Risk Analysis Related to Costing and Scheduling of Construction Projects

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Abstract
In construction projects, risks play a significant part in decision making and may affect the performance of the project. Nevertheless, construction projects always face uncertainty that leads to cost and schedule risks. Most of those risks can be mitigated with better up-front planning and analysis. The cost estimate should be consistent with the schedule in terms of resources assumed, their productivity and other factors. Poor cost and schedule estimates lead to cost and schedule over-runs, poor decisions, funding problems, and other risks. As a result, project cost risk and schedule uncertainty should always be addressed and each task's most likely, optimistic and pessimistic cost and duration values should also be documented.

In this study, the cost and schedule risks associated to design and implementation of twenty housing units for low income people in Tripoli, Libya were analyzed. The qualitative risk analysis process carried results in a prioritized list of forty-four risk events. The cost and schedule risks are integrated and analyzed using Monte Carlo simulation. Two scenarios, pre and post mitigations, were conducted. The results showed a risk reduction from 20% high, 25% medium and 55% low risk to 22% medium and 78% low with no high risks.

Keywords
Construction project, Risk management, Schedule risk, Primavera risk analysis, Monte Carlo Simulation.

1- Introduction
In recent years, construction industry has made significant contribution to the country's economy growth. Large construction projects operates in a very uncertain environment where conditions can change due to the complexity of each project, many construction projects are faced by scheduling problems causing the projects to finish beyond their predetermined due date which in turn will cause increase overall cost of the project, and Contractor may have to face penalty for causing delay, Hence risks and uncertainties must be considered for overall duration of the project to complete the projects in time and within budget. The chance that project will be completed on time and within budget is one of the most important indicators for the decision-making.

This paper aims to be a guide that clarify and simplify cost and schedule risk assessment process for construction field using PMBOK guide procedure and Primavera Risk analysis (PRA) and provide hands-on guideline assist project controller in developing and conducting schedule risk analysis module to increase the likelihood and impact of positive events, and decrease the likelihood and impact of negative events in the project.

2- Literature Review
Many previous studies have been conducted within the field of integrated cost and schedule risk analysis but each presents a different approach to this concept. In 2012 Hulett studied the impact of schedule risk on cost risk using

Monte Carlo simulation and CPM model. The main tool of analysis of cost-loaded schedule is Monte Carlo simulation. Rajendra et al. (2016) states that project risks cause variations in activity duration, and in turn the entire network is affected by uncertainty. He presents the effect of uncertainties in the project on the total duration of the project in an Indian context. For this, he used Monte Carlo simulation (MCS) technique. Effect of different distributions for different activities and the number of simulations on the total project duration are determined and compared with the CPM and PERT. Finally, sensitivity analysis is carried out to show the influence of each uncertain activity on the total project duration.

Mhetre, K. (2017) states that Risk is present in all projects irrespective of their size or sector. If risks are not properly analyzed, the project is likely to lead to failures and he show the benefit of using computer software i.e. Primavera Risk Analysis in Risk Management Process of construction projects to analyze the risks involved in a construction project. It includes the preparation of schedule, assigning the 3-time estimate durations and performing iterations using primavera risk analysis.

3- Project (Case study) Overview

Project name: design and implementation of 20 housing units for low-income people in Tripoli / Libya.

Project sponsor: Organization for development and administrative centers (ODAC).

Project supervisor: Social Security Fund.

Project goals:

- Implementation of the project within budget.
- Implementation of the project on time.
- Implementation of the project with the quality required by the Clint.
- Implementation of the project according to the scope of work required.
- Reducing the problem of random housing, improving the environmental and living standards of the population and alleviating poverty.
- Reduce the large gap between the income of this segment and the prices of housing offered.

3.1- Project Description:

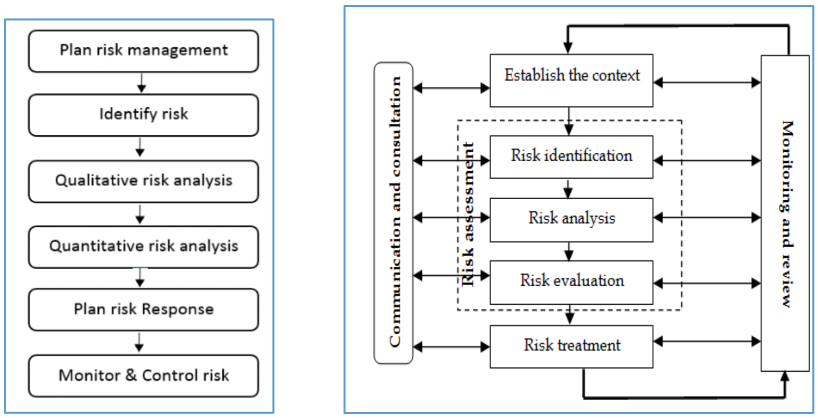
Implementation of 20 housing units in the city of Tripoli. Each housing unit is consisting of one floor contains two bedrooms, one of which is a main living room and men's salon, kitchen and bathroom in addition to the corridors linking the rooms and a total area estimated at 112 m^2. It shall be executed in accordance with the designs approved by the project consultant and on a piece of land that meets all the procedures of ownership and a total area 300 m^2.

Table 1. Project original planning information

phase	Planning & scheduling phase
Risk considering	Not Yet
Software	Microsoft Project 2013
Scheduling method	Critical path method (CPM)
Scheduling type	Deterministic CPM
Start date	01/01/2018
Finish date	26/07/2018
Project duration	178 days
Project cost	141,243.000 LD

4- Risk Management Methodologies.

Project Management Institute (PMI) defines risk as an uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives such as scope, schedule, cost, and quality (PMBOK Guide, 2013). where the uncertainty is lack of knowledge that reduces confidence in conclusions. however, International Organization for Standardization (ISO31000-2009) defines risk as an effect of uncertainty on objectives. Objectives can have different aspects such as financial, health, safety, and environmental goals and can apply at different levels, for instance, strategic, organization-wide, project, product and process. Project Management Institute (PMI) defines the risk management processes as: (1) Plan risk management, (2) Identify risk, (3) Qualitative risk analysis, (4) Quantitative risk analysis, (5) Plan risk Response, and (6) Monitor and Control risk. From the other hand, international Organization for Standardization (ISO31000-2009) defines the risk management processes as: (1) Communication and consultation, (2) Establishing the context, (3) Risk assessment (Risk identification, Risk analysis, and Risk evaluation), (4) Risk treatment, (5) Monitoring and review as illustrated in Figure 1. This work followed the structuring proposed by the PMBOK Guide 5th edition.



a) PMBOK Guide 5th edition (b) ISO 31000-2009

Figure 1. Risk Management Processes.

4.1- Identify Risks

Identify Risks is the process of determining which risks may affect the project and documenting their characteristics. Identify risks is an iterative process, because new risks may evolve or become known as the project progresses through its life cycle.

4.2- Qualitative risk analysis

Qualitative Risk Analysis is the process of prioritizing risks for further analysis using techniques such as Probability and Impact Matrix (Figure 2) and risk category (Figure 3), the key benefit of this process is that it enables project managers to reduce the level of uncertainty and to focus on high-priority risks.

Probability and Impact Matrix

Probability Rating						
	5 Very High	5	10	15	20	25
	4 High	4	8	12	16	20
	3 Moderate	3	6	9	12	15
	2 Low	2	4	6	8	10
	1 very Low	1	2	3	4	5
		1 very Low	2 Low	3 Moderate	4 High	5 Very High
Cost Impact		Insignificant cost increase	<5% cost increase	5-10% cost increase	10-20% cost increase	> 20% cost increase
Schedule Impact		Insignificant slippage	<1 month slippage	1-3 months slippage	3-6 months slippage	> 6 months slippage
		Impact Rating				

RISK RATING
1 to 6 = LOW
7 to 15 = MEDIUM
16 to 25 = HIGH

Each risk is rated on its probability of occurring and impact on an objective if it does occur, The organization's thresholds for low, moderate or high risks are shown in the matrix and determine whether the risk is scored as high, moderate or low for that objective.

Figure 2. Probability and impact matrix

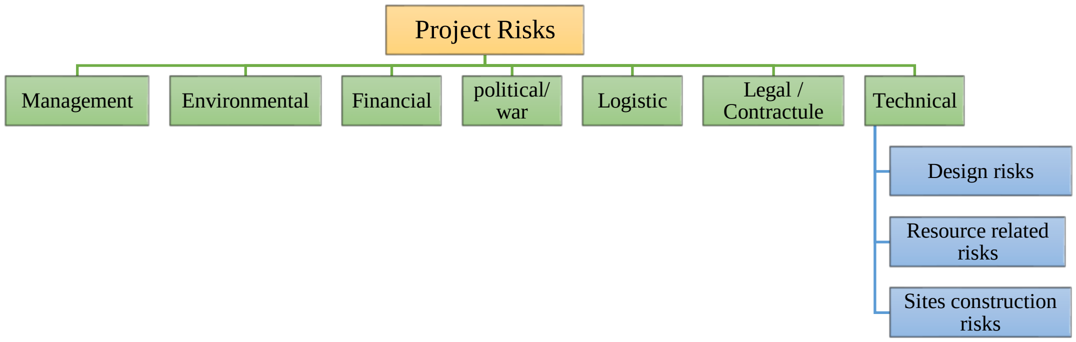


Figure 3. Risk Category

4.3- Quantitative risk analysis (Cost & Schedule risk analysis)

Quantitative risk analysis is the process of numerically analyzing the effect of identified risks on overall project objectives using modeling and simulation. The key benefit of this process is that it produces quantitative risk information to support decision making in order to reduce project uncertainty.

5- Case Study Modeling and Simulation

Simulations are typically performed using the Monte Carlo technique in a simulation, the project model is computed many times (iterated), with the input values (e.g., cost estimates or activity durations) chosen at random for each iteration from the probability distributions of these variables. A histogram (e.g., total cost or completion date) is calculated from the iterations. For a cost risk analysis, a simulation uses cost estimates. For a schedule risk analysis, the schedule network diagram, Oracle primavera risk analysis (Pert master) is used in our case study to modeling and perform Monte Carlo simulation (Figure 4). Modeling and simulation the schedule risk will be conducted as following:

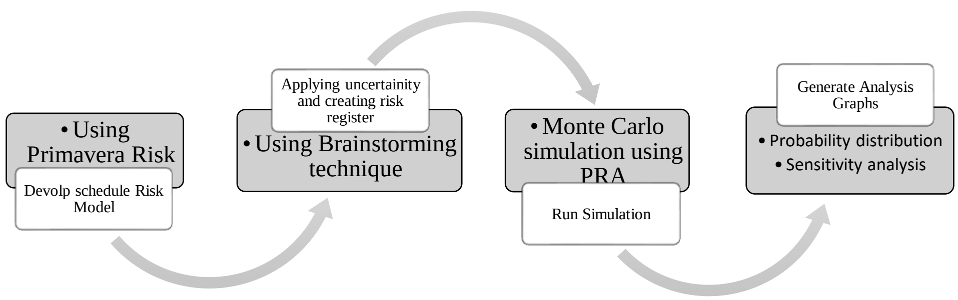


Figure 4. Modeling and Simulation processes.

a) Develop schedule risk model

To develop schedule risk model, we used primavera risk analysis tool throughout importing the original schedule from Microsoft project 2013 (MPP file), as showing in Figure 5 the project starting in 01/01/2018 and it is scheduled to be completed in 26/07/2018 (178 working days) at cost of 141,243.000 LD.

b) Applying uncertainty and creating risk register

The schedule risk analysis starts with applying uncertainty to the schedule activities duration and cost throughout brainstorming sessions to reflect the inherent uncertainty, estimating errors and estimating bias. Triangular distribution is used when the max, min and most likely values are known (Mory, 2015).

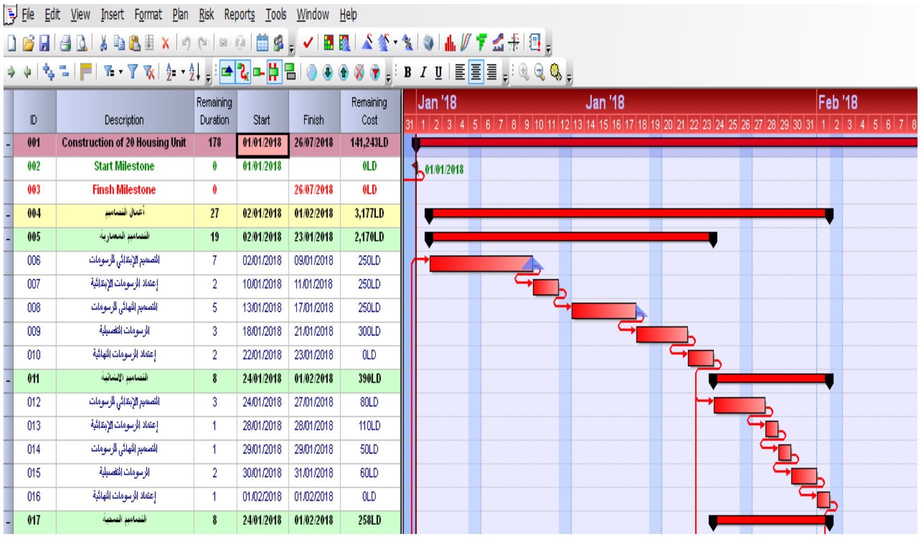


Figure 5. Schedule risk model

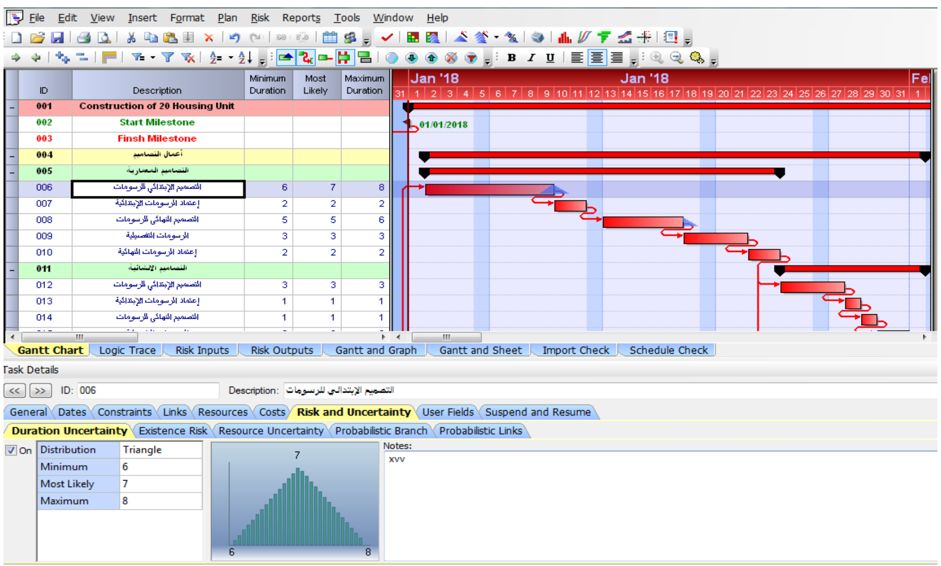


Figure 6. Uncertainty Range

After applying uncertainty to the schedule activities duration and cost risk register is build up to identify risk events (Figure 7) and linked (Map) it to activities in order to complete Monte Carlo analysis and build impacted risk plan as shown in Figure 8.

Risk		Pre-Mitigation (Data Date = 01/01/2018)			
ID	Title	Probability	Schedule	Cost	Score
DR01	Mistakes in preliminary Designe	L	L	VL	4
DR02	Changes in the design and specifications of the project materials	H (60%)	L (7)	H (22,49...	16
DR03	Delay in approval of project samples, Shop Drawing and Variation Orders	VH (85%)	H (24)	L (4,496....	20
ER22	Bad weather (rain , high temperatures ....etc.)	VH (85%)	N (0)	M (10,9...	15
ER23	Non-compliance with environmental legislation	VL	VL	VL	1
ER24	Environmental disasters (Earthquake, FloodS ... etc.)	VL	VH	VH	5
ER25	Fire broke out at the project site or the labor camp	H (60%)	N (0)	H (22,49...	16
FR04	Delay payment of completed worrks by owner	VH (85%)	N (0)	N (0.00L...	0
FR05	Unexpectedly delya in project funding	VH (85%)	N (0)	N (0.00L...	0
FR06	changes in Exchange Rates of Libyan Dinars against foreign currencies (+ , -)	VL	H	L	4
FR07	Financial difficulties of subcontractors	VH (85%)	N (0)	H (22,49...	20
FR08	Significant rise of construction materials prices	VH (85%)	N (0)	VH (45,0...	25
FR09	Significant rise of labor rates (workers wages)	VH (85%)	N (0)	N (0.00L...	0
LCR10	Legal disputes during the execution phase	VL	VH	M	5
LCR11	Difficulty in obtaining licenses and work permits	VL	M	VL	3
LCR12	New legislation (e.g. increase of fuel prices)	M (40%)	VL (2)	H (22,50...	12
LCR13	Amending (decrease) the Subject Matter Of the Contract (15% of the value of the contract).	L	N	VL	2
LR018	Changing in construction waste dump site a way from its current location	VL	VL	VL	1
LR019	Shortage or decrease of fuel supply (gasoline, diesel)	H (60%)	VL (2)	M (11,0...	12
LR020	Frequent power outages on the project site	H (60%)	N (0)	M (10,9...	12
LR021	lack of water supply in the project site	M (40%)	N (0)	N (0.00L...	0
MR37	Changing in the senior management policy of the company (e.g. priority of the project)	VL	H	H	4

Figure 7. Risk register in PRA

c) Running risk analysis and simulation

The final step and before of create analysis graphs is running the analysis (running Monte Carlo simulation), as shown in Figure 9 the analysis run cover 1000 iterations representing the simulation steps carried.

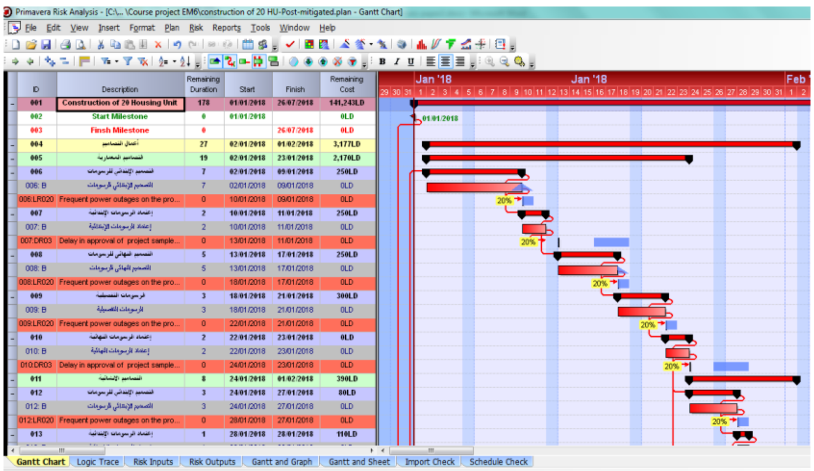


Figure 8. Impacted risk plan

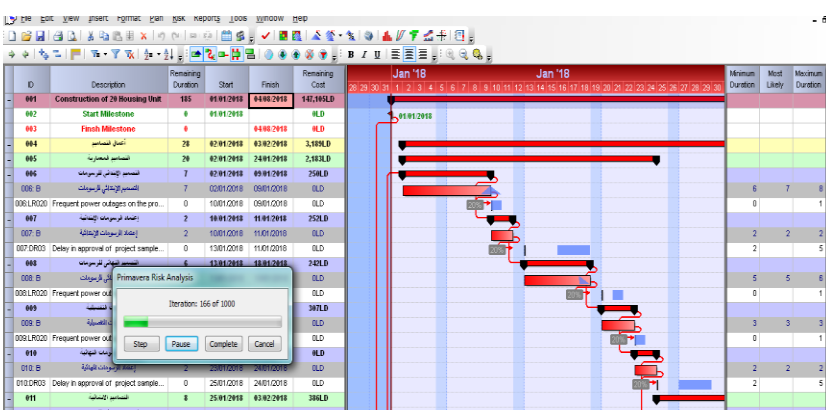


Figure 9. Running risk analysis and simulation

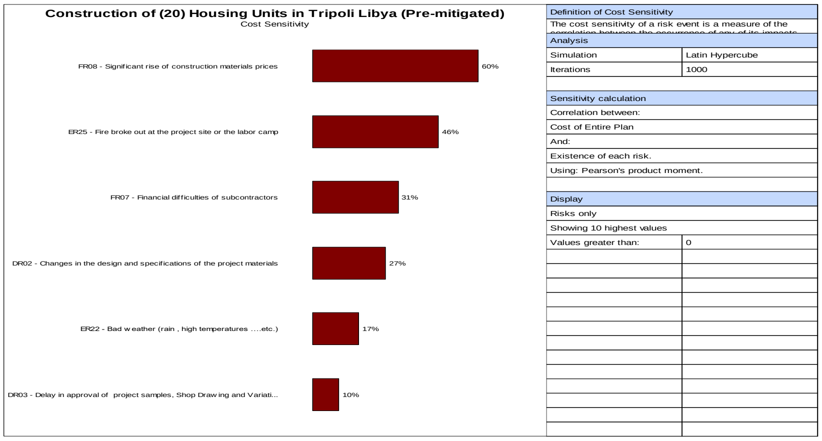


Figure 10. Cost sensitivity tornado diagram.

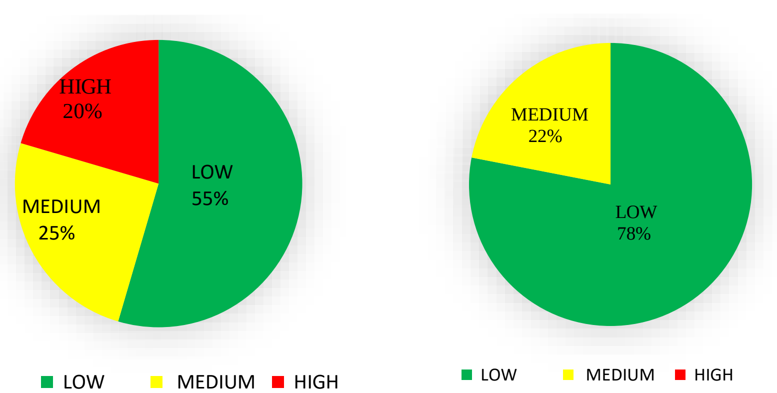
Sensitivity analysis helps to determine which risks have the most potential impact on the project using tornado diagram, as illustrated from (Figure 10) that has IDFR08 (significant rise of construction material) has most potential impact on overall project cost.

6- Plan risk Response

Plan Risk Responses is the process of developing options and actions to enhance opportunities and to reduce threats to project objectives, threats response Strategies can be: (1) *Avoid***.** Risk avoidance is a risk response strategy whereby the project team acts to eliminate the threat or protect the project from its impact. (2) *Transfer***.** Risk transference is a risk response strategy whereby the project team shifts the impact of a threat to a third party. (3) *Mitigate*. Risk mitigation is a risk response strategy whereby the project team acts to reduce the probability of occurrence or impact of a risk. and (4) *Accept***.** Risk acceptance is a risk response strategy whereby the project team decides to acknowledge the risk and not take any action unless the risk occurs.

7- Result and Observations

The risk score in percentage as they appear in risk register of the project before applying Mitigation strategy are shown in Figure 11a. The Figure indicate that 55% of identified risks are below the risk thresholds and it doesn't need any mitigation (response) action, 25% measured as medium risks while 20% of identified risks are high risks, for both high and medium risks need mitigation strategy and action. Whereas, after applying mitigation strategies, the residual risks in percentage as they appear in in Figure 11b, the figure shows that there are not left any risks considered as high risk while only 22% are still measured as medium risks and accepted low risks increase to 78%. Moreover, as shown in Figure 12 the applied response strategies were 55% accepted strategy, 34% transfer strategy, 7% reduce strategy, 4% avoid strategy.



a. Before applying Mitigation strategy b. After applying Mitigation strategy

Figure 11. Project risk before after applying mitigation strategy

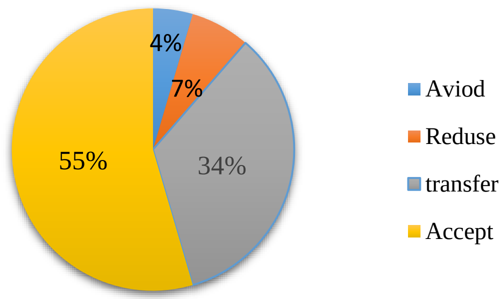


Figure 12. The usage of mitigation strategies

7.1- Original plan (with uncertainty in cost schedule)

Figure 13 represents the completion of the whole works cumulative distribution histogram for original plan (taking into account the uncertainty only in cost and schedule without risk event). The deterministic date 26/07/2018 indicates that by a probability 49% the project completion of whole works can finish at this date. At 50% probability the project completion of whole works could be finished at 28/07/2018, At 80% probability the project completion of whole works could be finished at 04/08/2018. As illustrated on the highlighter in Figure 13 indicates that nine days as time contingency reserve are needed if an organization needs to be 80% confident, in Figure 14 the deterministic cost was 141,242.95 LD. At 80 % probability the project completion cost of whole works could be 143,865.11 LD.

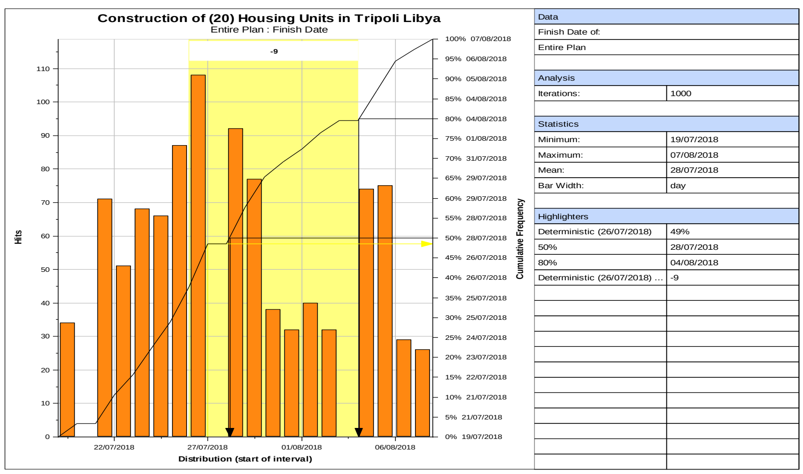


Figure 13. Entire plan work finish date Histogram

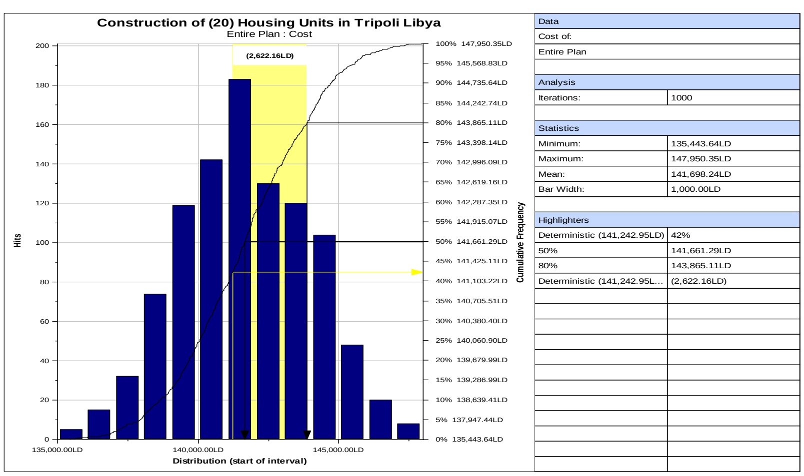


Figure 14. Entire plan Cost Histogram

7.2- Pre-mitigation plan.

Figure 15 represents the completion of the whole works cumulative distribution histogram after linking risk event which identify in risk register to project schedule. This histogram is the result of pre-mitigation scenario. This means that the mitigation response actions are not yet implemented. The deterministic date 26/07/2018 indicates that by a probability 5% the project completion of whole works can finish at this date. At 50% probability the project completion of whole works could be finished at 13/08/2018, at 80% probability the project completion of whole works could be finished at 20/08/2018. As illustrated on the highlighter in Figure 15 indicates that twenty-five days as time contingency reserve are needed if an organization needs to be 80% confident.

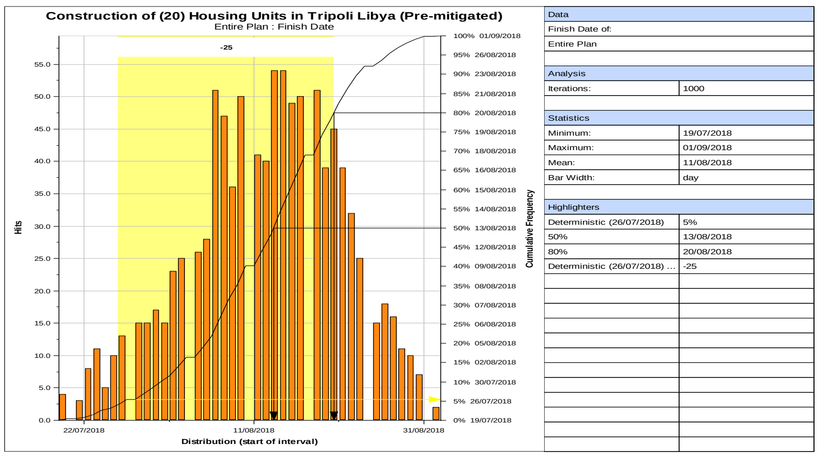


Figure 15. Work finish date Pre-mitigation plan Histogram

Figure 16 represents the completion of the whole works cumulative distribution histogram after linking risk event which identify in risk register to project schedule. The histogram shows the results of pre-mitigation scenario. This means that the mitigation response actions are not yet implemented. The histogram is for the completion of whole works representing the project cost. The deterministic cost was 141,242.95 LD. The histogram indicates that by a probability of less than one 1%, the project completion of whole works can finish by this cost. At 50 % probability the project completion cost of whole works could be 237,300.34 LD. At 80% probability the project completion cost of whole works could be 256,621.74 LD. As illustrated on the highlighter in Figure 16 indicates that an additional 115,378.79 LD as cost contingency reserve is needed if an organization needs to be 80% confident.

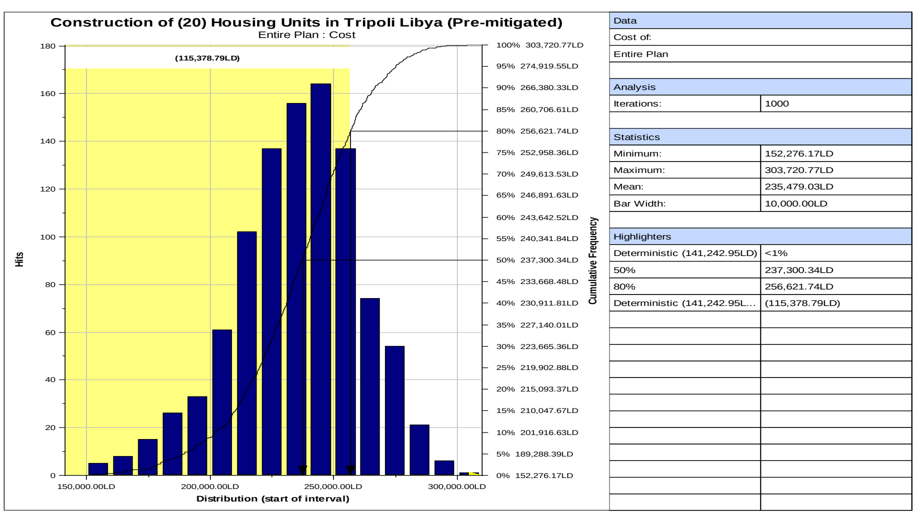


Figure 16. Cost Pre-mitigation plan Histogram

7.3- Post-mitigation plan

The histogram in Figure 17 is the result of post-mitigation scenario. This means that the mitigation response actions are implemented. The histogram is for the completion of whole works representing the finish date of the schedule. The deterministic date 26/07/2018 indicates that by a probability 37 % the project completion of whole works can finish at this date. At 50% probability the project completion of whole works could be finished at 29/07/2018, At 80% probability, (selected confidence level) the project completion of whole works could be finished at 07/08/2018. As illustrated on the highlighter in Figure 17 indicates that twelve days as time contingency reserve are needed if an organization needs to be 80% confident.

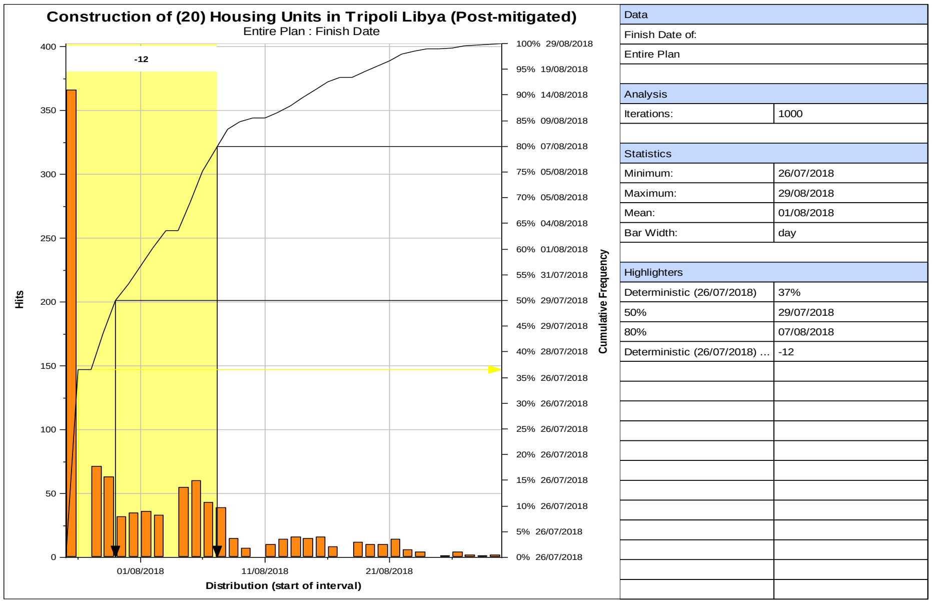


Figure 17. Work finish date post-mitigation plan Histogram

The histogram in Figure 18 illustrated the results of the post-mitigation scenario. This means that the mitigation response actions are implemented. The histogram is for the completion of whole works representing the project cost. The deterministic cost was (original cost + cost of mitigation) 179,342.95LD. The histogram indicates that by a probability of (15%) project completion of whole works can finish by this cost. At 50 % probability the project completion cost of whole works could be 192,428.07 LD. At 80 % probability, (selected confidence level) the project completion cost of whole works could be 206,460.76 LD. As illustrated on the highlighter in Figure 18 indicates that an additional 27,117.81LD as cost contingency reserve is needed if an organization needs to be 80% confident. As a result, Figure 19 illustrates the time and cost required for the deferent scenarios.

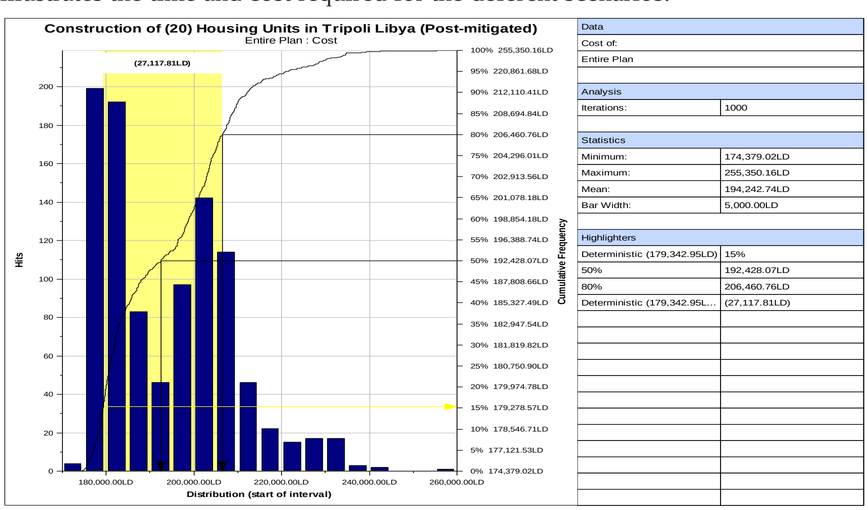


Figure 18. Cost Pre-mitigation plan Histogram

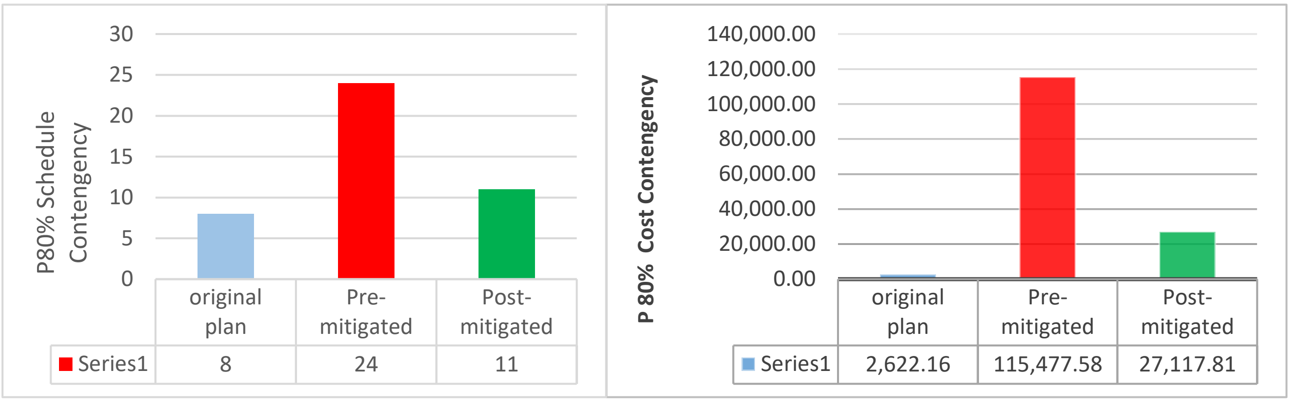


Figure 19. Cost and Schedule Required Amount as a Contingency Reserve

8- Conclusion

This case study represents the application of risk management process in construction projects. In order to carry the process perfectly, an efficient program tool was used called the PERT-Master Primavera Risk Analysis tool. By using an information gathering techniques a total number of forty-four risk events related to different risk categories were identified by the end of the risk identification process and experts suggested the probability of occurrence and impact scales of prioritized risk factors. Thus, the risk categories include 1) *Design Risks*, 2) *Financial risks*, 3) *Legal and Contractual risks*, 4) *Sites construction risks*, 5) *Logistic risks*, 6) *Environmental risks*, 7) *Resource related risks*, 8) *political and war risks*, and 9) *Management risks*.

Quantitative analysis for the most important risk events was done using Monte Carlo analysis simulation. The simulation passes through two different scenarios. First scenario is the pre-mitigation scenario by which risk factors are implemented without taking into consideration the suggested mitigation actions. The other scenario was the post-mitigation. Those scenarios are compared with original plan (uncertainty only in cost and schedule without risk event). As we observe from probability histograms (original plan, pre-mitigation, post-mitigation), the time needed as a time contingency reserve in pre-mitigation scenario was 3 times as large as time needed (time contingency reserve) in original plan whereas, post- mitigation plan was 1.4 times. Whereas, the cost needed as a cost contingency reserve in pre-mitigation scenario was 44 times as large as cost needed (cost contingency reserve) in original plan whereas, post-mitigation plan was 10.3 times.

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