A Comparative Model of EVM and Project's Schedule Risk Analysis Using Monte Carlo Simulation

Bahar Mojabi
M.A. Graduated of IT Management, Science & Research Branch, Islamic Azad University, Tehran, Iran
baharmojabi@gmail.com

Reza Radfar
Associated Prof. of Industrial Management, Science & Research Branch, Islamic Azad University, Tehran, Iran
radfar@gmail.com

Jamshid Nazemi
Faculty Member of Engineering Department, Science & Research Branch, Islamic Azad University, Tehran, Iran
email@nazemi.ir

ABSTRACT
The issue of successful project management and control is of vital importance in today's world. Although the time and cost of any project is determined in advance, paying less attention to an appropriate control and revision will result in a small chance of reaching those goals. The earned value management method that shows deviation of projects schedules and costs is of the good method for this problem however, it does not consider risks and uncertainties. Risk is defined as uncertainty of projects from internal and external environment. Identification and analysis of these risks with an appropriate and effective method is important. As regards conditions that risk imposes on project, the project will be deviated through its life cycle and managers should try to reduce deviations using corrective actions. However risk analysis is widely used in projects today, but this risk analysis is highly futuristic. The purpose of this research is designing a comparative model of earned value management and project schedule risk analysis that uses best corrective actions to improve the condition of the project. In this paper, earned value management indicators are calculated and analyzed and project completion time and delay factors are obtained by using a real project data. Also the project completion time and delay are investigated using project risk analysis and estimating activities completion time by doing Monte Carlo simulations. Finally by comparison of these two methods, a solution is proposed to improve the project condition.

Keywords
Earned Value Management, Schedule Risk Analysis, Monte Carlo Simulation

1. INTRODUCTION
In today's uncertain business environment there is understandable pressure to improve the quality of decision-making at all levels in the organization. A number of techniques have been developed to address this concern, in an attempt to introduce some rational framework to the decision-making process (Hillson, 2004). In project based organizations, one of the problems that always has considered, is whether a project would be ended based on its time schedule or not. One of the leading approaches is Earned Value Management (EVM) and another one is time schedule Risk Analysis. These two methods can and should be applied in an integrated way across the organization. Earned Value Management (EVM) is a project management technique used to measure project progress in an objective manner. According to Project Management Institute (PMI), when properly applied, EVM provides an early warning of performance problems. Referring EVM to EV (Earned Value) most often, the EV measures the project performance and the project progress by integrating efficiently the management of the three most important elements in a project, i.e. cost, schedule and scope. In fact, it calculates the cost and time performance indices of a project, estimates the completion cost and the completion time of a project, and measures the performance and the progress of a project by comparing the planned value and the actual costs of activities to their corresponding earned values (Moslemi Naeni et al., 2010).Schedule risk analysis is an effective technique to connect the risk information of project activities to the baseline schedule. This technique is used to provide sensitivity information of individual project activities to assess the potential impact of uncertainty on the final project duration. Monte Carlo simulation is a mathematical method used in risk analysis. In fact, Monte Carlo calculates the possible project cost and schedule values that may result from individual risks and translates them into project-level cost and schedule risk.

The purpose of this paper is getting attention of management to integrating of these two methods to determine an accurate coefficient of project's performance.

2. LITERATURE REVIEW

In this section, a review of earned value management and risk concepts would be presented first and then some papers for both of concepts will be exhibited.

2.1. Earned Value Management

During a project, until to be completed, earned value in each point of time shows the financial cost of worked perform to that time. In fact, earned value, is the budgeted cost of performed work (Moslemi and Geraviyan, 2009).

The earned value project management method is a powerful tool that supports the management of project scope, time and cost. It allows the calculation of cost and schedule variance and performance indicates, and forecasts of project cost and schedule at completion (Anbari, 2003).

EVM has become the predominant theoretical tradition for the evaluation of project performance and progress over the past several decades. That key role is underlined not only by its prominence in most PM textbooks and bodies of knowledge, but also its codification within the US Government Requirements and Standards (NDIA, 1998). It provides a narrow perspective on the project status, as it evaluates performance and progress using a metrics approach in which just three measures are derived, all based on cost or other resource calculations. That narrow focus is a weakness; obviously the EVM indicators and forecasts are only as good as the quality of the information on which they are based. Further, EVM only considers that internal performance of the project – that is, how well the project is performing in relation to its cost, time, and scope objectives. EVM does not address the performance of the results of the project, nor the impacts of those results on society, the environment, etc (Bower and Finegan, 2009).

2.2. Risk

In general, unexpected events occur in projects and may result in either positive or negative outcomes that are a deviation from the project plan. Positive outcomes are opportunities while negative outcomes generate a loss. Risk focuses on the avoidance of loss from unexpected events. Several definitions of risk are available in the literature and risk is usually referred to as an exposure to losses in a project (Ahmed et al., 2007).

The discipline of project risk management has developed over the recent decades as an important part of project management. Several researchers argue risk as being an exposure or a probability of occurrence of a loss. Further, other persons define risk as a barrier to success and argue that risk is related to concepts of chance such as the probability of loss or the probability of ruin. Risk can also be viewed as having a positive effect. Risk has defined as exposure to loss/gain, or the probability of occurrence of loss/gain multiplied by its respective magnitude. The PMBOK (2004) defines risk as an uncertain event or condition that, if it occurs, has a positive or negative effect on a project's objectives (Olsson, 2008).

After risk events are identified, their characteristics need to be assessed so that it is determined whether the risk event is worth further analysis. Once it is decided that a risk event needs analysis then it needs to be determined whether the risk event information can be acquired through quantitative or qualitative means. Measurement metrics for risk also need to be determined so that these metrics can be used for computation of risk magnitude and risk analysis leading to risk mitigation plans (Amornsawadwatana et al., 2002).

The main objective of risk analysis is to establish a rational foundation for objective decision making. The risk analysis aims at quantifying the undesirable effects that a given activity may impose on humans, environment or economical values. The objective of the decision process is then to identify the solution that in some sense minimizes the risk of the considered activity (Friis-Hansen, 2005).

2.3. The Studies consist of Both of EVM and Risk

The past studies of both EVM and risk concepts are presented and summarized in table 1

3. RESEARCH METHOD

3.1. Research Methodology

To improve project control methods and evaluating their conditions for a better project management, a functional goal has been selected. In order to identify and study project control variables, this research is descriptive for data types.

Library method is used in this paper to reach the goals of research literatures. Literatures on this subject from like most of ISI papers, consist project risk concepts, earned value management and Monte Carlo simulations.

Filed data from a gas and oil project has been used in this paper for the case study. The data is about project schedule, costs, activities etc. and gathered by project control section in rendered as Excel.

3.2. Research Process

EVM is developed for integrating, measuring and comparing trend of cost, time and scope in a project. All EVM related factors and indicators can be calculated by incoming data from a selected project. Using EVM together with risk analysis by Monte Carlo simulation gives the time of project completion. In fact the completion time is the main factor of this research. Finally, a comparison is done between these two models. Figure 1 shows the conceptual model of this paper.

Table 1. Literature of EVM and Risk

Field Studies	Year	Researchers	
This paper is about that how the RM and EVM processes are naturally interrelated, it is important to assess both methodologies independently and identify the natural overlap between the two.	2001	Teixeria	EVM & RISK
This paper summarized a study of the current status of the integration of risk management with earned value management and recommendations for further actions. This study was conducted by the National Defense Industrial Association Program Management Systems Committee's Risk Management Working Group.	2002	NDIA	
The Cost–Time–Risk diagram (CTR) presented in this paper and that is a new project planning and management technique that helps project managers consider project risk issues while monitoring and .controlling their project schedule and cost performance in one diagram	2006	Aramvareekul and Seider	
This study has offered a new cost management process that involves the identification, assessment and quantification of risky WBS elements in the cost estimating process for reporting feedback using Earned Value Management (EVM).	2007	Graham	
In this paper, researchers analyzed real cases of software development projects that adopted risk management but failed, and identified the root causes. Next, they proposed a permanent monitoring agency that predicts future risks generation using quantitative data captured by Earned Value Management technique.	2008	Akihiro and Nobuhiro	
This paper proposes a new analysis method to project duration risk based on earned value measurement, discusses the different possible risk types under different earned value indexes, then divides the severity of duration risk into five different levels which will be convenient for project .managers to take measures	2010	Xiaozhong and Hong	

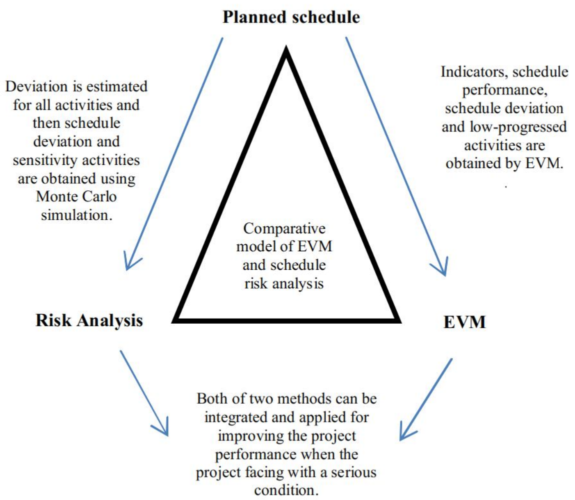


Figure 1. Conceptual Model

3.3. Research Tools

One method used by some project managers during the risk analysis process is Monte Carlo simulation applications. This activity has been widely used for decades to simulate various mathematical and scientific situations, and it is mentioned often in project management curricula and standards (Hoon Kwak and Ingall, 2007).

In this paper, @RISK is used for Monte Carlo simulations. @RISK is a simple-to-use tool that calculates scenarios for a given situation and its result shows likelihood of a scenario. This result leads to an easier judgment for the manager to whether take a risk or not.

4. RESEARCH FINDINGS

4.1. EVM Model

The selected project in this paper started in October 2011 and it should be finished in 22 months or August 2013. Data for 16 months is available for the simulation.

Planed value (PV), actual cost (AC) and earned value (EV) are calculated using earned value analysis and based on the available data. These indicators are shown in figure 2.

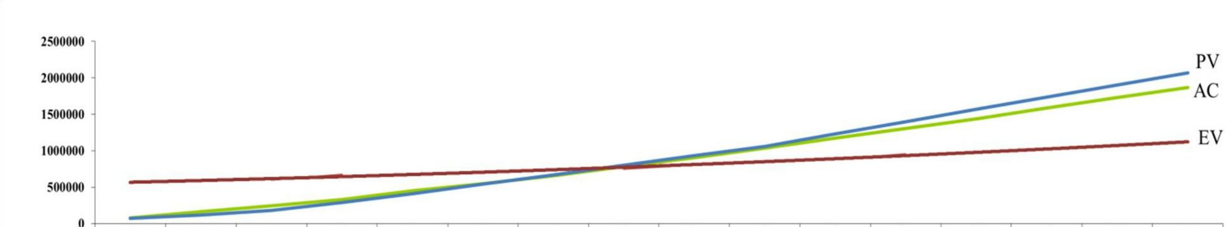
As shown in figure 2, project performance is better than schedule up to the 8th month. After that to the 16th month, project performance has a slower trend than schedule. That means after 8th month some activities do not have appropriate act and do not proceed based on their schedule.

Figure 3 shows Schedule performance indicator (SPI) and cost performance indicator (CPI). SPI is defined as the ratio of EV and PV, and CPI is the ratio of EV and AC.

SPI and CPI of greater than 1 shows that project is ahead of schedule and performance is efficient and if smaller than 1, they show project has lag and poor performance. If these values be 1, project acts according to the schedule. As is shown in figure 3, before 16th month these indicators are more than 1 and after that are less than 1.

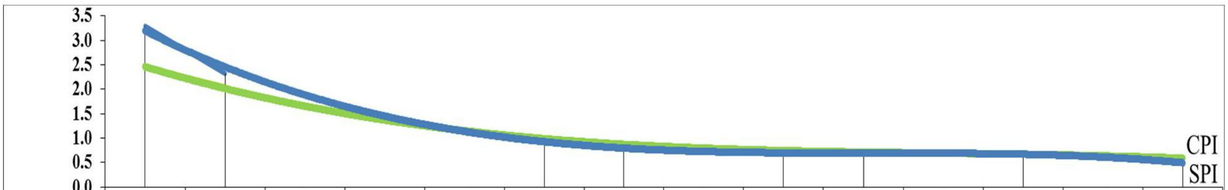
Estimate at Completion (EAC (t)) is the main variable of this study. EAC(t) can be calculated in different ways. From the simplest formula, it can be obtained by following equation where Planned Duration (PD) is the scheduled time duration at the beginning of the project.

$EAC(t) = PD / SPI$



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
AC	75,000	160,000	245,000	330,000	450,000	545,000	655,000	785,000	905,000	1,035,000	1,175,000	1,305,000	1,435,000	1,585,000	1,730,000	1,870,000
PV	70,400	118,000	182,000	290,800	411,600	542,400	670,800	802,200	933,600	1,057,000	1,227,800	1,398,600	1,567,000	1,735,400	1,901,400	2,067,400
EV			598,905	674,820				748,374	804,907		881,866	957,754		1,033,642		1,109,530

Figure 2. PV, AC and EV



	3	4	5	6	7	8	9	10	11	12	13	14	15	16
CPI	2.44451	2.04491				0.95334	0.88940		0.75052	0.73391		0.65214		0.59333
SPI	3.29069	2.32056				0.93290	0.86215		0.71825	0.68479		0.59562		0.53668

Figure 3. SPI and CPI

According to project schedule, planned duration of this project is 22 months and SPI was obtained an amount equal to 0.53 in 16th month, so EAC(t) will be calculated as follows.

$$EAC(t) = 22 / 0.53 = 41.5$$

According to the calculated amount, estimate at completion is equal to 41.5 months. But scheduled duration for this project planned 22 months which means a big delay for the project.

As shown in figures 2 and 3 at this time, the project has not good performance and is behind the schedule. Activities with the lowest percent of progress have been extracted based on the last information about project progress in the 16th month. These activities that have the most effect on the project delay are shown in table 2

Table 2. Sensitivity activities obtained by EVM

No.	Activity Name
1	INSTRUMENT DATA SHEET FOR ON/OFF VALVES FOR UNIT 23
2	LIQUID FUEL OIL AND NATURAL FUEL GAS UNIT ELECTRONIC INSTRUMENT AND JUNCTION BOXES LOCATION LAYOUT
3	UNIT 23-LIQUID FUEL OIL AND NATURAL FUEL GAS UNIT PNEUMATIC INSTRUMENTS LOCATION LAYOUT
4	UNIT 24-PLANT AND INSTRUMENT AIR ELECTRONIC INSTRUMENTS AND JUNCTION BOXES LOCATION LAYOUT
5	UNIT 24-PLANT AND INSTRUMENT AIR PNEUMATIC INSTRUMENTS LOCATION LAYOUT
6	FGS SIMPLIFIED LOOP DIAGRAM - DATABASE UNIT 21
7	INSTRUMENT DATA SHEETS FOR FIRE & GAS DETECTORS FOR UNIT 21
8	ELECTRONIC INSTRUMENTS AND JUNCTION BOXES LOCATION LAYOUT UNIT 21
9	FIRE & GAS INSTRUMENTS AND JUNCTION BOXES LOCATION LAYOUT UNIT 21
10	PNEUMATIC INSTRUMENTS LOCATION LAYOUT UNIT 21
11	INSTRUMENT DATA SHEETS FOR THERMOELEMENTS AND THERMOWELLS FOR UNIT 45
12	INSTRUMENT DATA SHEETS FOR TEMPERATURE TRANSMITTERS FOR UNIT 45
13	INSTRUMENT DATA SHEETS FOR LEVEL GAUGES GLASS AND MAGNETIC TYPE FOR UNIT 45
14	INSTRUMENT DATA SHEETS FOR PROCESS ANALYSERS FOR unit 45
15	TECHNICAL BID EVALUATION FOR TEMPERATURE TRANSMITTERS, THERMOELEMENTS AND THERMOWELLS
16	TECHNICAL BID EVALUATION FOR LEVEL GAUGES GLASS AND MAGNETIC TYPE
17	TECHNICAL EVALUATION FOR LOCAL INDICATORS ELECTRONIC TYPE
18	TECHNICAL BID EVALUATION FOR PROCESS ANALYSERS AND SAMPLING SYSTEMS

4.2. Risk Analysis Model

As mentioned earlier, the data of case study up to the 16th month has been analyzed. All activities before that date can be separated into two groups. One is activities ended by the date and their deviations from planned schedule are specified and the other is activities that have been started and are in progress. Duration of activities in second group and their completed time are not specified but it can be obtained by estimations. For estimating deviations, the activities that are similar should be gathered in same work groups. In the other word, activities with similar operation will be placed in one group with both types of activities that are ended or in progress activities. In each work group, completed activities have a deviation from schedule. A normal standard deviation for activities that have not completed yet can be calculated. The probability estimation that is considered in this study is 3δ. In fact, this time has been calculated by μ+3δ, where μ is activity's time schedule and δ is the obtained deviation for activities of each work group. After estimating deviations, an average amount for activities duration and a schedule deviation for all activities in the project are obtained.

Monte Carlo simulates final function using a group of random values from the probability functions. During a Monte Carlo simulation, values are sampled from the input probability distributions randomly. Normal distribution is selected in this study. The inputs are activities that introduced by a normal probability distribution according to their values and obtained from previous level and output is time at completion, the main variable of this study. Thousand Monte Carlo cases are simulated using @RISK and results are presented in following.

4.2.1. HISTOGRAM

Histogram is a graph that shows all iterations based on the probability of different occurring outcomes. Figure 4 shows the histogram and it is shown that time at completion have a value between 1090 and 1460 with probability of 90% and other values with probability of 10%.

4.2.2. TORNADO Diagram

This diagram shows sensitivity activities as a chart. Tornado diagram is to rank the distributions in the model according to the impact they have on the outputs. Tornado shows which risks cause most uncertainty in time schedule. Figure 5 shows a tornado diagram that for the study case of this paper.

4.2.3. Sensitivity Analysis

Sensitivity analysis determines the critical factors in models and ranks the uncertain factors or activities in the model, based on their effects on outputs. Sensitivity analysis shows the inputs with the most effect on output. Table 3 shows sensitivity activities.

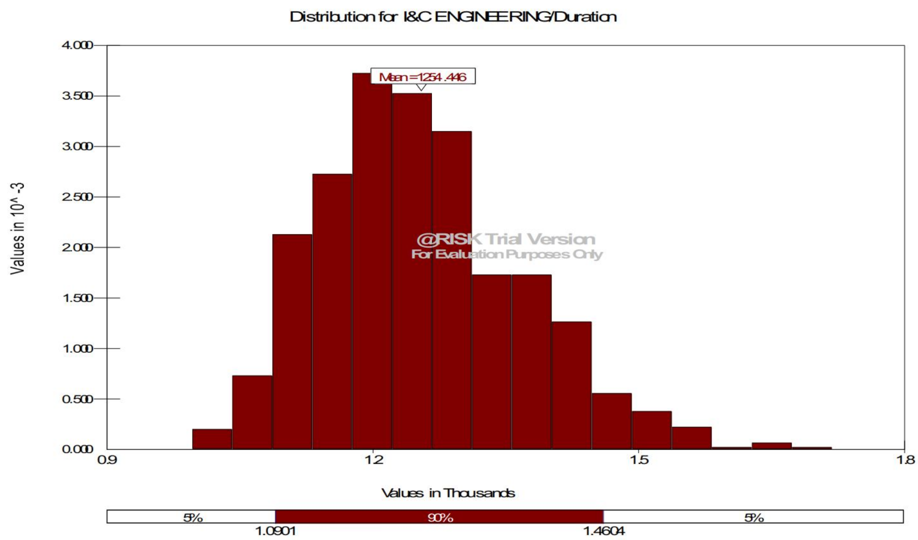


Figure 4. HISTOGRAM

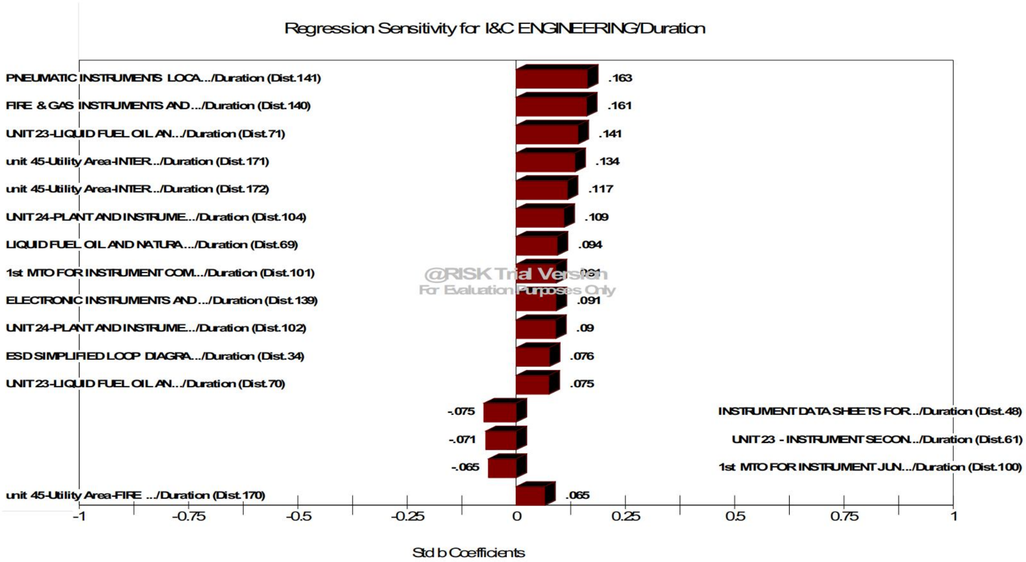


Figure 5. Tornado diagram

Table 3. Sensitivity activities obtained by Risk analysis

No.	Rank Inputs for Output I&C ENGINEERING/Duration	Distribution	Sensitivity Ranking
1	PNEUMATIC INSTRUMENTS LOCATION LAYOUT UNIT 21	NORMAL(425, 245)	0.163
2	FIRE & GAS INSTRUMENTS AND JUNCTION BOXES LOCATION LAYOUT UNIT 21	NORMAL(425, 245)	0.161
3	UNIT 23-LIQUID FUEL OIL AND NATURAL FUEL GAS UNIT PNEUMATIC INSTRUMENTS LOCATION LAYOUT	NORMAL(425, 245)	0.141
4	UNIT 45-INTERCONNECTING UNIT ELECTRONIC INSTRUMENTS AND JUNCTION BOXES LOCATION LAYOUT	NORMAL(425, 245)	0.134
5	UNIT 45-INTERCONNECTING UNIT PNEUMATIC INSTRUMENTS LOCATION LAYOUT	NORMAL(425, 245)	0.117
6	UNIT 24-PLANT AND INSTRUMENT AIR PNEUMATIC INSTRUMENTS LOCATION LAYOUT	NORMAL(425, 245)	0.109
7	LIQUID FUEL OIL AND NATURAL FUEL GAS UNIT ELECTRONIC INSTRUMENT AND JUNCTION BOXES LOCATION LAYOUT	NORMAL(425, 245)	0.094
8	1st MTO FOR INSTRUMENT COMPRESSION FITTINGS FOR UNIT 24	NORMAL(390, 210)	0.091
9	ELECTRONIC INSTRUMENTS AND JUNCTION BOXES LOCATION LAYOUT UNIT 21	NORMAL(425, 245)	0.091
10	UNIT 24-PLANT AND INSTRUMENT AIR ELECTRONIC INSTRUMENTS AND JUNCTION BOXES LOCATION LAYOUT	NORMAL(425, 245)	0.09
11	ESD SIMPLIFIED LOOP DIAGRAM-DATABASE UNIT 11	NORMAL(200, 10)	0.076
12	INSTRUMENT DATA SHEETS FOR PRESSURE AND DIFF. PRESS. TRANSMITTERS FOR UNIT 23	NORMAL(255, 90)	-0.075
13	UNIT 23-LIQUID FUEL OIL AND NATURAL FUEL GAS UNIT FIRE & GAS DEVICES AND JUNCTION BOXES LOCATION LAYOUT	NORMAL(105, 75)	0.075
14	UNIT 23 - INSTRUMENT SECONDARY ELECTRICAL HOOK-UPS	NORMAL(305, 95)	-0.071
15	1st MTO FOR INSTRUMENT JUNCTION BOXES AND CABLE GLANDS	NORMAL(390, 210)	-0.065
16	FGS SIMPLIFIED LOOP DIAGRAM - DATABASE UNIT 11	NORMAL(335, 125)	0.065
17	UNIT 45-FIRE & GAS DEVICES AND JUNCTION BOXES LOCATION LAYOUT	NORMAL(425, 245)	0.065
18	IINSTRUMENT DATA SHEETS FOR ULTRASONIC AND RADAR TYPE LEVEL TRANSMITTERS FOR UNIT 21	NORMAL(390, 210)	0.061
19	INSTRUMENT DATA SHEETS FOR FIRE & GAS DETECTORS FOR UNIT 21	NORMAL(405, 210)	0.059
20	UNIT 11 - DCS LOGIC DIAGRAM	NORMAL(120, 90)	0.059
21	INSTRUMENT DATA SHEETS FOR TEMPERATURE TRANSMITTERS FOR UNIT 45	NORMAL(375, 210)	0.058
22	INSTRUMENT DATA SHEETS FOR PRESSURE AND DIFFERENTIAL PRESSURE GAUGES FOR UNIT 45	NORMAL(375, 210)	0.055
23	UNIT 24 - JUNCTION BOX WIRING DIAGRAMS FOR FIRE AND GAS DEVICES ELECTRICAL CONNECTIONS	NORMAL(305, 95)	0.054
24	SUPPLY SPECIFICATION FOR THERMAL MASS FLOW METERS	NORMAL(35, 5)	-0.053
25	DCS LOGIC DIAGRAMS - UNIT 23	NORMAL(335, 125)	0.052

4.3. Comparative Model

EVM response is in the form of progress activities in percentage. Activities with low progress percentage have known as delay factors and will be warned by EVM. Since risky activities are very important, risk should be considered for all activities during the project execution. In the other word, risk is cause of change in duration of activities. Unlike EVM that cannot consider uncertainty for activities, risk can see the future and risk analysis can investigate the risk of each activity. Highly sensitive activities or similarly most risky activities have determined using Monte Carlo simulation. Two methods have been demonstrated in this paper, EVM and schedule risk analysis; each of these models extracts activities that have most effect on duration of project. These activities are shown in tables 2 and 3. Some similar activities can be seen by comparing the results in those tables. As mentioned earlier, EVM and Risk Analysis are applied in different ways but they give some similar factors. As a result, the control project management at each time should consider both earned value and risk model and its highest priority should be activities with warning in both models and should attempt to improvement these groups of activities.

5. CONCLUSION

In this study, the main variable was project time at completion. This variable is obtained by two methods; earned value management and schedule risk analysis. EVM looks to past and risk can see the future. Many projects like the one in paper may face with a big delay and hence finding reasons of this delay and suggesting solutions to project managers are important. Each of these models calculates the time at completion and monitors the factors that were cause of delay by their own methods. In both of the models, sensitive activities are found and they are introduced in the comparative model and it was obvious that they have the most effect on project delay. So the obtained goal is eliminating these delays and improving the time of projects and their performance. The most important action that project managers should take is focusing on the activities with largest sensitivity factors and spending the most energy for them. In this way, they are able to discover the problems and find a solution with a rapid action before those risks can damage the project.

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