

# Risk Assessment in Durations and Costs for Construction of Industrial Facilities in Egypt Using Equations and Computer

M. Kamal Elbokl, Negadi Kheira

**Abstract**—Risk Evaluation is an important step in protecting your workers and your business, as well as complying with the law. It helps you focus on the risks that really matter in your workplace – the ones with the potential to cause real harm. We are in this paper introduce basics of risk assessment then we mention some of ways to risk evaluation by computer especially Monte Carlo simulation and Microsoft project.

We use Program Evaluation and Review Technique (PERT) to deal with Risks in Industrial Facilities in Evaluation and Assessment for this risk. Using PERT Technique in Microsoft Project by the PERT toolbar and using PERTMASTER Program with Primavera Program we evaluate many hazards and make calculations for that by mathematical equation to make right decisions. We define and calculate risk factor and risk severity to ranking the type of the risk then dealing with it using in that many ways like probability computation, curves, and tables. By introducing variables in the equation of functions in computer programs we calculate the risk in the time and the cost in general case and then mention some examples in industrial facilities field.

**Keywords**—Risk, Industrial Facilities, PERT, Monte Carlo Simulation.

## I. INTRODUCTION

RISK evaluation is aware of the latest science, although the principles of this science about feel instinctive to humans since ancient times, a danger. The natural man does not love danger and can't find comfort in places or relationships, which is shrouded in danger. The man known the Risk since he came down to this earth. God has given the mind to cope with the problems and try to overcome the danger, or at least minimize its effects [1].

Religions have always called their followers to deal with risk and not rely. We believe in the Holy Quran which gives us examples of risk management in ancient times as narrated from Yusuf (the Prophet of God) when developing the plan time to face the threat of famine that were about to crash Ancient Egypt. Reference [24] shows the Holy Quran words, God Said ("Joseph, O man of truth, explain to us about seven fat cows eaten by seven [that were] lean, and seven green spikes [of grain] and others [that were] dry – that I may return to the people; perhaps they will know [about you] \*\*\* [Joseph] said, "You will plant for seven years consecutively;

and what you harvest leave in its spikes, except a little from which you will eat\*\*\*Then will come after that seven difficult [years] which will consume what you saved for them, except a little from which you will store\*\*\*Then will come after that a year in which the people will be given rain and in which they will press [olives and grapes])

The roots of modern risk management lie in a host of regulatory initiatives in the latter part of the twentieth century. Studies began to analyze the risks in organization after the fire which broke out in the U.S. spacecraft (Apollo) and that in early January of 1967 which led to the death of three astronauts. It was the U.S space research agency (NASA) before this incident; engineers rely on the experience of the process to ensure quality, safety and risk control. In April 1969, formed a body working to create standards for safety during space flight so that the safety factor by 95% and not exceed the proportion of risk of death or injuries to the crew of 1%. As for the sector of nuclear facilities in 1957 there have been a scientific study focused on several possible scenarios for the leakage radiation from the nuclear reactor at a distance of 30 miles of gathering place habitable and develop appropriate plans to address such scenarios.

Several methods to evaluate the Risk in Industrial and Construction Facilities have been introduced, such as Monte Carlo Simulation [2], Artificial Neural Network (ANN) [9], Belief Network [14] and linear regression [20].

Industrial Facilities face a lot of inherent uncertainties and issues like company's fluctuating profit margin, competitive bidding process, weather change, productivity, the political situation in a country, inflation, contractual rights, market competition, etc. Thus the industrial places, more than others, has been plagued by risk [8] and there is no industrial project with risk free [16].

## II. LITERATURE REVIEW

### A. Risk

The concept of risk became popular in economics during the 1920s. Since then, it has been successfully used in theories of decision making in economics, finance, and the decision science [18]. Risk has different meaning to different people; that is, the concept of risk varies according to viewpoint, attitudes and experience. Engineers, designers, and contractors view risk from the technological perspective; lenders and developers tend to view it from the economic and financial side [5].

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Project management institute [19] defines risk as the probability that an event will occur. It can also be defined as the combination of the probability of an event and its consequences to a specified amount of a hazard. When the risk analysis process has been completed, it is necessary to compare the estimated risks against risk criteria which the organization has established. The risk criteria may include associated costs and benefits, legal requirements, socioeconomic and environmental factors, concerns of stakeholders, etc. Risk evaluation therefore, is used to make decisions about the significance of risks to the organization and whether each specific risk should be accepted or treated [3].

Risk is a possible undesirable and unplanned event that could result in the project not meeting one or more of its objectives [22]. As the underlying concept of risk management is to manage risks effectively, risk management is a critical part of project management [17].

#### B. Risk Management

If a risk is not identified it cannot be controlled, transferred or otherwise managed [4] and trying to eliminate all risks in projects is impossible. Thus, there is need for a formal risk management process to manage all types of risks. Risk management can lead to a range of project and organizational benefits including: [6].

- 1) Identification of favorable alternative courses of action.
- 2) Increased confidence in achieving project objectives.
- 3) Improved chances of success.
- 4) Reduced surprises.
- 5) More precise estimates (through reduced uncertainty).
- 6) Reduced duplication of effort (through team awareness of risk control actions).

Risk management used the following three-step approach [25]:

- 1) Risk identification.
- 2) Risk assessment.
- 3) Risk mitigation.

Industrial risks can be categorized in a number of ways based on the source of risk, impact of risk or by project phase [15]. In the most reference one, project risks are divided into two groups, according to their source, into internal and external. Internal risks are initiated inside the project while external risks originate due to the project environment [11]. In risk identification step all internal and external risks must be identified. After the establishment of a list of risk events that had actually occurred in the process of project performance, these risks must be assessed.

#### C. Risk Evaluation

When the risk analysis process has been completed, it is necessary to compare the estimated risks against risk criteria which the organization has established. The risk criteria may include associated costs and benefits, legal requirements, socioeconomic and environmental factors, concerns of stakeholders, etc. Risk evaluation therefore, is used to make decisions about the significance of risks to the organization

TABLE I  
VALUES FOR RISK LIKELIHOOD (L) AND RISK IMPACT (I)

Risk Likelihood	L	Risk Impact	I
Almost Certain	0.9	Extreme	0.9
Highly Likely	0.7	Very High	0.7
Likely	0.3	Medium	0.3
Unlikely	0.1	Low	0.1
Rare	0.01	Negligible	0.01

and whether each specific risk should be accepted or treated [3]

The primary objective of risk evaluation is to estimate risk by identifying the undesired event, the likelihood of occurrence of the unwanted event, and the consequence of such event. Risk evaluation involves measures, either conducted quantitatively or qualitatively, to produce the estimation of the significance level of the individual risk factors to the project, so as to produce the estimation of the risk of the potential factors to project success. However, this step results will become the input to the determination of the optimum decision. With a better quantification measuring result, the managers can recognize which risks are more important and then deploy more resources on it to eliminate or mitigate the expected consequences.

Risk evaluation methods have ranged from simple classical methods to fuzzy approach mathematical models. Many Industrial project risk evaluation techniques currently used are comparatively mature tools [26]. Monte Carlo Simulation [23], Sensitivity Analysis [23], Critical path method [13], Fault tree analysis [21], Event tree analysis [12], Failure mode, effects and criticality analysis [7] are the classical quantitative methods, used in Industrial Facilities for risk evaluation.

#### D. Risk Management Standard

Is the result of work by a team drawn from the major risk management organizations in the UK - The Institute of Risk Management (IRM), The Association of Insurance and Risk Managers (AIRMIC) and The National Forum for Risk Management in the Public Sector (ALARM).

### III. EQUATIONS AND CALCULATIONS OF RISK EVALUATION

#### A. Risk Factor

$$\text{Risk Factor (R.F)} = L + I - (L * I) < 1 \quad (1)$$

We calculate R.F by assuming the values of risk Likelihood (L) and risk impact (I) by knowledge of the risk in the project and see how it affect.

From Table I we find the values of (L) and (I) then we get risk factor (R.F) and as we mentioned before there are not any industrial project without risk, so (R.F) cannot equal zero.

The values of risk factor were used as a second judgment factor for determination and evaluation the risk. At maximum probability for risk to happened with extreme impact for this risk we get (R.F) = 0.99 < 1.

### B. Risk Severity

$$\text{Risk Severity (R.S)} = (L) * (I) * 100 < 100 \% \quad (2)$$

Reference [10] shows from the Egyptian standard code no 311-2009 that, risk severity considered as a very important value in evaluating the risk and decision making. By getting the values of risk likelihood (L) and risk impact (I) from Table I we get the maximum value for (R.S) at the point of Probability as almost Certain Happened with Extreme Impact we find (R.S) = 81 %.

### C. Risk Evaluation in the Cost

$$\text{Equivalent Cost} = \text{Max Cost} - \text{Real Cost} \quad (3)$$

The real cost is the cost from calculation of industrial activities and works and it is include direct and indirect costs. The max cost is maximum of unexpected cost depending on the risk severity (R.S). Then we get the values of probability Cost from:

$$\text{Probability Cost} = \text{Eq Cost} * \text{Risk Likelihood (L)} \quad (4)$$

Then getting the total cost which considered and used for bill of quantity (BOQ) and for determination the final cost of the Industrial Project.

$$\text{Total Cost} = \text{Real Cost} + \text{Probability Cost} \quad (5)$$

## IV. RISK EVALUATION USING COMPUTER PROGRAMS

The reserves estimation is done using commercial software that provides for a probabilistic approach of calculating uncertainty in the occurrence of events or unknown variables. The software which designed for risk evaluation can only provide risk analyses based on the information input into the program. The risk evaluation results are only one factor in a delisting decision. The risk-based approach combines state-of-the-art fate and transport modeling with standardized exposure assessment algorithms to provide sound risk evaluation.

### A. Microsoft Excel (Spreadsheet Programs)

The famous program for dealing with previous equations and working with risk evaluation programs is Microsoft Excel. In general spreadsheet are used periodically to analyze data and supporting other programs in the field of risk evaluation like Crystal Ball, Risk Solver, @Risk, DFSS Master, Risk Analyzer and MC Add-In.

In this study we use MC Excel in calculation for risk severity, risk ratio and evaluate the total cost, and then we use Excel in evaluate risk in cost using Monte Carlo simulation and evaluate risk in Time using PERT Model and PERTMASTER Program.

### B. PERT Model

Program evaluation and review technique (PERT) model was developed in 1950s to address uncertainty in the estimation of project parameters. According to classic PERT, expected task duration is calculated as the weighted average of the most optimistic, the most pessimistic, and the most likely

time estimates. The expected duration of any path on the precedence network can found by summing up the expected durations.

Using PERT in Microsoft Project is very easy using the PERT toolbar. To enable the PERT toolbar on the view menu, from the Toolbars menu, choose PERT Analysis. Microsoft Project has four views that help to enter data for PERT analysis: separate views for optimistic, expected, and pessimistic duration, as well as a PERT entry sheet. The most powerful view is the last one as it allows the user to enter and see all durations together. After we enter project data, we press the calculate PERT button on the toolbar; we find the calculations are performed based on optimistic, expected, and pessimistic durations. We will see the results of the calculation in the Gantt chart view.

We use PERT in evaluation in the time and we defined three types of the time which are required to compute the parameters of Industrial work duration distribution in the next equation:

$$\text{Mean (Expected Time)} = t_e = \frac{(t_p + 4 t_m + t_o)}{6} \quad (6)$$

$$\text{Varians} = V_t = \left( \frac{(t_p - t_o)}{6} \right)^2 \quad (7)$$

where pessimistic time ( $t_p$ ) is the time the activity would take if things did not go well, most likely time ( $t_m$ ) is the consensus best estimate of the activity's duration and optimistic time ( $t_o$ ) is the time the activity would take if things did go well.

Probability computation related to PERT theory can get from:

$$Z = (X - \mu) / \sigma \quad (8)$$

where  $\mu = t_p$  = project mean time,  $\sigma$  = project standard mean time and  $X$  = (proposed) specified time.

### C. Monte Carlo Simulation

To overcome the challenges, associated with the PERT method, Monte Carlo simulations can be used as an alternative. Monte Carlo simulation is a numerical modeling technique, named after the city of Monte Carlo in Monaco, where the primary attractions are casinos that play games of chance like roulette wheels, slot machines, dice, cards and others. It is a technique that uses a random number generator to produce and extract an uncertain variable within a distribution model for calculation in a given formula or correlation. Monte Carlo simulation became popular with the advent and power of computers; because the simulations are too tedious to do repeatedly.

#### 1) Using of Monte Carlo Simulation

Monte Carlo simulation can be programmed using an Excel or Lotus spreadsheet to making the statistical analyses for the project like graphs of input and output parameters and, frequency, cumulative frequency, linear plot, mean, median, mode, standard deviation and Sensitivity test.

Then the program introduces many simulations. Each simulation is generated by randomly pulling a sample value for each input variable from its defined probability distribution, e.g. uniform, normal, lognormal, triangular, beta, etc. These input sample values are then used to calculate the results, i.e. total project duration, total project cost, project finish time. The inputs can be task duration, cost, start and finish time, etc.

## 2) The Input Cells

The Monte Carlo simulation program is embedded in MS Excel spreadsheet and, like other programs, various cells that have links to the main output or target reserves need to be filled-up. We introduce many values for cost and time like maximum, minimum and most likely values.

## 3) Output

To obtain the required output, the user has to specify the targeted input and output to print and plot. At this step we get the values of the final Cost and time.

## 4) Steps of Computer Design in M.C Simulation

The first step is creating a parametric model,  $y = f(x_1, x_2, \dots, x_q)$ . Then step two was generate a set of random inputs,  $x_{i1}, x_{i2}, \dots, x_{iq}$ . And the third step was evaluate the model and store the results as  $y_i$ . Then repeat steps 2 and 3 for many times. In our study we do the last step 10 times. The final step we make it analyze the results using histograms and summary statistics.

## D. PERTMASTER

This program is working with project management program (Primavera) to evaluate the time. We used the two programs in many industrial Facilities as we will mention later.

By introduce the values for minimum and maximum durations for every activity, and then define the types of the risks. PERTMASTER runs and give the results according to the previous data and according to the data which are given from Primavera about the durations and activities like actual and remaining work, critical remaining work, start and finish dates, and Resources.

We get many charts for all of activities in all industrial facilities which we are studied it. These charts give us the actual values for the real time which we consider it with our work.

## V. RESULTS AND ANALYSIS

In this study we use many equations and many Computer Programs as we mentioned before. We evaluate the risk in Time using PERT model, PERTMASTER and Excel Sheets. Monte Carlo simulation and equations for risk factor, risk severity, and risk ratio by Excel are used for evaluating risk in the cost.

### A. Risk Evaluation in the Cost

In this study we select a randomly specimen to evaluate the effect of the risk on the total cost. The specimen contains 15 industrial facilities in Egypt and the minimum budget for

smallest one is larger than 37 Millions Egyptian Pound (EGP), approximately larger than 5 Millions American Dollars (USD) = 5,000,000 \$

We get the initial cost and the total cost for every facility, then introduce risk severity for every industrial project. The maximum (R.S) value was 21% and the minimum (R.S) value was 0.1%.

In the step of risk evaluation in the cost and after calculations for equivalent cost, probability cost and total cost we make a comparing between total cost and real cost and we find risk ratio from:

$$1 - (\sum \text{Real Cost} \div \sum \text{Total Cost}) * 100 \quad (9)$$

In Fig. 1 which study the comparing between the total cost and the real cost for randomly selected industrial facility, we find the maximum ratio for difference between total and real cost was at the activity number (24) and equals 20% and the minimum ratio was at activity number (3) and equals 2.3%. Risk ratio is having maximum and minimum point for all of activities, the maximum point was 16.67% at activity number (24) and the minimum point was 2.25% at activity number (3). That means the values of risk ratio is closed to the values of the difference between total and real cost.

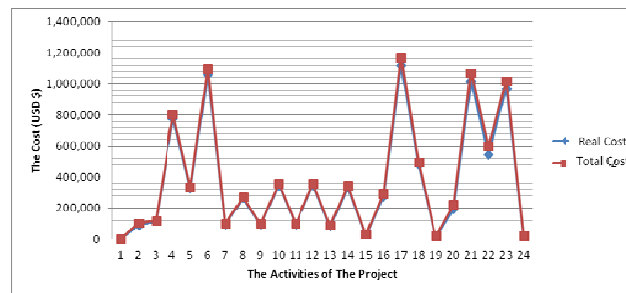


Fig. 1 The Real and Total Cost for 24 Activities for One Facility

For the previous example, the average of risk ratio was 3.52%.

For all 15 industrial facilities we get risk ratio equals 3.94 and the maximum risk ratio was for facility (3) with value of 5.23% and the minimum risk ratio equals 2.82% for facility (14). Fig. 2 summarizes these results.

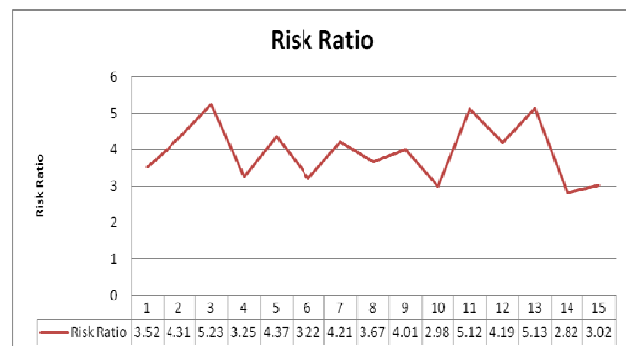


Fig. 2 Risk Ratio for all 15 Industrial Facilities

### B. Risk Evaluation in the Time

For the 15 industrial facilities we introduce the durations for activities for every single facility using the programs of Microsoft Project and Primavera supporting with PERT and PERTMASTER.

Fig. 3 showed an Example for the actual, maximum and minimum duration for 24 activities for a facility as (A), (B), (C) respectively. The minimum duration was for activity (3) and the maximum was for activity (16). The total minimum duration was 519 days and the maximum one was 618 days. We calculate the actual duration by computer programs as we mentioned before. At this example we get the total actual duration for all Activities and it was 565 days. We can get Risk Ratio from:

$$1 - (\sum \text{Min Durations} / \sum \text{Actual Durations}) * 100 \quad (10)$$

For this example we find risk ratio equals 8.14% and this value was the biggest one for all the fifteen facilities. The Average value for risk ratio for all 15 facilities was 5.2% and this is accepted Value.

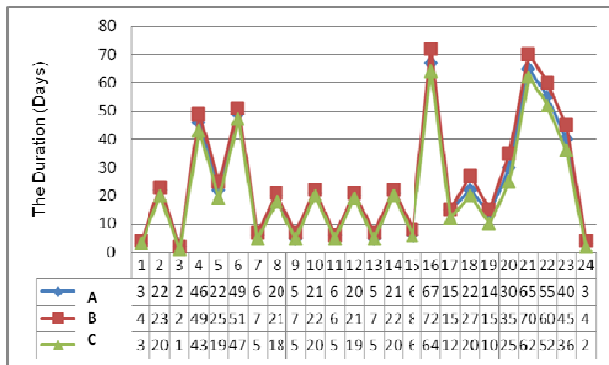


Fig. 3 The Actual (A), Maximum (B) and Minimum (C) Duration for 24 Activities for one Facility

## VI. CONCLUSION

The following conclusions are drawn from this study:

- 1) In general case, the minimum values for risk factor and risk severity was larger than zero and the maximum values were 0.99 and 81% for risk factor (R.F) and risk severity (R.S) respectively.
- 2) There are many computer programs for risk evaluation but we in this study use Microsoft Excel, Monte Carlo Simulation, PERT with Microsoft Project and PERTMASTER with Primavera. There are programs evaluate the risk in the time like PERTMASTER, and there are programs evaluate the risk in the cost like SAFEXPERT. Monte Carlo simulation evaluates the risk in time and cost together.
- 3) In our study case we dealt with 15 Industrial Facilities in Egypt. For these Facilities, the Maximum Risk Severity (R.S) was 21% and the Minimum (R.S) was 0.1%.
- 4) Risk ratio for all facilities was 5.2% in time and 3.94% in cost. And these values are accepted.

- 5) By increasing in the duration of activity we find the risk ratio was decreased.

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