Delaying of issue the license and agreement to construct the project (code of Factor NF 1) with mean 4.1553 RII = 0.83106 (Level of importance = very important) and the poor management (code of Factor NF 17 with mean 4.106) RII = 0.82136 (Level of importance = very important). Table (2) and Fig (7) illustrates the relative importance index for the delaying factors in the construction projects in Egypt.

Table (2)

| Ser | Code of Delay Factor | Description | Mean | Standard Deviation | RII | Importance Level |
|-----|----------------------|-------------|------|--------------------|-----|------------------|
| 1   | DF 1                 | Delaying of issue the license and agreement to construct the project | 4.1553 | 1.02668 | 0.83106 | Very important |
| 2   | DF 2                 | Lack of communication between different department inside the organization | 3.9903 | 0.85744 | 0.79806 | Very important |
| 3   | DF 3                 | Effects of absence of work authorization system | 3.7864 | 0.9666 | 0.75728 | Very important |
| 4   | DF 4                 | Absence of the communication requirement inside the organization | 3.8835 | 0.94247 | 0.7767 | Very important |
| 5   | DF 5                 | The delaying in the procurement process | 4.1456 | 0.98427 | 0.82912 | Very important |
| 6   | DF 6                 | The delaying of the supplies | 4.2039 | 0.96365 | 0.84078 | Very important |
| 7   | DF 7                 | The delaying of payment request for vendors and subcontractors | 3.9903 | 1.00484 | 0.79806 | Very important |
| 8   | DF 8                 | The delaying of the fee of the labor and incentives | 3.6893 | 1.11169 | 0.73786 | important |
| 9   | DF 9                 | Absence of justice in distribution the fees between the labors | 3.3981 | 1.08772 | 0.67962 | important |
| 10  | DF 10                | Poor performance management of the subcontractors | 3.7379 | 1.13726 | 0.74758 | important |
| 11  | DF 11                | Slow making decision | 3.9223 | 0.98707 | 0.78446 | Very important |
| 12  | DF 12                | Hesitated and change in the decision making | 3.8058 | 0.99072 | 0.76116 | Very important |
| 13  | DF 13                | careless the risk management factors in the projects | 3.7087 | 1.07221 | 0.74174 | important |
| 14  | DF 14                | A lot of change Orders | 4.1845 | 0.89385 | 0.8369 | Very important |
### Delay Factor Analysis

| Ser | Code of Delay Factor | Description                                                                 | Mean   | Standard Deviation | RI | Importance Level |
|-----|----------------------|-----------------------------------------------------------------------------|--------|--------------------|----|-------------------|
| 15  | DF 15                | Lack of Skilled workers                                                     | 3.7476 | 0.96729            | 0.74952 | important         |
| 16  | DF 16                | Absence of Inflation and the change in the prices of the materials, equipment and wages | 3.7379 | 1.16283            | 0.74758 | important         |
| 17  | DF 17                | the poor management                                                         | 4.1068 | 0.87349            | 0.82136 | Very important    |
| 18  | DF 18                | the weakness of the technical performance                                   | 3.8738 | 0.97699            | 0.77476 | Very important    |
| 19  | DF 19                | the absence of communication outside the organization                       | 3.835  | 0.85287            | 0.767   | Very important    |
| 20  | DF 20                | Delaying of the deliverables at the working stages                          | 3.9417 | 0.92699            | 0.78834 | Very important    |
| 21  | DF 21                | the effects of type of leadership on the time and cost of the project       | 3.7184 | 0.98436            | 0.74368 | important         |
| 22  | DF 22                | The effects of type of organization (centralized, decentralized)            | 3.5728 | 1.09904            | 0.71456 | important         |

#### Relative Importance Index for the Delaying Factors

![Relative Importance Index for the Delaying Factors](image)

5.2 Factor Analysis

Factor analysis can be used to categorize the delay factor into groups, sorting the 22 delaying factors into seven groups and created the factors into modeling as a tool for management, the reliability of the modeling has been investigated by the communalities of each variable, Table (3) clarify the factor analysis of the delaying factors, it has been created by using SPSS software, the sample size has been investigated in our study is 103 samples,
Communalities indicate the common variance shared by factors with given variables. Higher communality indicated that a larger amount of the variance in the variable had been extracted by the factor solution. For better measurement of factor, analysis communalities should be 0.3 or greater. All the communalities are above 0.4, so that there are acceptance. In our study the delay factor analysis had a value bigger than 0.4 so that it can be reliable in the research to create the factor model, the parameters in factors analysis are Varimax Rotation and the value of KMO (Kaiser-Meyer-Olkin) = 0.664 which is greater than 0.5 means it is acceptance value, the results of factor analysis created 7-factor model, which is extracted depends on the eigen values more than 1, so that the factor models can name by the organization management (Factor model 1), The procurement process (Factor Model 2), the performance of worker and subcontractors and the wages incentive process (Factor Model 3), Make a decision (factor model 4), Communication process (Factor Model 5 ), The inflation and delaying in payment request, Fairless in the fee (Factor Model 6), and License and the work authorization system (Factor model 7) respectively for factor model 1 & 2 &3 &4 &5 &6 & 7, it can be shown in Fig (8), and the factor analysis created seven core models to represent 22 delay factors.

| Code of Factor | Delay | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Factor 5 | Factor 6 | Factor 7 |
|----------------|-------|----------|----------|----------|----------|----------|----------|----------|
| DF21           | 0.732 |          |          |          |          |          |          |          |
| DF18           | 0.700 |          |          |          |          |          |          |          |
| DF17           | 0.642 |          |          |          |          |          |          |          |
| DF22           | 0.617 |          |          |          |          |          |          |          |
| DF14           | 0.596 |          |          |          |          |          |          |          |
| DF13           | 0.519 |          |          |          |          |          |          |          |
| DF6            | 0.844 |          |          |          |          |          |          |          |
| DF5            | 0.815 |          |          |          |          |          |          |          |
| DF15           | 0.809 |          |          |          |          |          |          |          |
| DF10           | 0.706 |          |          |          |          |          |          |          |
| DF8            | 0.459 |          |          |          |          |          |          |          |
| DF20           | 0.436 |          |          |          |          |          |          |          |
| DF12           | 0.831 |          |          |          |          |          |          |          |
| DF11           | 0.772 |          |          |          |          |          |          |          |
| DF2            | 0.819 |          |          |          |          |          |          |          |
| DF4            | 0.653 |          |          |          |          |          |          |          |
| DF19           | 0.563 |          |          |          |          |          |          |          |
| DF9            | 0.608 |          |          |          |          |          |          |          |
| DF7            | 0.569 |          |          |          |          |          |          |          |
| DF16           | 0.493 |          |          |          |          |          |          |          |
| DF1            | 0.832 |          |          |          |          |          |          |          |
| DF3            | 0.790 |          |          |          |          |          |          |          |

Fig (8)
5.3 Fault Tree analysis:

The fault tree of the delaying factors constructed as shown Fig (9), it composed the top undesired event (delaying of the construction projects) and the intermediate events composed into seven Events which link to the basic events of the delaying factors, the intermediate events of the delaying factors submitted from factor analysis modeling, they compose to the organization management, the procurement process, the performance of worker and subcontractors and the wages incentive process, make a decision, Communication process, The inflation and delaying in payment request, Fairless in the fee, and License and the work authorization system.

Each intermediate event connect to the basic events by logical gates, where the organization management connects to the basic events the effects of type of leadership on the time and cost of the project, the weakness of the technical performance, the poor management. The effects of type of organization (centralized, decentralized). A lot of change Orders, and Carless the risk management factors in the projects.

Intermediate event (the procurement process) connects to the basic events (the delaying of supplies and the delaying in the procurement process)

Intermediate event (the performance of worker and subcontractors and the wages incentive process) connects to the basic events (Lack of Skilled workers, Poor performance management of the subcontractors, the delaying of the fee of the labor and incentives, and Delaying of the deliverables at the working stages)

The intermediate event (Make a decision) connects to the basic events (Hesitated and change in the decision making, slow making decision)

The intermediate event (Communication process) connects to the basic events (Lack of communication between different departments inside the organization, absence of the communication requirement inside the organization and the absence of communication outside the organization)

The intermediate event (The inflation and delaying in payment request, Fairless in the fee) connects to the basic events (Absence of justice in distribution the fees between the labors, the delaying of payment request for vendors and subcontractors, and absence of Inflation and the change in the prices of the materials, Equipment, and wages)

The intermediate event (License and the work authorization system) connects to the basic events (Delaying of the issue the license and agreement to construct the project)

Fig (9) illustrate the fault tree analysis with all components from the top event to the basic events and the connections between all events with the logical gates.

![Fault Tree Diagram](image-url)
6. Conclusion:

Using fault tree analysis to determine the main delaying causes for the construction projects, it can identify the primary causes of delaying (the organization management, the procurement process, the performance of worker and subcontractors and the wages incentive process, make a decision, Communication process, The inflation and delaying in payment request, Fairless in the fee, and License and the work authorization system).

Due to the statistical analysis: the relative importance index for the delaying of the supplying has the biggest value for RII (RII = 0.84078), and then A lot of change Orders with RII = 0.8369 and then Delaying of the issue the license and agreement to construct the project with RII = 0.83106.

Using the factor analysis in the creation of the modeling of factor analysis, FAM composes seven-factor models with the main causes of delaying.

In the final study: the effects of delaying of supplies is the most significant problems and to solve these problems or avoiding it can be achieved by following the process of management of procurements, Measure and evaluate the vendors performance are important for solving the problem of extension time in the project so that it should create the performance measurement for suppliers which contains the communication system to easy the contact with the vendors to solve the shortcoming early, recommendation for the organizations is to start to measure key suppliers delivery performance and support the vendors to improve the delivery performance.

Many change orders are the other big problems lead to extension in time in the construction project, the change orders have been caused by the errors or omission in the project scope or missing the details, misinterpretation in the drawings or other reasons and to prevent the common problems, it can achieve by review the contract documents and specification before starting the construction projects and confirm that the owner should provide an accurate information during the project life cycle.
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