CHAPTER (5)

CASE STUDY

5.1 Introduction

Quantitative risk analysis and risk response process are both applied on a sewage network project case study. Quantitative risk analysis is the process of numerically analyzing the effect of identified risks on overall project objectives. Objectives in this study will include both time and cost of construction of sewage networks. Quantitative risk analysis is applied on risk factors which have been prioritized previously during the qualitative analysis process. Numerical ratings are given to those risks individually or aggregate effect of these events towards the project objectives. The quantitative analysis process will present a quantitative approach in making decisions in the presence of uncertainties. This should be repeated again after the risk response plan process as well as part of monitoring and controlling risk events. This is done to be sure if the overall project risk has been satisfactory decreased. Trends obtained from reports after the analysis can indicate the need of more or less risk management action. **A Guide to the Project Management Body of Knowledge Book (2008).**

Furthermore risk response planning is done in this chapter and applied on a sewage network project case study. Plan risk response is the process of developing options and actions to enhance opportunities and to reduce threats to the project objectives. Mitigating actions is implemented into the risk register for further analysis. Planned risk responses must be appropriate to the significance of risk, cost effective in meeting the challenge, realistic with the project context. Selecting the best risk response from several options is often required. The plan risk response section presents commonly used approaches to planning responses to the risks. Risks used in this study include threats that can affect the project success. Later through this chapter responses are discussed in more details. **A Guide to the Project Management Body of Knowledge Book (2008).**

5.2 Risk Analysis Methodology

5.2.1 Introduction

Fig 5.1 illustrates Risk Analysis methodology carried including both quantitative risk analysis and risk response plan processes. Updated risk register is used as an input of this process. This risk register was obtained previously as the output of the qualitative risk analysis process**.** Modeling analysis technique which is used is called Monte Carlo Analysis. This analysis is carried with the aid of Pert Master program. Risk factors are analyzed numerically obtaining several reports which reflect the result of this analysis. Finally, an updated risk register is further obtained as the output of these processes.

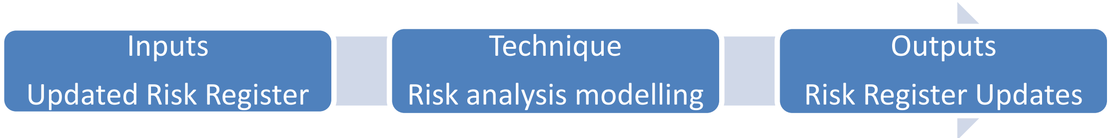


Fig 5.1 Risk Analysis and Risk Response Plan Methodology.

5.2.2 Risk Analysis Input

Risk Register is started during identifying risk stage. The Risk Register is updated with information from Qualitative Risk Analysis stage. Thus an updated risk register is included in the project documents. The risk register conducted from qualitative risk analysis Impact on cost and time are represented in Tables 5.2 A and 5.2 B below. Risk register tables include, riskfactors, their code and whether risk is an opportunity or a threat (T/O). It also reflects the professionals opinions conducted during this stage about both probability and impact of risks. Risk score is further calculated and represented which was used for ranking these risk factors. Ranked risk factors are the most important factors which are further imported into the modeling program risk register.

Table 5.1 Updated Risk Register for Cost.

Risk ID	T/O	Risk Title	Risk Category	Probability (%)	Impact (%)	Risk Score
B4	T	Poor equipment's productivity	Project Management Risk	0.46	0.50	0.232
F3	T	Delay in shop drawing approval	Organizational Risks	0.47	0.48	0.224
B10	T	Poor planning errors	Project Management Risk	0.46	0.48	0.221
C1	T	Funds unavailability	Financial Risks	0.44	0.50	0.220
A3	T	Delay in material approval	Technical Risks	0.44	0.50	0.218
B5	T	Low subcontractor performance	Project Management Risk	0.46	0.48	0.217
F4	T	Third party delay approval	Organizational Risks	0.44	0.50	0.216
B7	T	Poor site management by the contractor	Project Management Risk	0.45	0.48	0.215
D1	T	Permits delayed	External Risks	0.43	0.50	0.212
F5	T	Change in tax regulations	Organizational Risks	0.42	0.50	0.211

Cont. Table 5.1 Updated Risk Register for Time.

Risk ID	T/O	Risk Title	Risk Category	Probability (%)	Impact (%)	Risk Score
F3	T	Delay in shop drawing approval	Organizational Risks	0.46	0.56	0.26
B4	T	Poor equipment's productivity and efficiency measures	Project Management Risk	0.46	0.53	0.24
B7	T	Poor site management in the contractors organization	Project Management Risk	0.45	0.54	0.24
B10	T	Poor planning errors	Project Management Risk	0.46	0.52	0.24
B1	T	Misleading management focus	Project Management Risk	0.46	0.51	0.24
A3	T	Delay in material approval	Technical Risks	0.43	0.55	0.23
B9	T	Lack of construction management	Project Management Risk	0.41	0.57	0.23
B5	T	Low subcontractor performance	Project Management Risk	0.45	0.52	0.23
C1	T	Funds unavailability	Financial Risks	0.44	0.53	0.23
D1	T	Permits delayed	External Risks	0.42	0.54	0.23

5.2.3 Case Study Modeling

5.2.3.1 Introduction

The most effective risk factors obtained from the output of the qualitative risk analysis process are analyzed using a Monte Carlo model. Using the schedule and estimated costs of a case study in Egypt these risk factors are analyzed and mitigations actions are added. The case study used is Cairo Festival City project, were its time schedule and cost estimates was used in the analysis. Modeling technique is a commonly used technique which includes both events oriented and project oriented analysis approaches. In order to achieve an efficient analysis, Oracle primavera risk analysis (Pert master tool) is used. It is most used by risk analysts in risk analysis field and is full of key features and benefits. Key features include tracking risks, managing project risks, studying impacts on risks and best responses towards different risk factors.

Key features also includes, Integrating updated risk register with project schedule and costs, comprehensive risk analysis graphics and reports, use of Monte Carlo simulation to produce risk reports on probability and confidence levels, Analyze project program sure track, good technique of determining contingency and production of risk response plans as comprehensive technique of risk levels. Primavera risk analysis risk will close projects to the risk register and risk templates before using Monte Carlo simulation to analyze them. Reports are produced including, risk histogram, tornado diagrams. These reports will enable the risk analyzer to analyze risk drivers prior publishing risk resulting schedule.

Benefits will include, identifying common schedule pitfalls that may result in misleading schedule or risk analysis results, integrate pre-developed risk registers and define new risk register, address full life cycle risk management through advanced Monte Carlo is based on cost and schedule analytics and report confidence levels with regards to finish dates, costs, float, internal rate of return and net present value. The program can provide a comprehensive means of reporting project confidence levels. It is a proper technique for determining contingency and risk response plans. Primavera risk analysis tool delivers objective view of required contingency and risk response plans analysis. Pert-Master tool follow a systematic sequence of steps in order to obtain an accurate reports reflecting risk events impact on both time and cost. These steps include, complete schedule check, template quick risk, updating risk register and risk analysis reports.

5.2.3.2 Pert-Master Project Schedule Check

5.2.3.2.1 Introduction

Pert-Master schedule risk analysis will improve the schedule maturity via schedule checks and test Monte Carlo analysis iterations to validate the integrity of the schedule logic. The primavera risk schedule check will flag areas of concern or note in the schedule. Any project program mistakes is identified and represented in terms of flag marks. A flag mark does not mean the area of the schedule must be fixed; it is flagging a condition that could be a concerned. The tool will find fundamental flaws in the logic that would indicate that the schedule is not clean. If not cleaning a flaw is chosen, it should be clearly documented why it is acceptable to the risk analyst.

A poor schedule invalidates a schedule Monte Carlo analysis. It is better to show and explain flaws than to have an analysis ruled as wrong. Schedule check report Primavera Risk will bookmark all flagged activities. The bookmarked activities will allow the planner to create filters or jump to the problem areas of the project schedule very quickly. Flags can be either accepted if they seem to be logical with respect to the project constructed. Flags can be broken down by viewing the importance relative to running an accurate schedule Monte Carlo analysis. There are two types of flags to be broken, critical schedule check flags and lower risk flags.

5.2.3.2.2 Open Ended Tasks (Lacking Predecessor, Successor)

Pert-Master will view open-ended tasks differently, and more correctly, than Primavera P6 and some other scheduling tools. A true open end is an item that does not have a predecessor connected to the activity start or a successor connected after the activity finish. Many scheduling tools look for a predecessor or successor relationship. PrimaveraP6 does not see this as open-ended, however Primavera Risk disagrees. One open-ended task in a vital location can compromise the results of the Monte Carlo analysis. Although scheduling theory says that there should only be two open-ends, at the beginning and end.

In order to correct these open ended tasks sequence of steps is carried. Using the primavera risk analysis tool, open ended tasks is conducted. This is represented in the primavera risk analysis schedule check report illustrated in Fig 5.2.The figure shows that there are 146 tasks having constraints. There are 417 open ended tasks (neither a predecessor nor a successor is detected for these tasks). There are 61 out of sequence or broken logic tasks. There are 2197 tasks having lags. There are 80 items of negative lags and 58 items of positive lags. Only 2 items are found having the relation start to finish links. The total number of checked items found by primavera risk analysis is 2961 item.

CFC Infrastructure Baseline Programme - Rev 3 (10th May DD).plan-ScheduleCheckReport

ORACLE
PRIMAVERA RISK ANALYSIS

Schedule Check Report

Plan Summary

Title	CFC Infrastructure Baseline Programme - Rev 3 (10th May DD)		
File name	C:\Users\hp\Desktop\primavera\CFC Infrastructure Baseline Programme - Rev 3 (10th May DD).plan		
Plan finish date	01/09/2012	Tasks with no progress	2712
Plan remaining duration	482	In progress tasks	188
Normal tasks	2456	Completed tasks	430
Summary tasks	579	Total tasks	3330
Milestone tasks	295	Resource assignments	12036
Hammock tasks	0	Budget cost	$555,070
Monitor tasks	0	Remaining cost	$466,113
Calendars	29	Actual cost	$87,229
Links	6589	Total cost	$553,343
Resources	96		

Report Summary

Task view	All tasks
Constraints	146
Open-ended tasks (Does not include ignored links)	417
Out of sequence updates ("broken logic")	61
Lags longer than 0 units	2197
Negative lags ("leads")	80
Positive lags on Finish-to-Start links	58
Start-to-Finish links	2
Lags between tasks with different calendars	0
Links to / from summary tasks	0
Duration uncertainty distribution shape 2	0
Total number of items found	2961

Fig 5.2 Primavera Risk Analysis Schedule Check Report

These open ended tasks will occur due to different reasons. Open ended tasks which have no predecessor and no successor due to scheduler error. These tasks are clear on scheduling primavera p6 report Fig 5.3. The figure represents two different types of open ended activities. As shown in this sewage project schedule there are activities without predecessors as well as activities without successors.

```
Errors:
-------
Warnings:
---------
        Activities without predecessors.................................99
                Project:        CFC/INFRA/BL/Rev3-4     Activity:       A1000   Commencement date
                Project:        CFC/INFRA/BL/Rev3-4     Activity:       A1010   Receives site with no obstacles
                Project:        CFC/INFRA/BL/Rev3-4     Activity:       A11030  Installation for water hammer protection vessel
                Project:        CFC/INFRA/BL/Rev3-4     Activity:       A11040  Installation for overhead crane
                Project:        CFC/INFRA/BL/Rev3-4     Activity:       A11290  Provide electrical and water source
                Project:        CFC/INFRA/BL/Rev3-4     Activity:       A11890  Installation for over head crane
```

```
Activities without successors.................................136
        Project:        CFC/INFRA/BL/Rev3-4     Activity:       A1020   Notification of Award
        Project:        CFC/INFRA/BL/Rev3-4     Activity:       A10290  Handing over buildings with roads
        Project:        CFC/INFRA/BL/Rev3-4     Activity:       A10400  Curing for parapet
        Project:        CFC/INFRA/BL/Rev3-4     Activity:       A10430  Finish control room
        Project:        CFC/INFRA/BL/Rev3-4     Activity:       A11030  Installation for water hammer protection vessel
```

Fig 5.3 Primavera P6 Schedule Check Report

Thus, correction is done by returning to the primavera 6 program and correcting their logic. Only a start and an end of the program is left indicating the successful correction of the schedule logic. This is clear in the primavera p6 scheduling report Fig 5.4. The figure shows that only one predecessor representing the project commencement date. In addition to that only one successor for completion of whole works is represented. The risk analyst must take this corrective action with the aid of theses program checks thus accurate risk analysis can be obtained.

```
Errors:
-------
Warnings:
---------
        Activities without predecessors.................................1
                Project:        CFC/INFRA/BL/Rev3-4     Activity:       PSD000  Project Commencement Date

        Activities without successors...................................1
                Project:        CFC/INFRA/BL/Rev3-4     Activity:       PCD000  Completion of Whole Works
```

Fig 5.4 Primavera P6 Schedule Check Report

After running a primavera risk analysis schedule check report Fig 5.5, it is clear that not all the open ended tasks are cleaned. Primavera risk analysis tool is a more effective tool in scheduling check than Primavera P6 tool. Primavera risk analysis tool detects an open ended task which can be a milestone or a task of S.S successor. The figure shows that there are 146 tasks having constraints. Fig 5.5 illustrates that there are 206 open ended tasks (without a predecessor or a successor). There are 61 out of sequence or broken logic tasks. There are 2197 tasks having lags. There are 80 items of negative lags and 58 items of positive lags. Only 2 items are found having the relation start to finish links. The total number of checked items found by primavera risk analysis is 2751 item.

ORACLE
PRIMAVERA RISK ANALYSIS

Schedule Check Report

Plan Summary

Title	CFC Infrastructure Baseline Programme - Rev 3 (10th May DD)		
File name	C:\Users\hp\Desktop\primavera\CFC INFRA BL Rev3-4.plan		
Plan finish date	09/09/2013	Tasks with no progress	2712
Plan remaining duration	447	In progress tasks	188
Normal tasks	2456	Completed tasks	430
Summary tasks	579	Total tasks	3330
Milestone tasks	295	Resource assignments	11274
Hammock tasks	0	Budget cost	LE82,022,597
Monitor tasks	0	Remaining cost	LE78,366,147
Calendars	7	Actual cost	LE3,789,532
Links	6826	Total cost	LE82,155,678
Resources	78		

Report Summary

Task view	All tasks
Constraints	146
Open-ended tasks (Does not include ignored links)	206
Out of sequence updates ("broken logic")	61
Lags longer than 0 units	2197
Negative lags ("leads")	80
Positive lags on Finish-to-Start links	58
Start-to-Finish links	3
Lags between tasks with different calendars	0
Links to / from summary tasks	0
Duration uncertainty distribution shape 2	0
Total number of items found	2751

Fig 5.5 Primavera Risk Analysis Schedule Check Report

These tasks are corrected by using Primavera P6, giving successor and predecessor for them. Still Primavera P6 cannot indicate the corrected tasks as shown in scheduling report Fig 5.6 also only start and end task are left. The figure represents only one predecessor and successor as obtained before. It is clear that Pert-Master program used here is a more effective tool than primavera P6.1.

```
Errors:
-------
Warnings:
---------
       Activities without predecessors.................................1
              Project:       CFC/INFRA/BL/Rev3-4     Activity:      PSD000  Project Commencement Date

       Activities without successors...................................1
              Project:       CFC/INFRA/BL/Rev3-4     Activity:      PCD000  Completion of whole Works
```

Fig 5.6 Primavera P6 Schedule Check Report

Furthermore, through using primavera risk analysis schedule check report Fig 5.7, cleaning open ended tasks is clear. The report reflects cleaning all open ended activities through the schedule, only now risk analysis simulation can be carried successfully. The risk analysis program can easily detect any further open ended activities. The Primavera program could not detect these open ended activities as shown in the figure below.

CFC INFRA BL Rev3-4.plan-ScheduleCheckReport

ORACLE
PRIMAVERA RISK ANALYSIS

Schedule Check Report

Plan Summary

Title	CFC Infrastructure Baseline Programme - Rev 3 (10th May DD)		
File name	C:\Users\hp\Desktop\primavera\CFC INFRA BL Rev3-4.plan		
Plan finish date	11/09/2013	Tasks with no progress	2712
Plan remaining duration	447	In progress tasks	188
Normal tasks	2456	Completed tasks	430
Summary tasks	579	Total tasks	3330
Milestone tasks	295	Resource assignments	11274
Hammock tasks	0	Budget cost	L.E82,022,597
Monitor tasks	0	Remaining cost	L.E78,366,147
Calendars	7	Actual cost	L.E3,789,532
Links	7033	Total cost	L.E82,155,678
Resources	78		

Report Summary

Task view	All tasks
Constraints	146
Open-ended tasks (Does not include ignored links)	1
Out of sequence updates ("broken logic")	61
Lags longer than 0 units	2196
Negative lags ("leads")	80
Positive lags on Finish-to-Start links	58
Start-to-Finish links	3
Lags between tasks with different calendars	0
Links to / from summary tasks	0
Duration uncertainty distribution shape 2	0
Total number of items found	2545

Fig 5.7 Primavera Risk Analysis Schedule Check Report

The logic becomes very hard to trace and the scheduler looks sloppy. If the activity truly cannot be a driver, then it would be preferable to discuss a path forward internally. However documenting these open-ends can often save a headache during an audit. Whether you link the activities or not, they should always be documented that they are in the schedule but cannot under any circumstance be a driving activity.

5.2.3.2.3 Critical Schedule Check Flags

5.2.3.2.3.A Constraints

Hard constraints such as must-finish-on constraints are generally seen as the most damaging constraint. Hard constraints should be looked at very hard and documented if they are truly correct. A hard constraint is basically taking the place of logic so if an activity has a hard constraint and predecessors, then the scheduler should determine if the task is logically or constraint driven. Soft constraints can be equally damaging in a schedule Monte Carlo analysis. Soft constraints should be used; however it is important that they are used properly.

Often constraints and lags are interchanged which is a critical problem in many schedules. A lag will has a static duration that will not change as durations in the schedule change, however a constraint is generally used to hold float in the appropriate place. One constraint in the wrong place can completely destroy the validity of a Monte Carlo analysis. Fig 5.8 illustrates constraints from a schedule check report for sewage networks project. Constraints conducted are said to be logically placed in this program. They are without any relative impact on the program as they are placed without predecessors. Most of constraints placed are for material delivery and milestones instructed by the owner of sewage networks project. Thus, constraints used have no impact on the risk analysis validity for this project.

☐	CON-SPS-290	Sewage Pump Station Predicted Completion	Finish milestone	Finish on or before	27-03-12 17:00
☐	A6430	Release scope of Engineering	Finish milestone	Finish on	13-12-10 17:00
☐	A11290	Provide electrical and water source	Finish milestone	Finish on	31-10-11 17:00
☐	A6330	Submittal for masonry work	Normal	Start on or after	26-04-11 09:00
☐	A6360	Submittal for plaster work	Normal	Start on or after	02-05-11 09:00
☐	A6390	Submittal for Aluminum work	Normal	Start on or after	17-07-11 09:00
☐	A6420	Submittal for cement tiles	Normal	Start on or after	24-04-11 09:00
☐	A6460	Submittal for heavy duty ceramic	Normal	Start on or after	11-08-11 09:00
☐	A6490	Submittal for metal work	Normal	Start on or after	15-02-11 09:00
☐	A6520	Submittal for marble & granite work	Normal	Start on or after	11-09-11 09:00
☐	A6550	Submittal for painting work	Normal	Start on or after	20-08-11 09:00
☐	A7690	Submittal for earthing system	Normal	Start on or after	02-01-11 09:00
☐	A7700	Submittal for panel boards	Normal	Start on or after	15-07-11 09:00
☐	A7710	Submittal for lighting poles	Normal	Start on or after	28-09-11 09:00
☐	A7720	Submittal for lighting fixtures	Normal	Start on or after	30-08-11 09:00
☐	A7730	Submittal for wiring devices	Normal	Start on or after	10-01-11 09:00
☐	A7740	Submittal for fire alarm system	Normal	Start on or after	13-12-10 09:00
☐	A7760	Submittal for fire fighting system	Normal	Start on or after	06-11-11 09:00
☐	A7770	Submittal for fertilization system	Normal	Start on or after	11-08-11 09:00
☐	A7780	Submittal for filtration system	Normal	Start on or after	11-08-11 09:00
☐	A7790	Submittal for chlorination system	Normal	Start on or after	16-08-11 09:00
☐	A7800	Submittal for HVAC works	Normal	Start on or after	23-04-11 09:00
☐	A7810	Submittal for fuel system	Normal	Start on or after	20-08-11 09:00
☐	A7830	Submittal for penstocks	Normal	Start on or after	02-04-11 09:00

Fig 5.8 Schedule Check Report - Constraints

5.2.3.2.3.B Out of Sequence Logic ("broken logic")

Out of sequence logic is technically wrong. Based on the progress override or retained logic setting, the analysis will still run, however activity splits and other unexpected issues may occur during the analysis. Although Pert-Master can technically handle out of sequence logic, by definition it is incorrect logic and casts doubt on the validity of the analysis. If a scheduler cannot follow a logic chain, then it might be concluded that they are less equipped to deal with a logic chain that now has uncertainty and risk events entered into the equation.

Often scheduler's status items out of order due to miss of experience in dealing with similar sewage network projects. It is more time consuming to break the logic than to status items out of order. It is a shortcut used when workloads become too heavy. That being said, breaking the logic and correctly using a project should be the desired method, especially before running a schedule Monte Carlo analysis on the logic. Fig 5.9 illustrates broken logic from a schedule check report for sewage networks project. All broken logic made in this program is due to change of working sequence on site to that sequence of work planned to be done in the program. Thus tasks appearing here are logically to appear due to difference in work sequence which has no impact on the project program.

Out of sequence updates ("broken logic")

The logic in a plan can be broken when tasks have started or finished before their predecessors. It is recommended that any broken logic is removed or corrected to ensure the project schedules as expected. For example, if task A has a Finish-to-Start link to task B, but B has been started (by giving it an Actual Start date), this is broken logic. It is not clear whether B's remaining work should wait for task A to finish, or start straight away. Consider fixing the broken logic by either removing the link or removing the actual dates. Also consider using the retained logic / progress override options on the Scheduling tab of the Plan | Options dialog box.

From Task				To Task					
Bookmark	ID	Description	Type	Bookmark	ID	Description	Type	Link	Details
☐	CON-SW-R07-070	Road 7 Sewage Connection Available	Finish milestone	☐	CON-IR-R07-010	Excavate & Trim Trench Including Bedding	Normal	FS	Task CON-IR-R07-010 has already started
☐	CON-SW-R07-070	Road 7 Sewage Connection Available	Finish milestone	☐	CON-PW-R07-010	Excavate & Trim Trench Including Bedding	Normal	FS	Task CON-PW-R07-010 has already started
☐	CON-SW-R08-070	Road 8 Sewage Connection Available	Finish milestone	☐	CON-IR-R08-010	Excavate & Trim Trench Including Bedding	Normal	FS	Task CON-IR-R08-010 has already started
☐	CON-SW-20A-070	Road 20 A Sewage Connection Available	Finish milestone	☐	CON-IR-R20-010	Excavate & Trim Trench Including Bedding	Normal	FS	Task CON-IR-R20-010 has already started
☐	CON-IR-20A-130	Road 20 A Irrigation Connection Available	Finish milestone	☐	CON-RW-20A-010	Excavate, Fill & Trim Road Formation	Normal	FS	Task CON-RW-20A-010 has already started
☐	MA-PC-010	Client Approval of P.C. Units; Conc Ancillaries	Normal	☐	CON-RW-20A-010	Excavate, Fill & Trim Road Formation	Normal	FS	Task CON-RW-20A-010 has already started
☐	MA-PC-010	Client Approval of P.C. Units; Conc Ancillaries	Normal	☐	CON-RW-R08-010	Excavate, Fill & Trim Road Formation	Normal	FS	Task CON-RW-R08-010 has already started
☐	RDA-SW-R21-020	Rework Approval of Sewage GRP & MH Drawings - Road 21	Normal	☐	CON-SW-R21-010	Excavate & Trim Trench Including Bedding	Normal	FS	Task CON-SW-R21-010 has already started
☐	SDS-DC-R22-010	D.C. Pipework & Valves Drawings - Road 22	Normal	☐	SDA-DC-R22-010	Approval of D.C. & Valves Drawings - Road 22	Normal	FS	Task SDA-DC-R22-010 has already started
☐	SDS-DC-R22-040	D.C. Pipework & Valves Drawings - Road 2	Normal	☐	SDA-DC-R22-050	Approval D.C. Pipework & Valves Drawings - Road 2	Normal	FS	Task SDA-DC-R22-050 has already started
☐	SDS-DC-R22-060	D.C. Pipework & Valves Drawings - Road 4	Normal	☐	SDA-DC-R22-040	Approval D.C. Pipework & Valves Drawings - Road 4	Normal	FS	Task SDA-DC-R22-040 has already started
☐	RSS-RW-R21-010	Rework Roads & Paving Drawings - Road 21	Normal	☐	RDA-RW-R01-030	Rework Approval of Roads & Paving Drawings - Road 21	Normal	FS	Task RDA-RW-R01-030 has already started
☐	TUN01180	Relocate JV Fence	Normal	☐	TUN01160	Cut Existing Road 2 Traffic	Finish milestone	FS	Task TUN01160 has already started
☐	CON-FO-R06-050	Relocation / Protection of Existing FO Lines	Normal	☐	CON-BX-R04-010	Bulk Excavation and Fill for Road 4	Normal	FS	Task CON-BX-R04-010 has already started

Fig 5.9 Schedule Check Report Broken Logic Tasks

5.2.3.2.3.C Lags

Lags are quite simply an absence of logic. A one day absence of logic can do very little damage. The scheduler should use a constraint to hold float instead of a lag. The bigger lags the much the look scarier. Long lags are one reason that Monte Carlo analysis on a summary schedule becomes challenging. Large lags and great quantities of representative logic exist in many summary schedules. As illustrated in Fig 5.10, Lags placed in this project for fast tracking and milestones. Overlapping activities in order to logically have logical project duration is done. Thus there is no impact on the risk analysis carried throughout this chapter.

Lags longer than 0 units

Option selected: Display lags greater then 0 Day

A lag is a gap in the logic between two tasks – a delay between the dates of two tasks that are linked together. Lags cannot have risk or uncertainty. In reality it is likely that the lag represents either work or a delay, whose duration is uncertain. This is particularly significant for long lags. Consider replacing the lag with a task, so that uncertainty and risks can be assessed against it. Use the Convert Lags to Tasks tool when a project contains a large number of long lags.

From Task				To Task				
Bookmark	ID	Description	Type	Bookmark	ID	Description	Type	Link
☐	0040A	IFC Drawings from Client for District Cooling Network	Start milestone	☐	SDS-DC-R22-010	D.C. Pipework & Valves Drawings - Road 22	Normal	FS [30]
☐	0040C	IFC Drawings from Client for MV Network	Start milestone	☐	MSS-MV-R10-030	Rework M.V Ducts; Pits & Cable Drawings - Road 10 A	Normal	FS [30]
☐	0040C	IFC Drawings from Client for MV Network	Start milestone	☐	MSS-MV-R04-070	Rework M.V Ducts; Pits & Cable Drawings - Road 4	Normal	FS [30]
☐	0040C	IFC Drawings from Client for MV Network	Start milestone	☐	MSS-MV-R19-030	Rework M.V Ducts; Pits & Cable Drawings - Road 19	Normal	FS [30]
☐	0040C	IFC Drawings from Client for MV Network	Start milestone	☐	MSS-MV-R02-030	Rework M.V Ducts; Pits & Cable Drawings - Road 2	Normal	FS [30]
☐	0040C	IFC Drawings from Client for MV Network	Start milestone	☐	MSS-MV-R05-030	Rework M.V Ducts; Pits & Cable Drawings - Road 5	Normal	FS [30]
☐	0040C	IFC Drawings from Client for MV Network	Start milestone	☐	MSS-MV-R22-030	Rework M.V Ducts; Pits & Cable Drawings - Road 22	Normal	FS [30]
☐	0040C	IFC Drawings from Client for MV Network	Start milestone	☐	MSS-MV-R03-030	Rework M.V Ducts; Pits & Cable Drawings - Road 3	Normal	FS [30]
☐	0040C	IFC Drawings from Client for MV Network	Start milestone	☐	MSS-MV-R21-030	Rework M.V Ducts; Pits & Cable Drawings - Road 21	Normal	FS [30]
☐	0040C	IFC Drawings from Client for MV Network	Start milestone	☐	PROC-EL-020	Electric MHs and Covers	Normal	FS [46]
☐	0040G	IFC Drawings from Client for E/W Roads etc	Start milestone	☐	PROC-RW-010	Kerbs / Signs / Road Marking	Normal	FS [60]
☐	0040G	IFC Drawings from Client for E/W Roads etc	Start milestone	☐	PROC-RW-020	Sub Base / Asphalt	Normal	FS [61]
☐	0040H	IFC Drawings from Client for Sewage Network	Start milestone	☐	MA-PC-010	Client Approval of P.C. Units; Conc Ancillaries	Normal	FS [30]
☐	CON-DC-R06-070	Road 6 District Cooling Connection Available	Finish milestone	☐	CON-MV-R06-010	Excavate Trench and Manholes	Normal	FF[10]

Fig 5.10 Schedule Check Report – Lags

5.2.3.3 Pert-Master Test Monte Carlo Iterations

5.2.3.3.1 Value and Strategies Associated with Running Test Simulations

Primavera Risk (Pert-Master) Monte Carlo analysis validates the integrity of the schedule logic. Running test simulations will speed up the process of schedule audit and clean-up. Project managers must validate that the logic is realistic before running the delivering the final reports. Test simulations allow a project manager or risk analyst to test the network logic without the detailed knowledge a scheduler might have. It also allows planners and schedulers to see what the logic does during a simulation without having to visually trace the logic.

Risk analysts will put random levels of uncertainty or three-point-estimates on the schedule in order to test how the network of activities moves and the driving activities in the schedule. It is a very simple process and project managers without a scheduling background can usually interpret the histogram and tornado chart data more easily than massive chains of predecessors and successors. Experienced schedulers can get great value as thousands of activities are filtered down to much more manageable amounts to trace the root cause of the schedule issue.

5.2.3.3.2Test Simulation Steps

5.2.3.3.2.1Adding Uncertainty

Add uncertainty to the schedule via the duration quick risk. Risk analysts may want to use optimistic and pessimistic values to see how the logic network reacts to different levels of risk. As illustrated in Fig 5.11, This project is an over aggressive project hard to finish on time due to political reasons in Egypt. Thus ranges of uncertainties are placed as 95% for Min., 100% for Most Likely and 120% for Maximum Uncertainty. The used distribution is the triangular distribution which is used in this study. The reason for choosing triangular distribution is further discussed through this study.

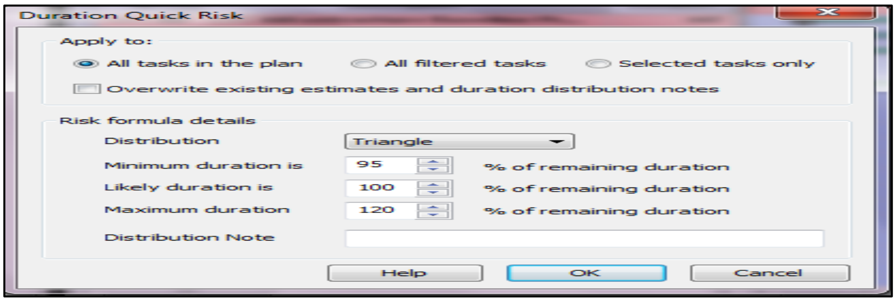


Fig 5.11Primavera Risk Analysis Uncertainty

5.2.3.3.2.2 Choosing Suitable probability distribution

5.2.3.3.2.2.1 Random Variable Definition

One of the basic concepts in probability theory is that of the random variable. When a characteristic is observed to assume different values in different situations, that characteristic is called a variable. By contrast if a characteristic retains the same value from situation to situation, it is called a constant. Examples of variables are heights of adult males, number of customers entering a shop each day, the spots showing on tossing a die. A random variable has a value that changes from situation to situation in no predictable manner. i.e., outcomes are uncertain. Hence "a random variable is a numerical quantity the value of which is determined by chance" (Mansfield, 1991). A Random variable can be discrete or continuous:

5.2.3.3.2.2.1.A Discrete Random Variable

A discrete random variable "is a random variable whose numerical values are limited to specific values within a range" (Sandy, 1990). Counting will always result in discrete numerical data. Discrete data have values that are limited to specific points within a range of values. For example, the number of workers on a project is 0, 1, 2 etc., but it cannot be say 2.7 or 3.2. Discrete data need not be just whole numbers. Hence a discrete variable is characterized by 'gaps' between the values that the variable can assume.

5.2.3.3.2.2.1.B Continuous Random Variable

A continuous random variable "is a random variable that can take any value over a continuous range of values" (Sandy, 1990). Therefore the possible values of a continuous random variable are not isolated numbers but an entire span of numbers. Continuous data is usually based on the measure of a quantity. Continuous data are measurements that can include any value within a range. This can be measured in centimeters to any number of digits to the right of the decimal place, depending on the accuracy of the measuring device. In reality data cannot be really continuous as there are limitations on the ability to obtain accurate measurements. The distinction between discrete and continuous random variables is important because different mathematical procedures are used to describe the probability distributions of each.

5.2.3.3.2.2.2 Continuous Random Variables

5.2.3.3.2.2.2.1 Introduction

A continuous random variable, unlike discrete random variables, can take any value over a continuous range of values. Therefore the possible values of a continuous random variable are not a distinct number of values but an entire span of values within a range. So it is not possible to assign probabilities to particular possible values. How can we assign probabilities to a range of possible values that can be any value between say 5 and 20, as there are any of an infinite number of values in this range? The answer is producing a continuous probability distribution to represent the probability model for a continuous random variable. A continuous probability distribution assigns probabilities by means of areas under a curve known as the probability density function. i.e., area is used to assign probabilities.

Continuous probability distributions “are convenient ways to represent discrete distributions that have many possible outcomes, all very close to each other" (Levin & Rubin, 1994). They show the range of possible values for a continuous random variable, the most likely values and how the likelihood of values varies between the minimum and maximum values. As with discrete random variables, the probabilities of all the possible values of a continuous random variable must total 1. Therefore the area between the curve and the x-axis must equal 1. This curve is useful in determining the probability that the random variable will take a value between two values and this probability corresponds to the area under the curve between these two values. Hence one of the key differences between discrete and continuous random variables is: discrete variable - the probability of a single value occurring can be assigned continuous variable - probability is interpreted by area and only considered in terms of intervals between values rather than the probability of individual values.

5.2.3.3.2.2.2.2 Continuous Probability Distributions

Risk analysts can specify a probability distribution for any project variable (e.g., duration of an activity; cost of a project item). Several types of continuous probability distribution exist, common ones including: Uniform; Triangular; Normal; Poisson; Binomial; Lognormal; Exponential; Beta. Three most commonly used probability distributions is described including uniform, triangular, normal. To select an appropriate continuous probability distribution for a project variable, the following three rules should be followed (Flanagan & Norman, 1993). It is important to emphasize that the selection of a suitable probability distribution for a variable is not based on a search for the true distribution.

The choice is based on consideration of representing the risk analyst's perception of the range and probability of likely outcomes for the variable - ‘we are in the realm, not of repeatable statistical assessment, but of subjective definitions of probability”. (Raftery, 1994). Fundamentally, the selected distribution should be easy to understand with the aim of keeping the risk analysis process as simple as practically possible. Interestingly, Chapman & ward (1997) do not advocate the use of probability distribution functions and propose a ”Simple Scenario” approach - “while specific probability distribution functions can provide more precision, this is usually spurious, and specific probability distributions usually provide less accurate estimates” The main uses of a continuous probability distribution are :it provides the necessary data for performing a Monte Carlo simulation it permits a prediction of the probability of a outcome occurring between two values.

5.2.3.3.2.2.2.2.A Uniform Distribution

In a continuous uniform distribution, "all equal intervals in the range of the distribution have the same probability" (Sandy, 1990). The minimum and maximum values are fixed but all values between minimum and maximum are equally likely to occur Fig 5.12. So it useful when we can identify a range of possible values but are unable to decide which values is most likely to occur than others. This distribution is useful “where you only have a minimum and maximum to go on” (Grey, 1995). The mean is the average of the two extreme values and there is no mode. In practice, it has limited applications.

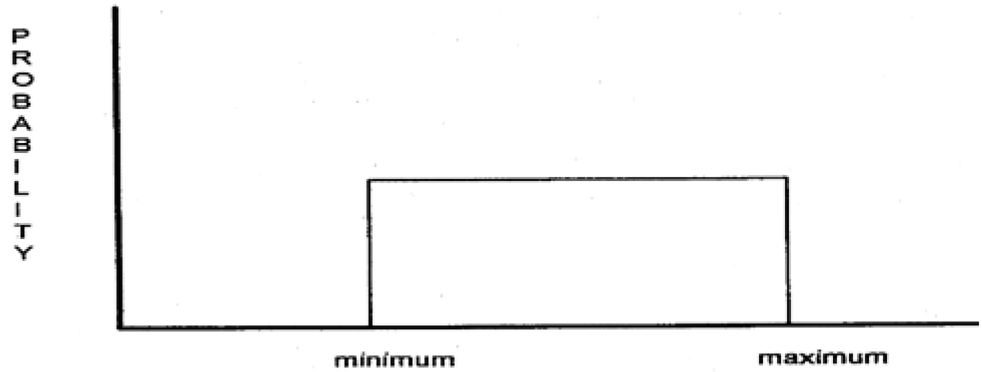


Fig 5.12 Uniform Distribution, Sandy 1990.

5.2.3.3.2.2.2.2.B Normal Distribution

The normal distribution is "the most important distribution in probability theory" (Flanagan & Norman, 1993). The importance of the normal distribution is that it has been found that quantitative data gathered for a wide variety of phenomena form distributions close to that of a normal distribution. And so it is a reasonably good approximation for many situations. That is, values cluster around some central value with deviations above and below that value being equally likely and has decreasing frequency as the deviations increase Fig 5.13. However there is no way to be sure that a particular distribution closely follows a normal curve without collecting data and testing to see if the normal distribution provides a good fit.

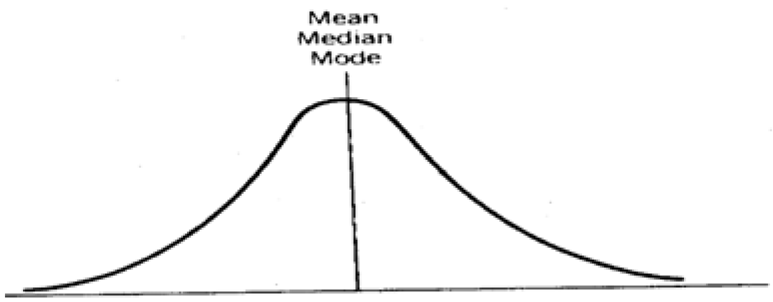


Fig 5.13Normal Distribution, Levin & Rubin 1994

A normal distribution curve has the following characteristics Fig 5.14:The curve has one mean, median, mode. i.e., they all have the same value and lie at the center of the curve**.** The curve has a single peak and is symmetrical around the mean**.** It is a bell-shaped curve, and spreads outwards and downwards. It is composed of an infinite number of cases. So the tails of the curve never touch the horizontal axis. The shape of the curve is determined by two factors - the mean and the standard deviation Fig 5.14. The mean determines the height and location whilst the standard deviation determines the spread.

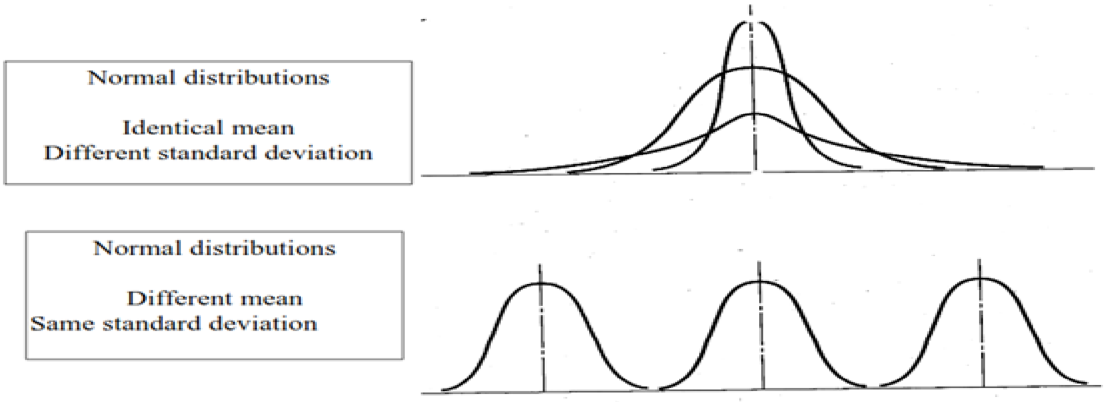


Fig 5.14Normal Distribution, Levin & Rubin 1994

5.2.3.3.2.2.2.2.C Triangular Distribution

Triangular distribution are applied to those variables where the minimum, maximum and most likely (i.e. mode) values can be estimated Fig 5.15.Values near the minimum and maximum are less likely to occur than those near the most likely. It is claimed that the triangular distribution "is the most commonly used distribution for modeling expert opinion" (Vose, 1995) and "is sufficient in the vast majority of practical situations. There is no need to use anything more complex, so hardly anyone does" (Grey, 1995). The triangular distribution curve is chosen to be used in this study and is favored by the Eastman Kodak Company (Dysert& Lucas, 1993) because: It is easy to specify only the minimum, maximum, and most likely values. It does not require dealing with standard deviations. It can also be made exhibit the skewers often associated with the expected range of outcomes. i.e. skewed towards a larger probability of the minimum or maximum. e.g. for project activities, durations tend to have a 1:2 skew to the right , that is the likely value is one-third along from the minimum value (Chapman & Ward, 1997). Chapman & Ward (1997) have reservations in using the triangular distribution as it may cause significant underestimation of extreme values and that setting an absolute maximum value is conceptual unsound.

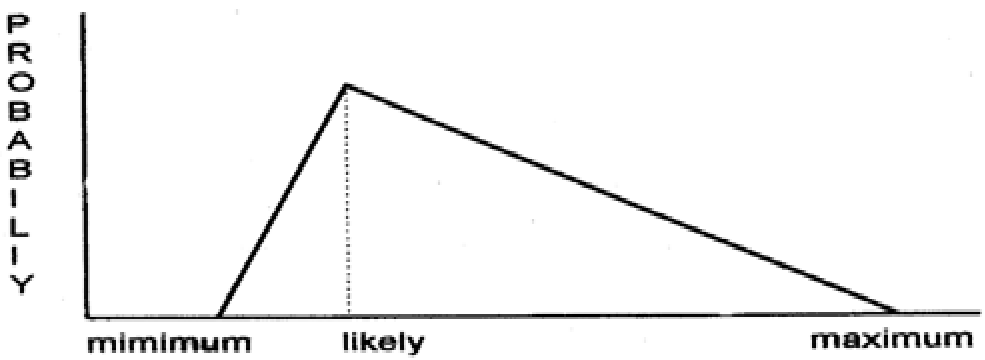
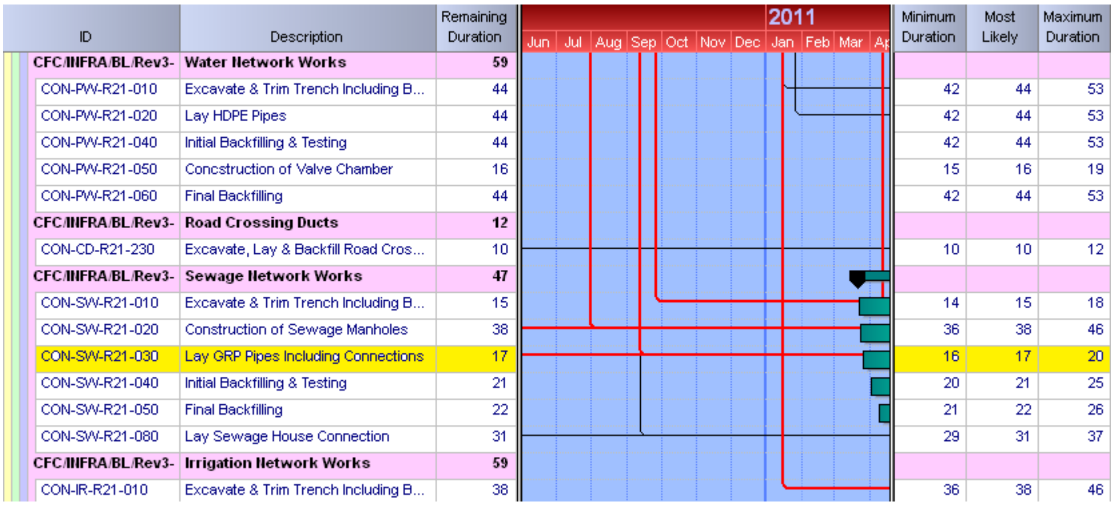


Fig 5.15Triangular Distribution, Chapman and Ward 1997

5.2.3.3.2.3 Grant Chart View

Fig5.16 represents the grant chart view were minimum, most likely and maximum ranges are represented. As shown in the grant chart in Fig 5.16 activity laying GRP pipes for sewage network is 17 days duration. This activity based on uncertainties input will give a range of 16 to 20 days. Thus, some pessimism was loaded. Activities were scud things 20 % to the pessimistic side. Pessimistic results should be obtained in return. The activities now can push out a good range for an aggressive sewage project.



ID	Description	Remaining Duration	Minimum Duration	Most Likely	Maximum Duration
CFC/INFRA/BL/Rev3-	**Water Network Works**	59			
CON-PW-R21-010	Excavate & Trim Trench Including B...	44	42	44	53
CON-PW-R21-020	Lay HDPE Pipes	44	42	44	53
CON-PW-R21-040	Initial Backfilling & Testing	44	42	44	53
CON-PW-R21-050	Concstruction of Valve Chamber	16	15	16	19
CON-PW-R21-060	Final Backfilling	44	42	44	53
CFC/INFRA/BL/Rev3-	**Road Crossing Ducts**	12			
CON-CD-R21-230	Excavate, Lay & Backfill Road Cros...	10	10	10	12
CFC/INFRA/BL/Rev3-	**Sewage Network Works**	47			
CON-SW-R21-010	Excavate & Trim Trench Including B...	15	14	15	18
CON-SW-R21-020	Construction of Sewage Manholes	38	36	38	46
CON-SW-R21-030	Lay GRP Pipes Including Connections	17	16	17	20
CON-SW-R21-040	Initial Backfilling & Testing	21	20	21	25
CON-SW-R21-050	Final Backfilling	22	21	22	26
CON-SW-R21-080	Lay Sewage House Connection	31	29	31	37
CFC/INFRA/BL/Rev3-	**Irrigation Network Works**	59			
CON-IR-R21-010	Excavate & Trim Trench Including B...	38	36	38	46

Fig 5.16 Grant Chart After Placing Uncertainties

5.2.3.3.2.4 Run Risk Analysis

This is done as a trial only to test the validity of the schedule before carrying on risk analysis. As shown in Fig 5.17, the test analysis run cover 1000 iterations representing the simulation steps carried or no. of iterations to complete the test . 1000 iterations were used as optimum no. of iterations; many scenarios are considered taking most possibilities thus reflecting respectful results as moving between max and min 1000 iteration times.

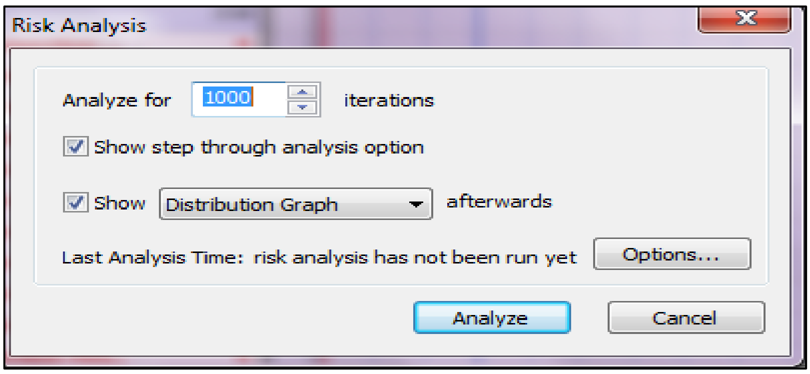


Fig 5.17 Running Risk Analysis Test

Through these iterations the activity bars will move within the ranges of minimum and maximum durations. Through this schedule validity test, critical path tasks could be viewed on the grant chart. As shown in Fig 5.18 a sewage connection available as a critical activity at date 4/9/2012. This was after 71 trials throughout the simulation process. Thus the risk analyst could stop at any iterative step and view any activity dates from the grant chart view.

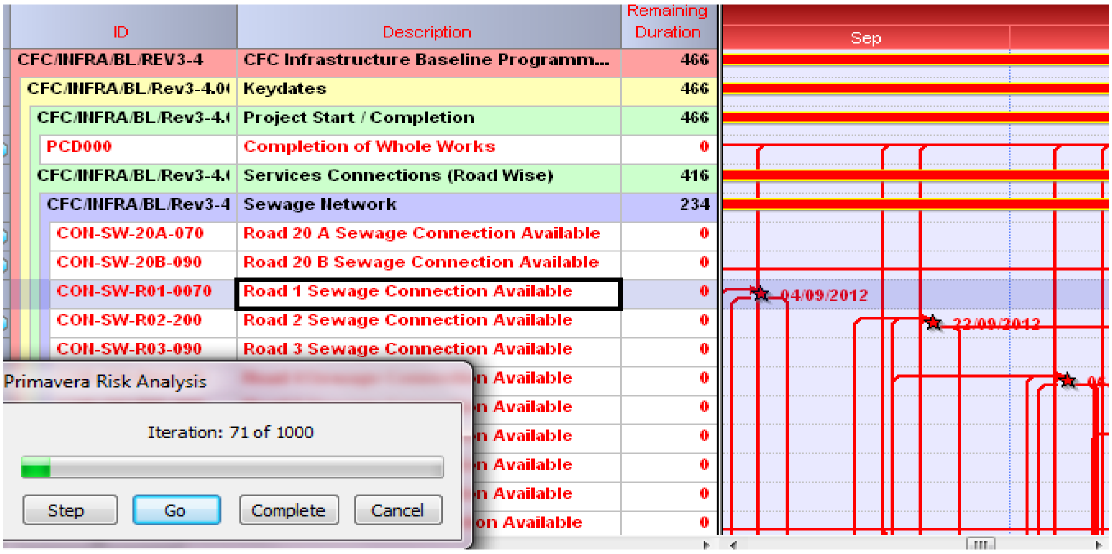


Fig 5.18a Critical Activity Viewed at 71 Iterations

The movement is clear in Fig 5.18 b were the critical path new date changes after 99 iterations to be 6/9/2012. Thus, any critical activity could be filtered and viewed at any iterative step .This proves that using 1000 iterations allows the risk analyst to move between the maximum and minimum ranges. This is reflected in the figure below were the activity bars moves and date is changed after several iterations. Furthermore, a histogram report will result representing the overall project tasks duration is analyzed.

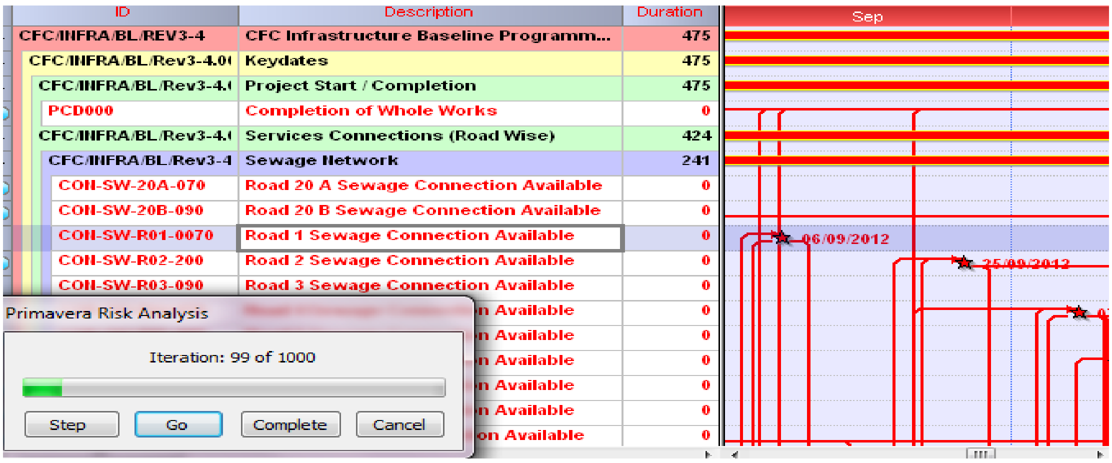


Fig 5.18 b Critical Activity Viewed at 99 Iterations

5.2.3.3.2.5 Simulation Output Reports

5.2.3.3.2.5.1Histogram Output

The test simulation can be represented graphically on a histogram. Fig 5.19 represents this histogram as a result of the analysis. The histogram consists of number of iterative hits at the y-axis on the left. Probability of finish dates with corresponding to the number of hits on y-axis on the left. Dates were all activities are supposed to finish on the x-axis. Cumulative curve based on pessimistic ranges entered before running the analysis. Column bars representing the schedule pattern throughout the iterative process. There are no large gaps in the graph which may show issues with constraints, non-working periods, or static paths like milestones strings are driving the schedule.

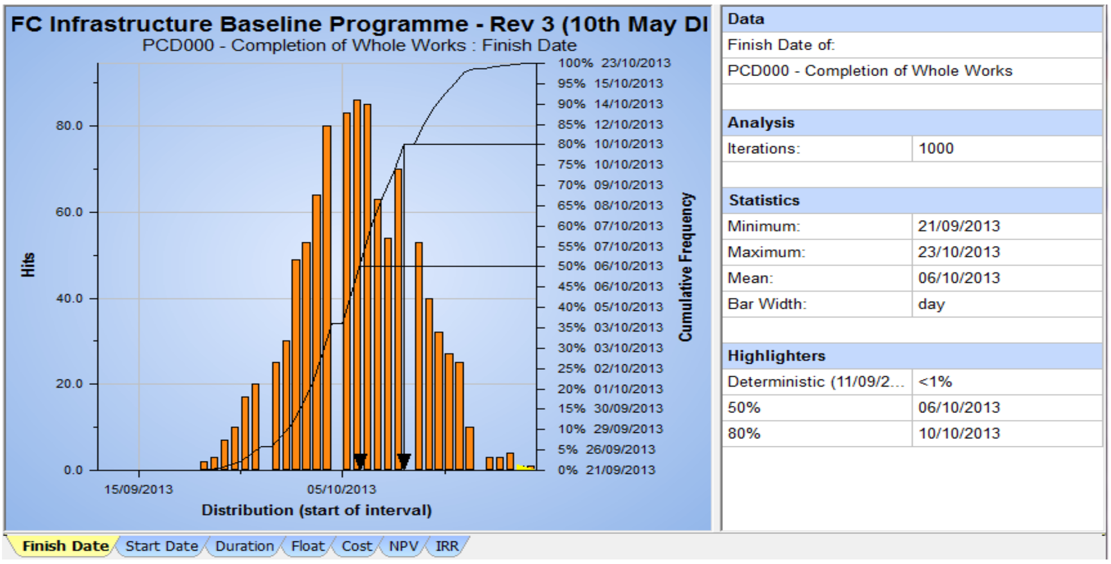


Fig 5.19 Schedule Check Simulation Histogram – Completion Works

As illustrated in Fig 5.19 has no large spike column bar at the beginning. A large spike at the beginning of a histogram often shows an activity cannot finish earlier than a finish-on-or-after constraint. The difference between the deterministic dates should make sense relative to the risk inputs. The risk inputs are skewed to the maximum (95%, 100%, 120%), then it would make no sense if the answer did not push out multiple months. Since the value is skewed 15% to the maximum, then you would expect at least a 12 to 18% push on activities. As shown in the figure the mean of finish date was 6/10/2013. Thus, working on our risk inputs min duration was 21/9/2013 and max duration was 23/10/2012. The push could be worse based on near critical paths. It is clear from the graph, the probability to finish at 6/10/2013 is 50% and the probability to finish at 10/10/2013 is 80%.

As shown on the left y-axis of the histogram is the percent chance of completion. It should give a hint about how the network is working. In this studies based on inserted ranges, the range of uncertainties reflects pessimistic inputs. Thus, pessimistic output results obtained seems to be logic results. A pessimistic answer would indicate that the confidence level is reducing due to the amount of critical path movement. As the amount of near critical paths increase, the confidence level should decrease. If the risk analyst uses a pessimistic distribution, then the answer should be very negative. A reasonable confidence level would dictate that the network has very few driving activities or the logic is broken in general.

5.2.3.3.2.5.2Tornado Chart Output

Fig 5.20 illustrates tornado chart which list activities that are driving the completion of whole works. Service connections and roads construction are the largest drivers of the work completion. These are logically drivers as connections are so important in order to complete finishing all sewage works. The results obtained are based on 1000 iterations made using pessimistic input ranges. If a project manager knows that engineering should be a driver but it does not show up on the tornado chart, then the schedule is probably missing a link from the engineering chain of activities. If a risk analyst sees a non-driving activity on the chart, then there is probably a link that should be removed in the base schedule.

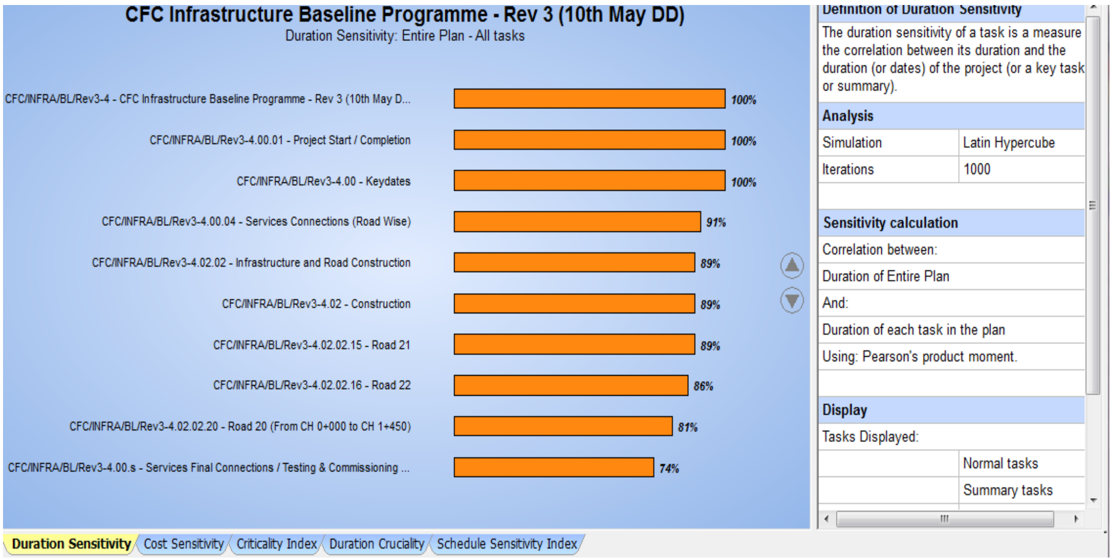


Fig 5.20 Tornado Diagram – Duration Sensitivity

Fig 5.21 represents the tornado diagram for the highest critical path activities drivers. A scheduler can check the drivers which pushes the critical path. Activities in the diagram are all on the critical path of the project program. Represented As the display shows they are all milestones and normal tasks according to the base plan made by the scheduler. A general rule is that the tornado chart should list mostly activities that people expect or the schedule does not reflect the project management team's expectations. In this case either the schedule is linked incorrectly or the project team does not understand how the job is being worked. When the tornado chart does not make sense, the base schedule should be revised. This process should be repeated until the logic reacts in a realistic fashion. There is no value running a risk analysis unless the team believes the sequencing reflects reality.

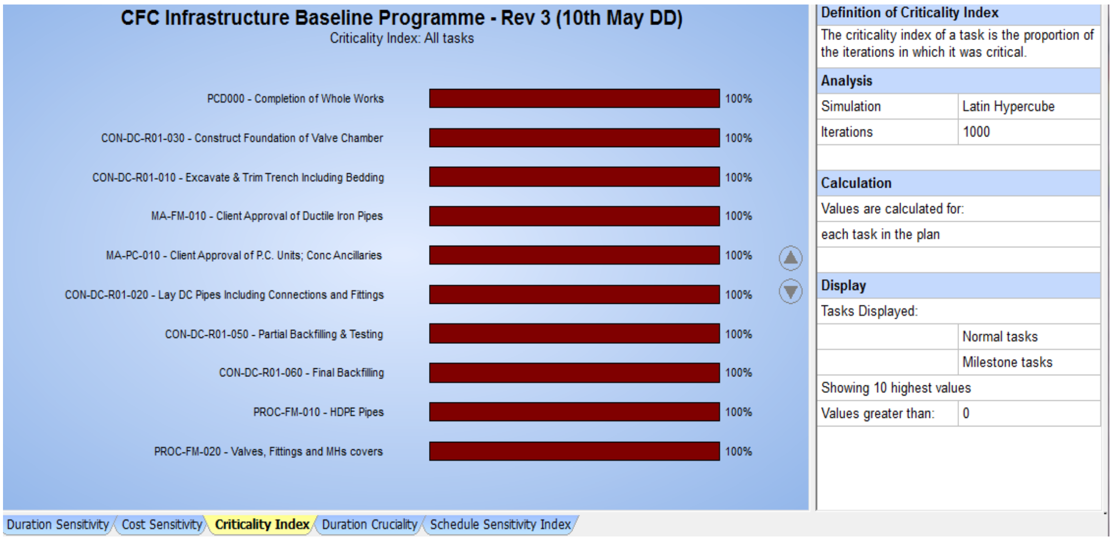


Fig 5.21 Tornado Diagram – Criticality Index

5.2.3.4 Template Quick Risk

The template quick risk is much quicker than manual risk loading. The inputs have increased traceability as there a manageable and comprehend-able amount of groupings. The templates are easy to update and manage for recurring reporting cycles. Filters can take into account schedule changes. The groupings may help with activity correlation instead of trying to correlate activities manually. Grouping activities helps all team members give input without a heavy statistics background.

Template quick risk is an uncertainty register. The theory beyond this is to create groupings of risk. As the project used has a huge amount of activity. Thus, it's good for both schedulers were hard to add uncertainty for each activity step by step. Top management must understand inputs of risk uncertainty. Risk template together with the risk register is linked to analyze all risk events. As shown in Fig 5.23 the template quick risk is represented. The grouping used is by discipline. Each project discipline might have independent correlation. A correlated group is a group which has their durations close to the distribution chosen. In our case by using triangular distribution the more the results are close to the mean the more they are correlated. On the other hand, low correlated groupings are away from the mean.

Very high correlation can be higher than 80%, high correlation from 60% to 80% and low correlation may be beyond 40%. As shown in Fig 5.22, there is construction grouping as the main discipline in any sewage project used in this study. The Construction Grouping has Min 95%, Most Likely 100% and Max 120%. We put much pessimism on them as the worst case. As sewage network project contractors are not all on board without a detailed schedule about their work.

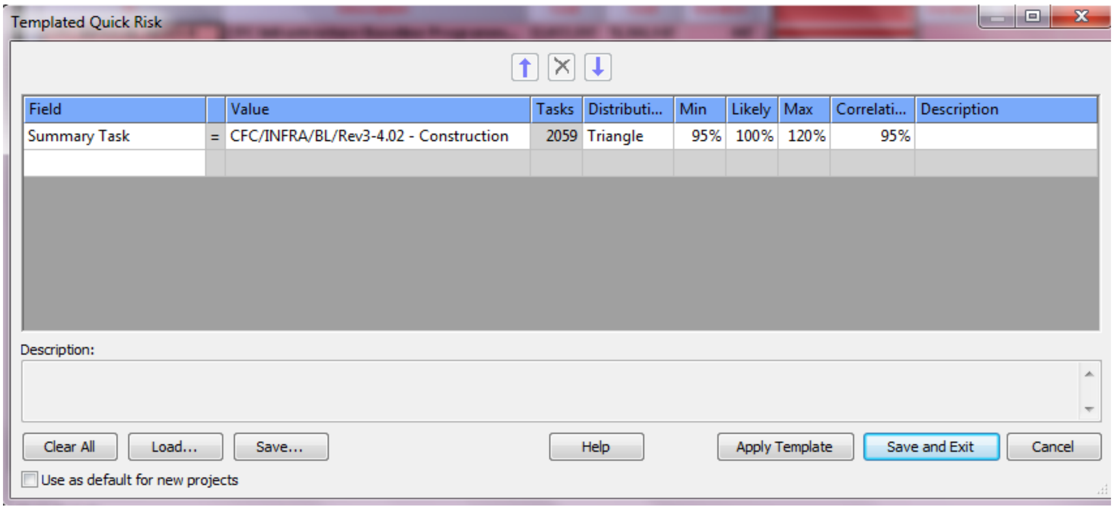


Fig 5.22 Template Quick Risk

5.2.3.5 Correlation Field

5.2.3.5.1 Introduction

The field allows a scheduler to create activity groupings that have similar behavior. It may not make sense to correlate activities when they are not truly related. Correlation may overcome the undesired cancellation effect of the central limit theorem in certain situations. Correlation may stop critical path switching in groups that have been placed in parallel for representation of work but not the sequenced accurately due to lack of scope or other issues. Example correlation: A project manager could correlate a grouping of activities for a construction crew as their productivity may extrapolate to all activities in their scope of work.

5.2.3.5.2Central Limit Theorem

The Central Limit Theorem states that the distribution of an average tends to be Normal, even when the distribution from which the average is computed is decidedly non-Normal. The basic result of the Central Limit Theorem on the Monte Carlo analysis is the results pushing toward the mean. The correlation value can be input between 0 and 100.

5.2.3.5.3 Correlation Percentage to Use

Often project managers, risk analysts, and statisticians will argue over the correct number to use for correlation. Very High: 80%-100%, High:60%-80%, Medium: 40%-60% and Very Low: 0%-40%. As shown in Fig 5.23, correlation chosen for engineering discipline is 95% as they stick to the range of pessimism given as an aggressive related to the schedule and due to harsh political environment surrounding the construction of the project.

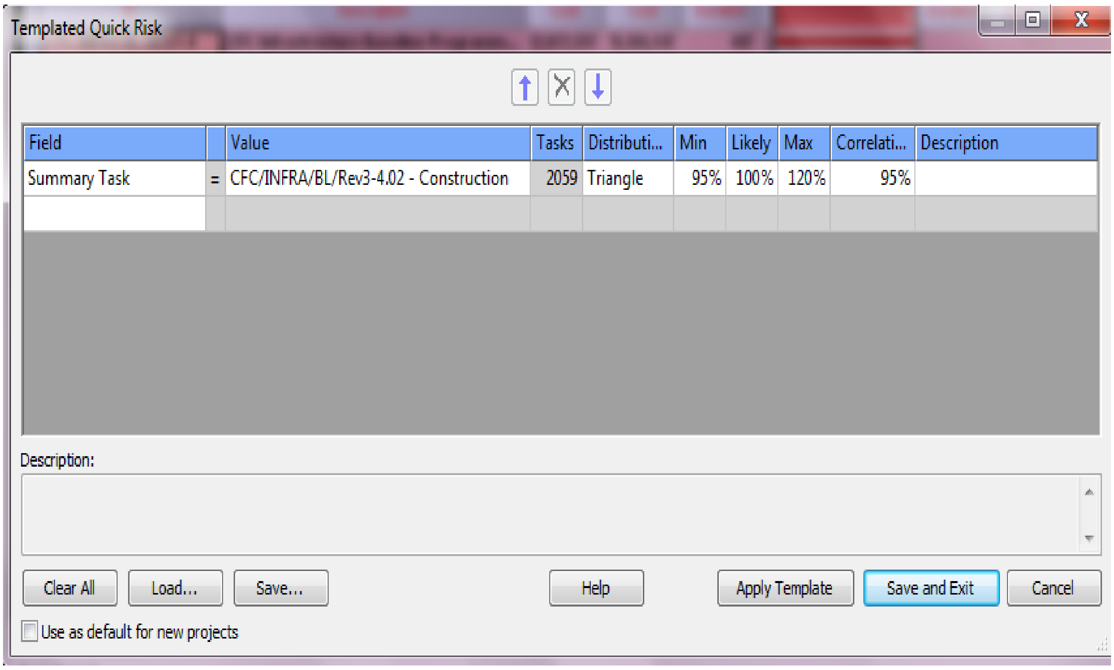


Fig 5.23 Inserting Correlation for Project Disciplines

For construction they have to follow the range of uncertainty as they already given pessimistic range they have to work hard to make it works. A project manager can look at the scatter plots for these ranges by manually correlating two activities that have fairly wide ranges. As shown in Fig 5.24 notice that the scatter plots of 95% does not look much different from 10%. Statistically the results are fairly similar. Using a very low correlation might raise a flag that the model could be statistically improved. The correlation calculation was made based on a statistical means. It was calculated using Pearson's moment product theory which is later on discussed through this chapter.

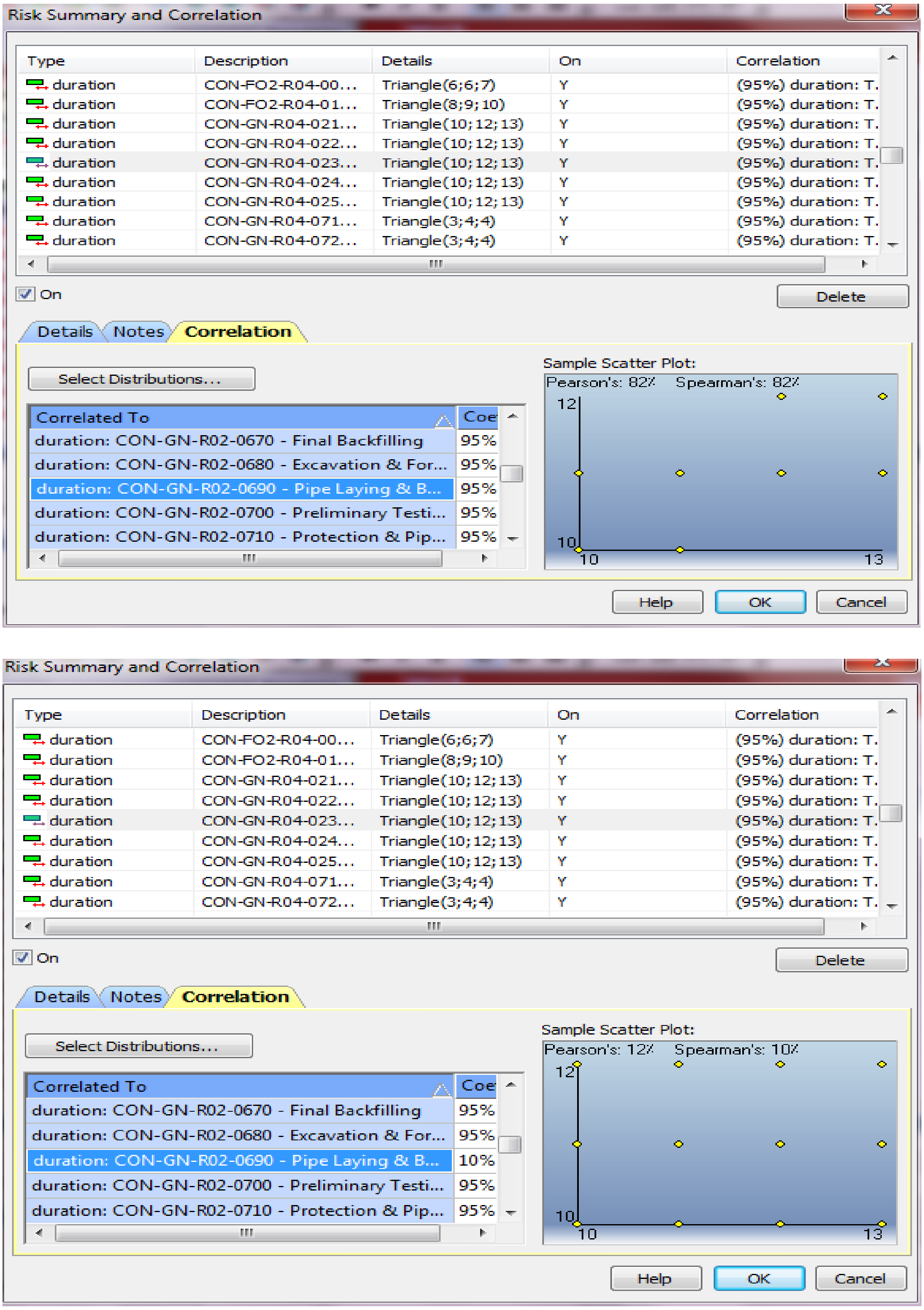


Fig 5.24 Tight and Scattered Correlation

5.2.3.6 Pert-Master Qualitative Risk Register

5.2.3.6.1 Introduction

In this step of a Pert-Master program, risk events are to be tracked, quantified, and linked to the project schedule in order to complete the Monte Carlo analysis. The Pert-Master risk register is simple and easy to use. It provides a good format for users that do not have a risk register in another tool. Primavera risk program does not have a database back-end so it limits project managers' ability to collaborate, track risk, create accountability, or roll risk up to portfolio levels.

The qualitative side of the risk register is all about tracking and categorizing risk. There is no right or wrong way to setup a risk register. In its simplest form, a risk register or risk log is just a list of risks. Much or little information are attached as needed based on what an organization would like to track. Some of the interesting fields in the Pert-Master Risk Register are often ignored by risk management teams regardless of the risk register product or template they are using.

5.2.3.6.2 Risk Scoring System Scales

The schedule and cost impacts are the default types in the Pert-Master program. The cost and schedule fields are numbers. These numbers are set based on the **Project Management Book of Knowledge (PMBOK) Guide (2008)**. As shown in Table 5.2 definitions of negative impacts that could be used in evaluating risk impacts related to two project objectives. The table reflects the defined conditions for impact scales of a risk on major project objectives. Activities construction cost and time obtained from a sample sewage project are the two objectives used in this study. The scales represented in the table are for both the probability of occurrence and the cost and time impact scales. The probability scale varies from very low to very high (0.1–0.9). The impact scales for cost and time are given as percentage of the overall cost and time of the activities. Furthermore risk events are linked to these activities.

Table 5.2 Impact on Cost and Time Ratings, PMBOK (2008).

Defined Conditions for impact scales of a risk on major project objectives					
Project Objectives	Very Low /0.10	Low / 0.3	Moderate /0.5	High / 0.70	Very High / 0.90
Cost	Insignificant Cost Increase	< 10% Cost Increase	10-20% Cost Increase	20-40% Cost Increase	>40% cost increase
Time	Insignificant Time Increase	< 10% Time Increase	5-10% Time Increase	10-20% Time Increase	>20% time increase

From the primavera P 6.1 program the overall construction activities are viewed for original time and budget cost. The sample project taken has the sewage construction works divided into the program by roads. As shown in Fig 5.25 out of twenty five roads road 1 has a list of sewage activities including their original duration and total cost. These two parameters are reviewed in road 1 including sewage, district cooling, water, irrigation, gas, medium and low voltage networks and road works. In Fig 5.25 the roads are listed so that the overall budget cost and original duration for road 1 is calculated to be 8,058,001 L.E and 196 days.

Activity ID	Activity Name	Budgeted Total Cost	Secondary Constraint	Original Duration
CFC/INFRA/BL/Rev3-4.02 Construction		L.E163,327,544		481
CFC/INFRA/BL/Rev3-4.02.02 Infrastructure and Road Construction		L.E163,275,116		417
CFC/INFRA/BL/Rev3-4.02.02.4 Road 1		L.E8,058,001		196
CFC/INFRA/BL/Rev3-4.02.02.4.8 Relocation / Protection for Existing Services		L.E0		32
CON-FO-R06-060	Relocation / Protection of Existing FO Lines	L.E0		12
CON-MV-R06-230	Relocation / Protection of Existing MV Lines	L.E0		12
CON-MV-R06-240	Obtain Permits & Approvals for Relocation / Protection Works	L.E0		10
CON-WD-R06-050	Relocation / Protection of Existing Water Lines	L.E0		18
CFC/INFRA/BL/Rev3-4.02.02.4.01 Bulk Excavation and Filling		L.E175,428		6
CON-BX-R01-010	Bulk Excavation and Fill for Road 1	L.E175,428		7
CFC/INFRA/BL/Rev3-4.02.02.4.11 Sewage Network Works		L.E562,397		19
CON-SW-R01-0010	Excavate & Trim Trench Including Bedding	L.E16,142		8
CON-SW-R01-0020	Construction of Sewage Manholes	L.E42,880		9
CON-SW-R01-0030	Lay GRP Pipes Including Connections	L.E79,845		8
CON-SW-R01-0040	Initial Backfilling & Testing	L.E256,567		8
CON-SW-R01-0050	Final Backfilling	L.E87,118		8
CON-SW-R01-0080	Lay Sewage House Connection	L.E79,845		8

Fig 5.25 Construction phase sewage networks for Road 1.

The Pert-Master program impact scales are shown in Table 5.3 below deals with numbers. That's to say, the overall cost and time for the construction of different networks in road 1 are used as an input of these scales. These two parameters are used in identifying the days and L.E impacts on both time and cost of activities during the construction phase. The table represents impact types and degree of impact V.L to V.H according to **Project Management Book of Knowledge (PMBOK) Guide (2008)**.

Table 5.3 Pert Master Impact on Cost and Time Ratings

Impact Scales & Types

Add Impact Type | Delete Impact Type | Items in the scale: 5

Impact Types	Score?	Very Low	Low	Medium	High	Very High
Schedule	☑	<=10	>10	>20	>29	>39
Cost	☑	<=L.E805,...	>L.E805,800	>L.E1,208,...	>L.E2,417,...	>L.E3,223,200

Risk assessment takes into account both the likelihood of a risk occurring and its impact on project objectives if it does occur. There are several ways to measure the likelihood and impact of a risk event. The best approach scales these two characteristics between 0.0 and 1.0. Likelihood is usually measured between 0.0 (no likelihood) and 1.0 (certainty). While this seems to be natural, questions can be developed that lead to answers that indicate the level of likelihood. One example of some questions to determine the likelihood of technical risk is shown in Table 5.4 below**. Hullet, David (2004)**.

Table 5.4 Likely Hood of Project Risk Factors, Hullet, David (2004).

Likelihood of Technology Risk	
Description to Technology	**Likelihood Rating**
Scientific research required	.9
Concept design formulated	.8
Concept design tested - bench scale	.7
Critical functions / characteristics demonstrated	.6
Process passed performance test at pilot scale	.4
Full-scale prototype passed performance test	.3
More than one full scale facility operational	.1

As illustrated in Fig 5.26, the above ranges of probabilities are used as an entry into the pert master program was they represent the risk probability occurrence during the sewage construction phase. The figure represents different scales used for risk probability of occurrence. The scale ranges from very high to very low scales. A risk event which has a scale greater than 50 % is considered to have a medium probability of occurrence. Furthermore risk probabilities are conducted from chapter 4 risk qualitative analysis output. These risk probabilities is used as one of the qualitative risk register entries in the Pert-Master program.

	Probability
Very High	>90%
High	>70%
Medium	>50%
Low	>30%
Very Low	<=30%

Fig 5.26 Probability Ranges Used in Pert Master Program.

5.2.3.6.3 Qualitative Risk Register Field

5.2.3.6.3.1 Introduction

The Qualitative risk register template filled in this pert master is conducted from several sources. The qualitative risk analysis made before in chapter 4 has an updated risk register output. This output reflects the most important risks which is analyzed in this chapter. Furthermore, Pert-Master risk register considers also proposed mitigations made to these risk factors. For this reason, three main divisions are considered in this risk register. These are the pre-mitigation, mitigation and post-mitigation divisions. The pre-mitigation consists of the probability scales and impact scale on both cost and time. These scales were used before for risk factors conducted through a field survey during the qualitative phase. Both mitigation field and post-mitigation probabilities and impacts are further more conducted through another field survey. Thus Risk responses technique must be implemented through a questionnaire and implemented into the Pert-Master risk register for further analysis.

5.2.3.6.3.2 Risk Response Strategies for negative Risks or Threats

The following strategies typically deal with threats or risks that may have negative impacts on project objectives if they occur. The fourth strategy, accept; can be used for negative risks or threats as well as positive risks or opportunities. These strategies, described below, are to avoid, transfer, mitigate, or accept. Furthermore the suitable action is chosen through a field sewage projects survey. These responsive actions are used as mitigation for improving the probability and impact scales that previously conducted form qualitative risk analysis. **A Guide to the Project Management Body of Knowledge Book (2008).**

5.2.3.6.3.2.A Avoid.

Risk avoidance involves changing the project management plan to eliminate the threat entirely. The project manager may also isolate the project objectives from the risk's impact or change the objective that is in jeopardy. Examples of this include extending the schedule, changing the strategy, or reducing scope. The most radical avoidance strategy is to shut down the project entirely. Some risks that arise early in the project can be avoided by clarifying requirements, obtaining information, improving communication, or acquiring expertise. **A Guide to the Project Management Body of Knowledge Book (2008).**

5.2.3.6.3.2.B Transfer.

Risk transfer requires shifting some or all of the negative impact of a threat, along with ownership of the response, to a third party. Transferring the risk simply gives another party responsibility for its management—it does not eliminate it. Transferring liability for risk is most effective in dealing with financial risk exposure. Risk transference nearly always involves payment of a risk premium to the party taking on the risk. Transference tools can be quite diverse and include, but are not limited to, the use of insurance, performance bonds, warranties, guarantees, etc. Contracts may be used to transfer liability for specified risks to another party. For example, when a buyer has capabilities that the seller does not possess, it may be prudent to transfer some work and its concurrent risk contractually back to the buyer. In many cases, use of a cost-plus contract may transfer the cost risk to the buyer, while a fixed-price contract may transfer risk to the seller. **Project Management Book of Knowledge (PMBOK) Guide (2008)**.

5.2.3.6.3.2.C Accept.

This strategy is adopted because it is seldom possible to eliminate all threats from a project. This strategy indicates that the project team has decided not to change the project management plan to deal with a risk, or is unable to identify any other suitable response strategy. This strategy can be either passive or active. Passive acceptance requires no action except to document the strategy, leaving the project team to deal with the risks as they occur. The most common active acceptance strategy is to establish a contingency reserve, including amounts of time, money, or resources to handle the risks.

5.2.3.6.3.2.D Mitigate .

Risk mitigation implies a reduction in the probability and/or impact of an adverse risk event to be within acceptable threshold limits. Taking early action to reduce the probability and/or impact of a risk occurring on the project is often more effective than trying to repair the damage after the risk has occurred. Adopting less complex processes, conducting more tests, or choosing a more stable supplier are examples of mitigation actions. Mitigation may require prototype development to reduce the risk of scaling up from a bench-scale model of a processor product. Where it is not possible to reduce probability, a mitigation response might address the risk impact by targeting linkages that determine the severity. For example, designing redundancy into a system may reduce the impact from a failure of the original component. Since post mitigation probabilities and impacts are needed as an entry in the risk register. Thus mitigation responses are used as response action by which the questionnaire participants will suggest to improve risk events scales.

5.2.3.6.3.3 Mitigation and Post Mitigation through Field Survey

In Table 5.5 below a sample of questionnaire fields is represented. Participants were asked to suggest a mitigation tittle for each risk. In addition to that, they will check mark the level by which post-mitigation is after implementing these mitigations into the pre-mitigation levels taken from the qualitative analysis. All levels of pre-mitigation taken from qualitative risk analysis stage vary between ranges moderate to low. Thus post-mitigation results obtained from survey results is either the same level or lower as shown in the sample below in Table5.5.

Table 5.5 Sample of distributed risk response questionnaire

Risk ID	Risk Factor	Time Impact			
		Mitigation Title	Post-Mitigation		
			V.L Insignificant. Time Increase	L <5% Time Increase	M 5-10% Time Increase
F3	Delay in shop drawing approval	Discuss any problems with consultant		√	
B4	Poor equipment's productivity	Experienced project team is required		√	
B7	Poor site management bycontractors	Use expert site managers		√	
B10	Poor planning errors	Use more involved planner in similar projects		√	
B1	Misleading management focus	Follow the mile stone suggested by owner facility		√	
A3	Delay in material approval	Eliminate any supplier problems		√	
B9	Approval delay of third party	Ask any reason for delay with engineer		√	
B5	Low subcontractor performance	Use more effective subcontractor		√	
C1	Funds unavailability	Increase cash available	√		
D1	Permits delayed	Good communication with government.		√	

The target of using a field survey was to add both mitigation title and reduced post-mitigation scales into the pert-master risk register. Samples of forty seven questionnaires were collected. As illustrated in Fig 5.27, the numbers above the column bars represents the agreed number of participants for each scale. In this manner, the reduced scale for time and cost objectives is taken from these results. The total number of participants is shown on the y-axis. The x-axis illustrates the reduced scales which vary from Very Low (V.L), Low (L) and Medium (M).It is clear that for example poor equipment productivity forty personnel agreed low. This means that they agreed that by implementing mitigation responses the scale is reduced to low

(<5% time increase) in time impact. Three of them only agreed scale to remain medium as it is (5-10% time increase) and only 5 of them agreed it is reduced to low scale. Thus for this risk factor it is conducted that most of the participants (40 participants) agreed reduced scale to low after implementing mitigation actions.

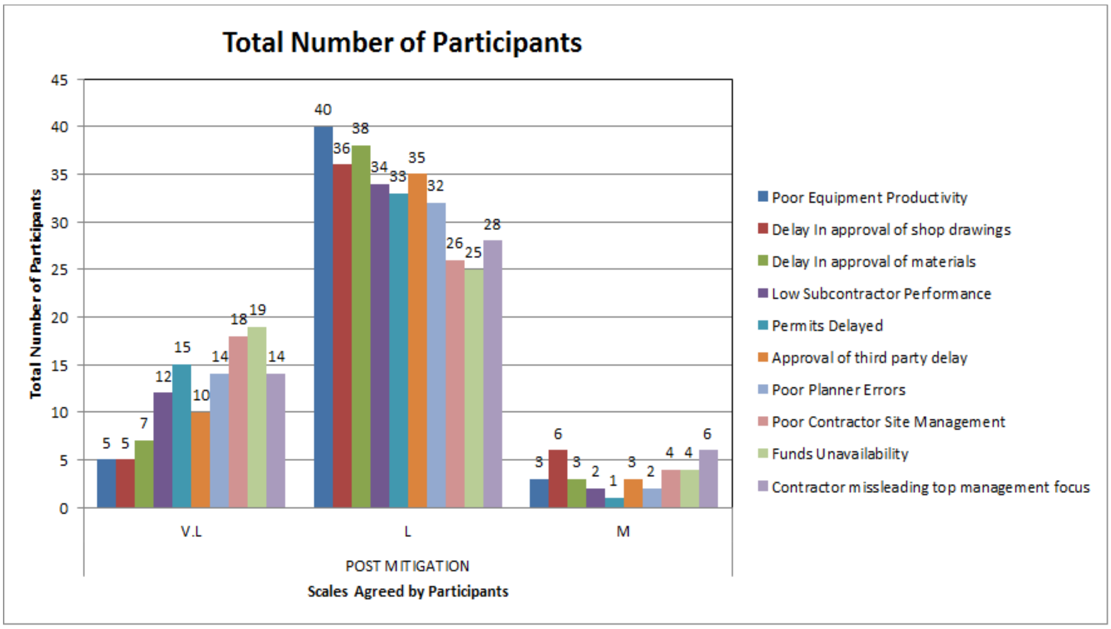


Fig 5.27 Total Number of Participants for Each Risk Factor

As represented in Fig 5.28, the percentage of the total number of participants is represented also in a chart. It is clear that also for poor equipment productivity risk factor most of participants 85.1 % agreed that mitigation suggested will result the post-mitigation scale to be low. Thus, low scale is implemented as the new scale in post mitigation step into the risk register of the Pert-Master program.

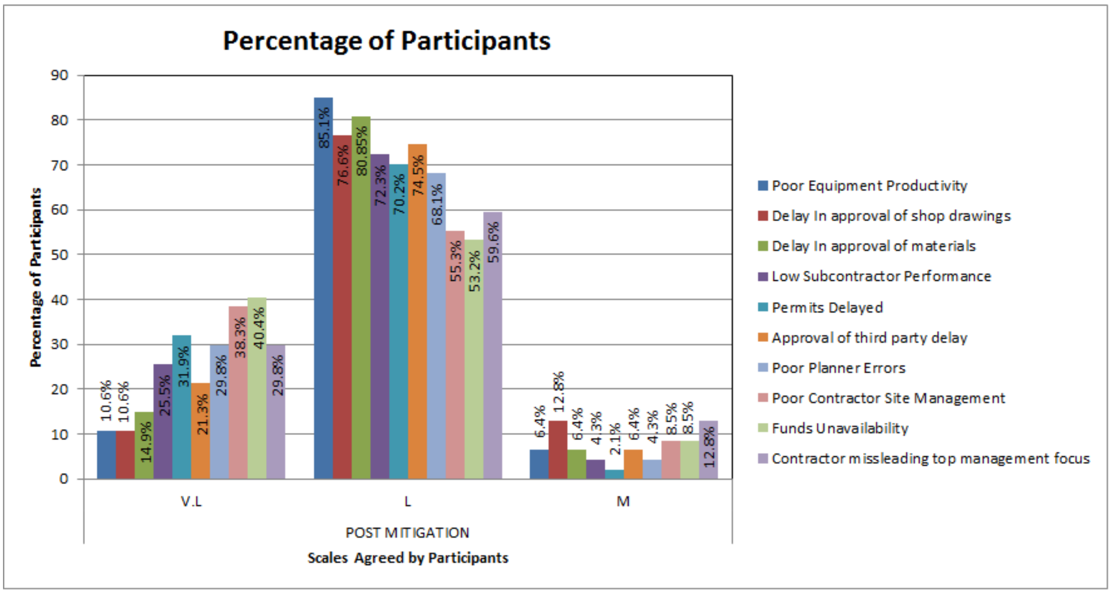


Fig 5.28 Percentage of Participants for Each Risk Factor

Using the above risk response questionnaires the risk register in the Pert-Master program is implemented. Fig 5.29 below represents the risk register of the Pert-Master program. Risk factors are shown together with their risk IDs. Three stages are filled, this include the pre-mitigation scales, the mitigation title and the post-mitigation scales. The pre-mitigation stage was implemented from the qualitative risk analysis output. Both mitigation title and post-mitigation scales are taken from participants opinions. Furthermore, this risk register is used in the analysis of the identified sewage risk factors. This risk register is placed under the qualitative risk register title. In the next step quantitative risk register is implemented. Quantitative part of risk register includes linking these risk factors to the sample project schedule for further analysis.

Risk Register

File Edit View Tools Reports Help

Qualitative | Quantitative

Risk			Pre-Mitigation (Data Date = 22/06/2012)				Mitigation		Post-mitigation			
ID	T/O	Title	Probability	Schedule	Cost	Score	Response	Title	Probability	Schedule	Cost	Score
b4	T	Poor equipment productivity	M	M	M	10	Reduce	Use more experienced project team . p...	M	L	L	5
f3	T	Delay in Shop drawings approval	M	H	M	20	Reduce	Discuss any problems with the consult...	M	L	L	5
a3	T	Delay in approval of material	M	M	M	10	Reduce	Try to discuss use other material . Con...	M	L	L	5
b5	T	Low subcontractor performance	M	M	M	10	Reduce	Use more Subcontractor . Use warning...	M	L	L	5
d1	T	Permits delayed	M	M	M	10	Reduce	Good comunication for contractor wit...	M	L	L	5
f4	T	Approval of third party Delay	M	M	M	10	Reduce	Perform regular meetings to discuss t...	M	L	L	5
b10	T	Poor planner errors	M	M	M	10	Reduce	Use more experienced planner who de...	M	L	L	5
b7	T	Poor site management by the contractor	M	M	M	10	Reduce	Consultant ca send warnings to the co...	M	L	L	5
c1	T	Funds unavailability	M	L	M	10	Reduce	Increase cash available before constru...	M	L	L	5
b1	T	Contractor misleading top management focus	M	M	M	10	Reduce	Project team must set regular weekly ...	M	L	L	5

Fig 5.29 Pert-Master Program Risk Register

5.2.3.7 Risk Reports Overview

5.2.3.7.1 Risk Scoring System Report

Fig 5.30 illustrates the risk scoring system report outlines the entire the scoring system that was setup previously. The report represents both project data and report summary similar to that discussed in the risk matrix report. Furthermore, the risk scoring system reflects the probability and impact scales which were entered prior starting the risk register. The probability impact scoring matrix is also represented. This matrix contains key numbers which are entered according to the sewage project organization view to identify areas red in color need to be mitigated. Yellow also are concern risk factors they need to be mitigated. Green zone were these risk factors could be simply passed to the project team and dealt during the construction of this sewage project.

ORACLE
PRIMAVERA RISK ANALYSIS

Risk Scoring

CFC INFRA BL Rev3-4

Project Data	
File Name	CFC INFRA BL Rev3-4.plan
Plan Title	CFC INFRA BL Rev3-4
Total Tasks	3330
Completed	430
In Progress	188
Plan TimeNow	22 Jul 2012
Deterministic Finish	11 Sep 2013
Total Deterministic Cost	L.E82,155,678
Actual Cost to Date	L.E3,789,532
Deterministic Remaining Cost	L.E78,366,147

Report Summary	
Report Name	Risk Scoring
Date Printed	20 Aug 2012
Total Risks	10
Proposed Risks	10
Open Risks	0
High	0
Medium	10
Low	0
Negligible	0
Impacted (Closed) Risks	0
Managed (Closed) Risks	0
Rejected (Closed) Risks	0
Threats	10
Opportunities	0

Probability Scale

Very Low	Low	Medium	High	Very High
Up to 30%	30% to 50%	50% to 70%	70% to 90%	90% or higher

Impact Scales and Types

	Very Low	Low	Medium	High	Very High
Schedule*	Up to 10	10 to 36	36 to 71	71 to 143	143 or higher
Cost*	Up to L.E10,000	L.E10,000 to L.E8,293,987	L.E8,293,987 to L.E16,587,974	L.E16,587,974 to L.E33,175,948	L.E33,175,948 or higher

* means impact is used in scoring

Probability and Impact Scoring (PID)
Risk Score is based on: **Highest Impact**

	Impact Very Low	Low	Medium	High	Very High
Very High	5	9	18	36	72
High	4	7	14	28	56
Medium	3	5	10	20	40
Low	2	3	6	12	24
Very Low	1	1	2	4	8

Key

Up to 5	5 to 23	23 or higher

Fig 5.30Risk Scoring System Report

5.2.3.7.2 Risk Matrix Report

As illustrated in Fig 5.31 the built-in risk register reports are designed to be easy to use. The figure identifies some project data. These data include the total number of activities 3330 activity used in this sample sewage project. Since this sample project was taken at the start of construction phase 430 tasks are shown as completed. The total construction cost 82,155,678 is also shown. The report summary is then represented. Data concerned with report name, total of 10 risk factors studied and the number of risk factors which has a medium scale.

ORACLE
PRIMAVERA RISK ANALYSIS

Risk Matrix

CFC INFRA BL Rev3-4

Project Data	
File Name	CFC INFRA BL Rev3-4.plan
Plan Title	CFC INFRA BL Rev3-4
Total Tasks	3330
Completed	430
In Progress	188
Plan TimeNow	22 Jul 2012
Deterministic Finish	11 Sep 2013
Total Deterministic Cost	L.E82,155,678
Actual Cost to Date	L.E3,789,532
Deterministic Remaining Cost	L.E78,366,147

Report Summary	
Report Name	Risk Matrix
Date Printed	20 Aug 2012
Total Risks	10
Proposed Risks	10
Open Risks	0
High	0
Medium	10
Low	0
Negligible	0
Impacted (Closed) Risks	0
Managed (Closed) Risks	0
Rejected (Closed) Risks	0
Threats	10
Opportunities	0

Fig 5.31 Risk Matrix Report

The risk matrix report will show where the risk is on the probability and impact risk matrix. The risk matrix report represented in Fig 5.32 also reflects the impact probability matrix for pre mitigation stage. This is before implementing any mitigation actions suggested by the risk response questionnaire participants. In the pre mitigation matrix it is clear that most of risk lye in yellow medium zone thus they have to be mitigated. The second post mitigation matrix reflects the location of risk factors inside the probability impact matrix after implementing mitigation actions. It is clear that the scale was lowered now the risk factors lie in the low scale zone. Thus these risk factors can now be transferred to the sewage project team to deal with during the construction period.

Pre-Mitigation

	Very Low	Low	Medium	High	Very High
Very High					
High					
Medium			b4 - Poor equipment productivity, a3 - Delay in approval of material, b5 - Low subcontractor performance, d1 - Permits delayed, f4 - Approval of third party Delay, b10 - Poor planner errors, b7 - Poor site management by the contractor, c1 - Funds unavailability, b1 - Contractor misleading top management focus	f3 - Delay in Shop drawings approval	
Low					
Very Low					

Post-Mitigation

	Very Low	Low	Medium	High	Very High
Very High					
High					
Medium		b4 - Poor equipment productivity, f3 - Delay in Shop drawings approval, a3 - Delay in approval of material, b5 - Low subcontractor performance, d1 - Permits delayed, f4 - Approval of third party Delay, b10 - Poor planner errors, b7 - Poor site management by the contractor, c1 - Funds unavailability, b1 - Contractor misleading top management focus			
Low					
Very Low					

Fig 5.32 Pre-Mitigation and Post Mitigation Matrixes

5.2.3.8 Pert-Master Quantitative Risk Register

5.2.3.8.1 Different risk views

The quantitative risk register is where a risk analyst will turn risk events into probabilistic schedule activities for the Monte Carlo cost or schedule simulations. The Pert-Master program offers different quantitative risk register views. These views are the risk view and the task view was both are used for linking the program activities to the risk factors. Fig 5.33 illustrates the risk view. The quantitative risk register reads from the qualitative risk register side. It is clear in Fig5.33 that the most important ten risk factors list are located in the left pane. The left panel contains the risk ID, risk title, threat or opportunity (T/O), whether the risk is quantified, probability, and the task ID that is the risk affects. The right panel contains all activities in the project plan. All sewage network activities for road 1 are checked at the right side. Thus by this means activities is linked to each risk factor located on the left side. The project manager can filter tasks, sort activities, and check mark the tasks a risk links to.

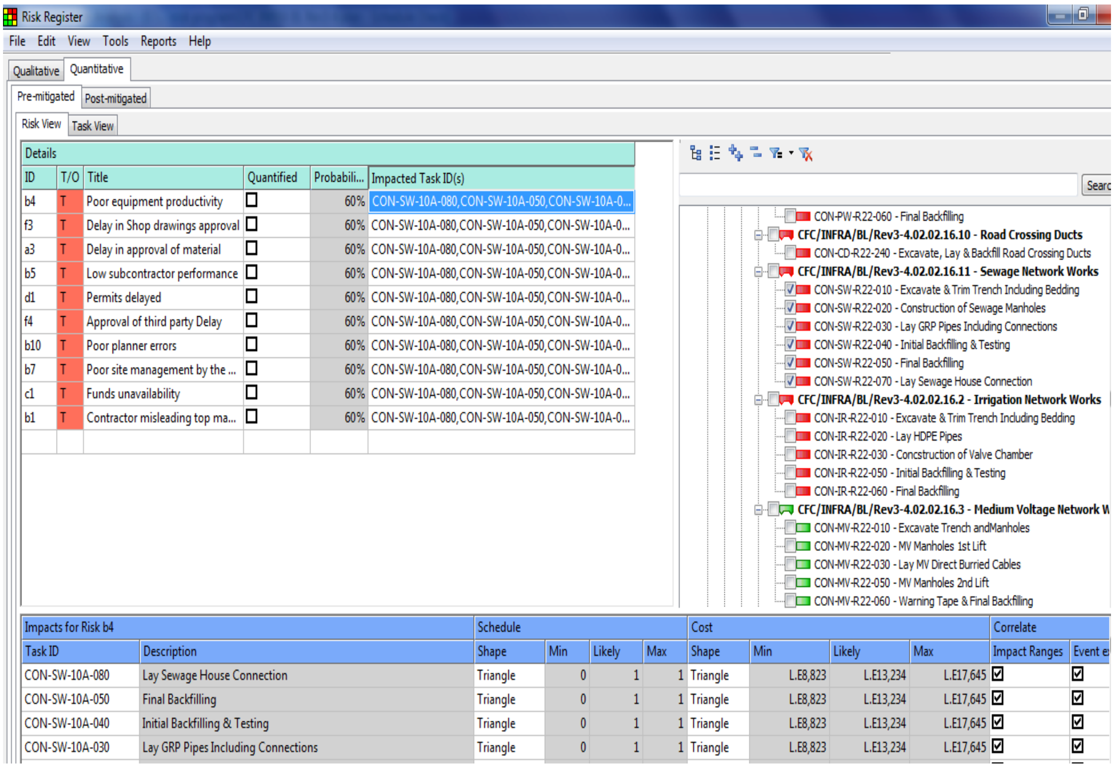


Fig 5.33 Risk View

The Task View is illustrated in Fig 5.34. The left panel contains all schedule activities. The right panel contains all risk events added into the risk model. Bottom Pane for Risk Impacts, The bottom panel lists the quantified impacts a risk has on a task and the task affected. The info is similar to an activity, such as duration and cost. Risk event existence and impact can be correlated. Risk event correlation is covered in detail later. Risk events link to an activity with a finish to start link. Risk events link in parallel by default. Risk can stack or be put in series but this could result in an increase of risk events durations.

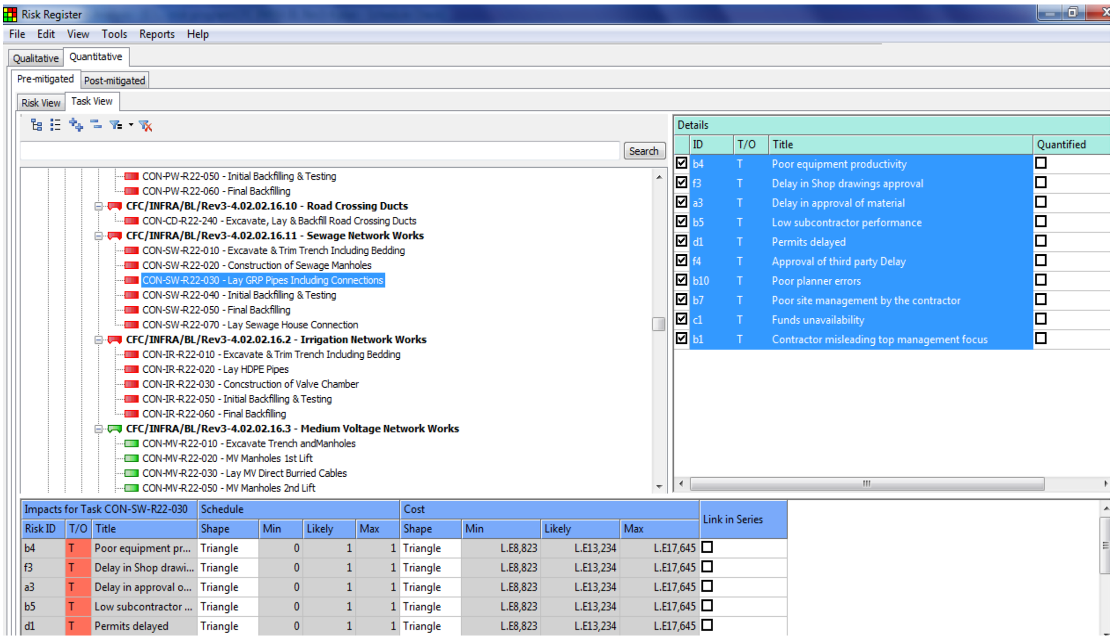


Fig 5.34 Task View

5.2.3.8.2Overview of Risk Event Correlation

If risk ranges are correlated, then they will hit the same portion of the risk triangle just like a correlated activity. The check box will set the correlation coefficient to 100%. A risk can be tied to more than one activity. As illustrated in Fig 5.35 if the event existence is correlated, then if a risk event occurs on one activity, and then it will happen to the other activities as well. For example, if a hurricane risk event is tied to the different tasks in the schedule, then it can occur in all places when the hurricane risks event fires.

Impacts for Task CON-SW-R22-030			Schedule				Cost				Link in Series
Risk ID	T/O	Title	Shape	Min	Likely	Max	Shape	Min	Likely	Max	
b4	T	Poor equipment pr...	Triangle	0	1	1	Triangle	L.E8,823	L.E13,234	L.E17,645	☐
f3	T	Delay in Shop drawi...	Triangle	0	1	1	Triangle	L.E8,823	L.E13,234	L.E17,645	☐
a3	T	Delay in approval o...	Triangle	0	1	1	Triangle	L.E8,823	L.E13,234	L.E17,645	☐
b5	T	Low subcontractor ...	Triangle	0	1	1	Triangle	L.E8,823	L.E13,234	L.E17,645	☐
d1	T	Permits delayed	Triangle	0	1	1	Triangle	L.E8,823	L.E13,234	L.E17,645	☐

Fig 5.35 Risk Event Correlation

5.2.3.9 Risk Register Integration with Schedule

In this step of Pert-Master Monte Carlo analysis is to link risk events to the project schedule for the Monte Carlo analysis. The Primavera Risk software will basically treat risk events as probabilistic activities that have logical ties to the schedule like any other task. As shown in Fig 5.36 once the risks have been linked to the schedule in the risk register. Fig 5.36 reflects wizard will launch that begins the process of converting risk events into probabilistic activities. Two risk plan scenarios are used, pre-mitigation and post mitigation scenarios.

Pre-Mitigated scenario is used to study the risk analysis prior implementing mitigation actions. Despite this, the second scenario is considered with the Post-Mitigation scenario, in this scenario the risk analysis is studied after implementing the mitigation actions that was previously suggested by the questionnaire participants. In both scenarios including the Post-Mitigation scenario and the Pre-Mitigation scenario, the prioritized risk factors are to be linked to the schedule as shown in right side of Fig 5.36 below.

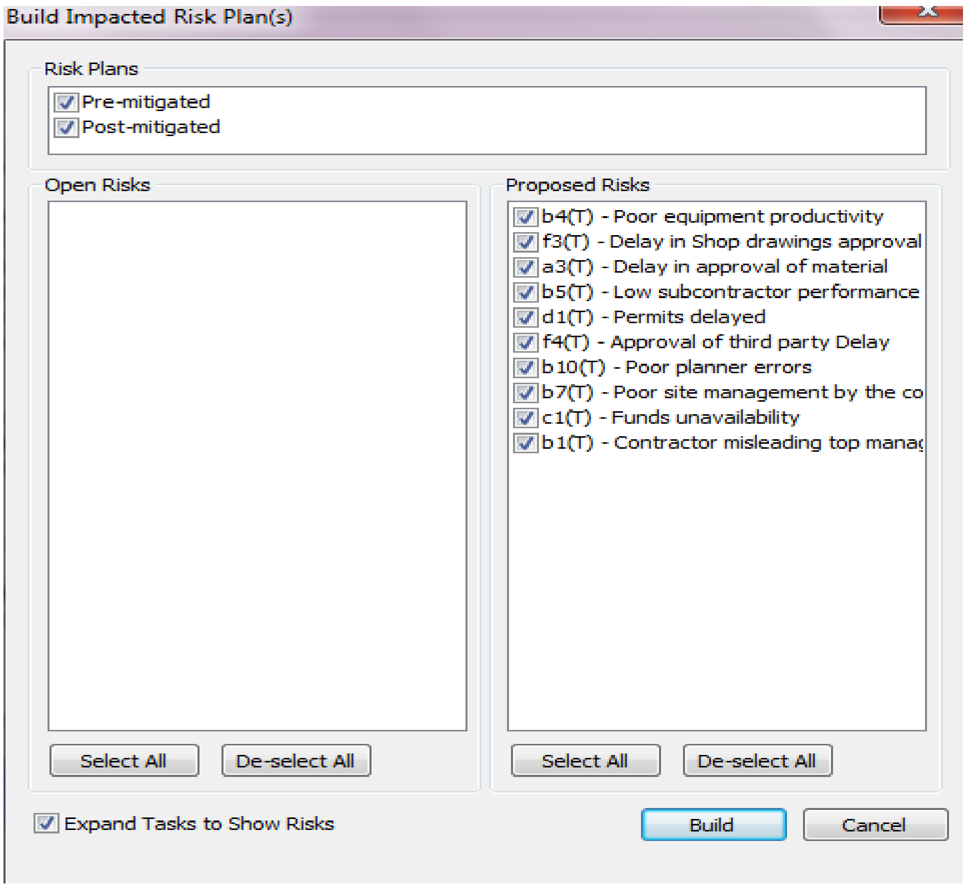


Fig 5.36 Build Impacted Risk Plan Launching

5.2.3.10 Grant Chart View after Integrating Risk Events

As illustrated in Fig 5.37 risk events will appear in the Gantt chart like activities with the main difference being a probability of occurrence less than 100% has been populated. Risk events can be quickly spotted as they will come in as highlighted red lines. Risk Event logic may look odd to a project manager or scheduler. The risk event is linked finish-start with the original or impacted activity as the predecessor. The original predecessor and successor links are moved to a risk summary bar. The linking method may create a small problem for viewing the drivers and critical path because the original activity and the risk event are not technically seen as predecessors. Only the risk summary bar will show up on the tornado chart unless some manual linking is done.

Fig 5.37 Integrated Risk Events on the Grant Chart

5.2.3.11 Pert-Master Running Simulations

5.2.3.11.1 Introduction

The next step of Pert-Master Monte Carlo analysis is running the analysis. This section will outline the steps involved in running the Monte Carlo simulations. If the project team decides to watch the analysis run, then they may be able to gather some interesting data to assist the project manager, scheduler, or risk analyst during the simulations. The simulation will highlight how often and where the critical path is changing. Filters can be applied to view how predecessor chains are rippling or disconnecting in the project. Logic views can also be shown to trace for missing or faulty links.

The scheduler can judge if the milestone or activity movement seems correct and appropriate to find flaws in the logic. As shown in Fig 5.38 running risk analysis wizard has several benefits. The analysis is made for 1000 iterations. The more the iterations made the more scenarios can be made. This allows the simulations to run between maximum and minimum range estimates of both time and cost of activities several times. Moving between the ranges several times reflects all possibilities and allows the risk analyst to check the grant chart at any iterative step.

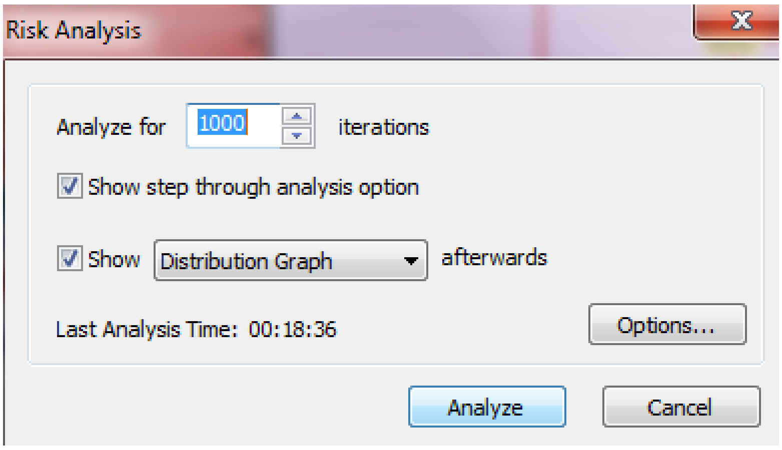


Fig 5.38 Running Risk Analysis

Run risk analysis analyze can be stopped as shown in Fig 5.39 and Fig 5.40. As represented in Fig 5.39 the first step of these iterations is shown. Taking an example on the grant chart at lay out grp pipe activity I step through first step risk fired logic runs through risk summary bar and pushes up successor. The probability 60 % reflects that the analysis probability. Fig 5.40 reflects the iterative step 34. This shows that the iterative process can be stopped and checked at any iterative step. By viewing the grant chart it is clear that the activity bar is moving between the maximum and minimum ranges.

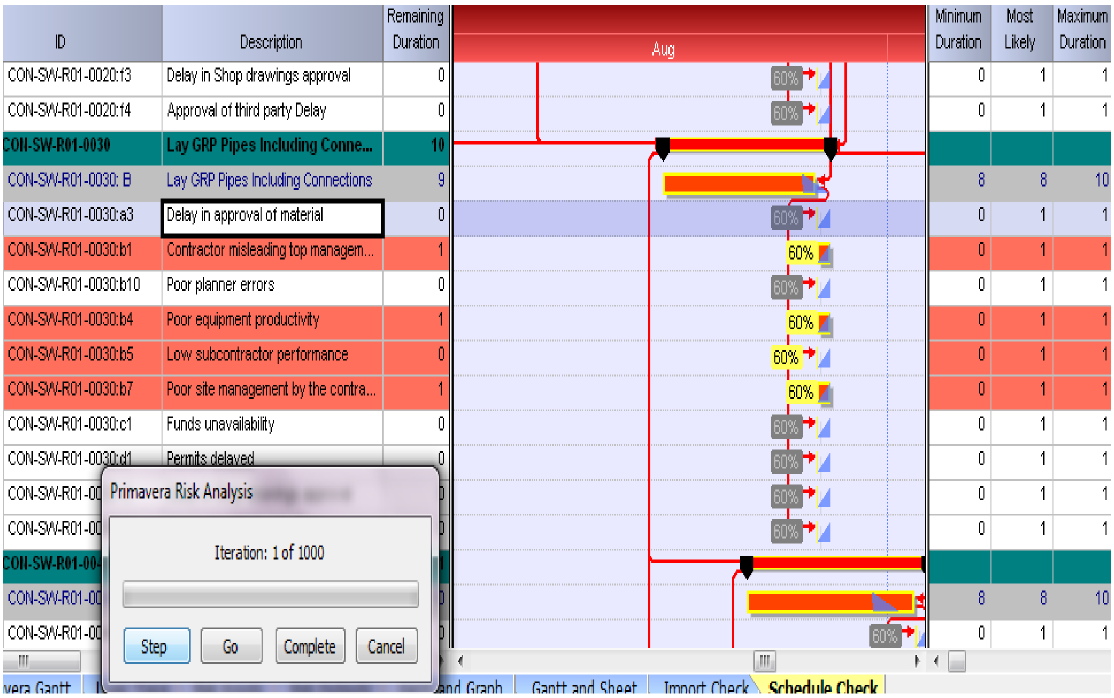


Fig 5.39 Iteration 1 of the Analysis

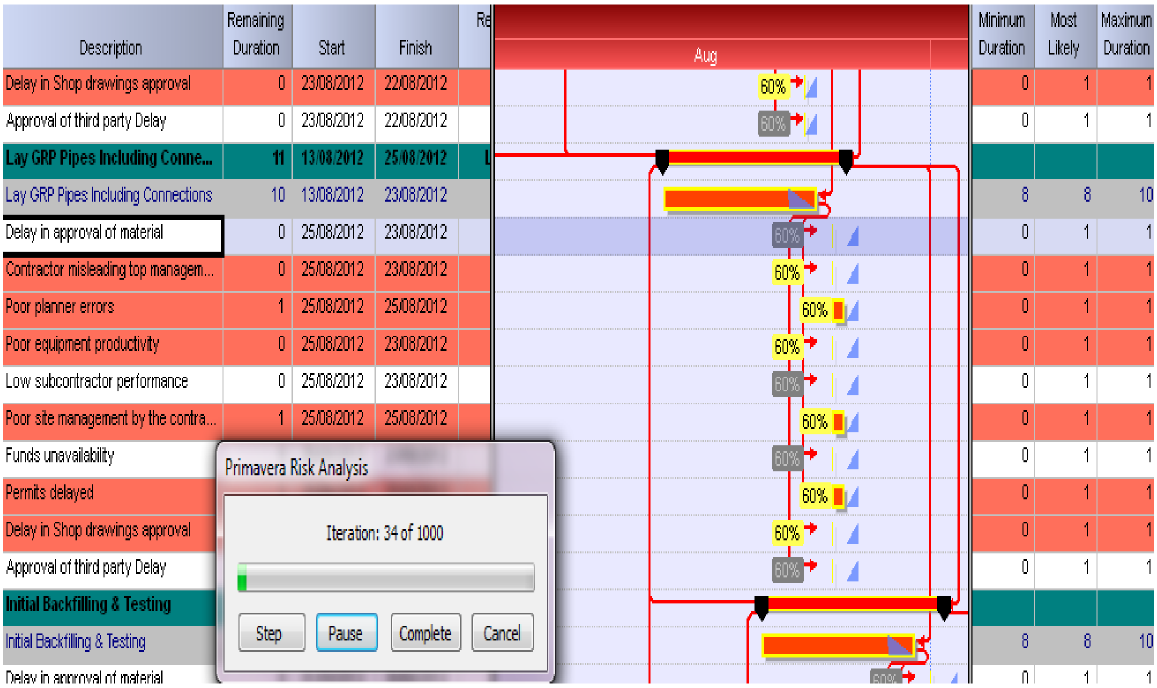


Fig 5.40 Iteration 34 of the Analysis

5.2.3.12 Pre-Mitigation Scenario Analysis

5.2.3.12.1Pre-mitigation Probability Histogram for Time

The next step of a typical Pert-Master Monte Carlo analysis is to use standard risk reports for proactive planning and project management. Fig 5.41 represents the completion of the whole works cumulative distribution histogram after linking risk factors to sewage networks in the program. This histogram is the result 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 finish date of the schedule.

The completion of whole works histogram chart in Fig 5.41 has two y-axes. The left axis corresponds to the number of hits (orange bars).The right y-axis corresponds to the cumulative curve which highlights the confidence level or percentage value. The cumulative curve does not highlight the chance of finishing on a metric, it illustrates whether the simulations finish by the metric. As the risk analyst ran 1000 simulations, then an 80 percent confidence (probability) level can be explained as the date which 800 of 1000 (80%) iterations finished on or before. During the iterative process done, the number of hits indicates the number of times at a certain probability (cumulative frequency – on the right y – axis) the finish date is date on the x- axis. When viewing the chart notice that 80% of the histogram bars is to the left of the 80% intersection mark of the cumulative curve.

The histogram bars give insight into not only the risk data but how the schedule logic and milestones are sequenced. Spikes in the histogram, gaps in the data, large standard deviation, and the data skew may highlight how the risk ranges are trending, constraints that are causing issues, problematic non-working periods. At the left of the histogram lie program activities. Each column bars (hit) represent a calendar day at the base as shown in the bottom left corner. The histogram bars will represent monetary or time ranges. A bar on the histogram chart can represent the iterations that landed in a certain day period. The bars can be changed based on user preference.

The graphical data are represented on the right of the histogram. The statistics represents the range were the hit column bars lye. This range is between 24/09/2013 till 26/10/2013 with an average of 09/10/2013 was most hits lye. The bar width is also shown in days were viewing in a different bar width is capable. The deterministic date 11/09/2013 indicates that by a probability of less than one percent the project completion of whole works can finish at this date. At 50 % probability, the project completion of whole works could be finished at 09/10/2013. At 80 % probability, the project completion of whole works could be finished at 14/10/2013. The distribution histogram allows project managers to ask about the probability to finish the whole works at a certain date. It also allows the project managers to know the date by which the whole works is completed at a proposed probability.

Tracing the tallest bar to the left, 86 times out of 1000 times hits landed on or before 9/10/2013. Different arrows at 50 % and 80 % probabilities or confidence level are set. These arrows can be placed for any confidence level suggested by an organisation. An organization would ask a risk analyst to see the date for a certain confidence level. The answer would give an organisation to get the decision whether to accept the project or not. Everything to the left of the 80 % intersection at the curve represents 80 % of the iterations. The scheduled date is that we will finish at 11/9/2013 as shown on the right bottom corner of the diagram. We have <1% of hitting this September date as shown on the right axis cumulative probability (yellow arrow). An option given by the probability distribution histogram is the highlighter which can shade and show the delta between the confidence level (80 %) and the date at which the program was scheduled. As illustrated on the highlighter in Fig 5.41 indicates that 33 days are needed if an organization needs to be 80 % confident. So we need mitigation strategies in order to meet there scope.

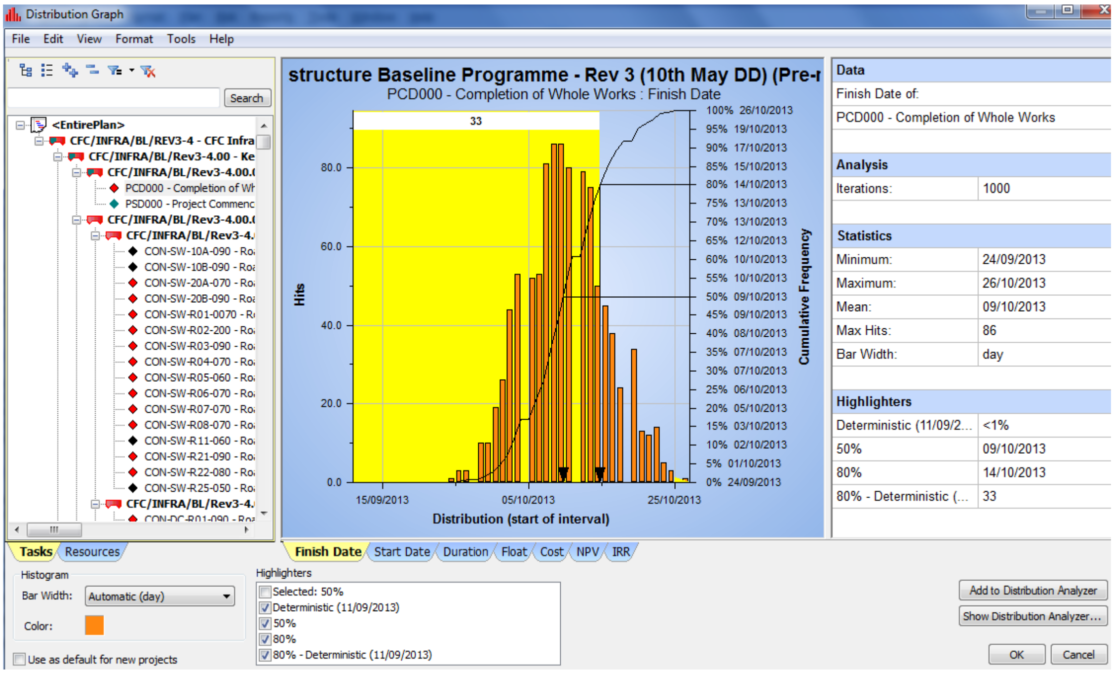


Fig 5.41 Completion of Works-Finish Date Pre-mitigation Histogram

As represented in Fig 5.42 the cumulative level histogram can be also viewed for construction of sewage manholes activity within sewage network in road 22. Risk factors were linked before during the quantitative risk register to all sewage networks activities in all roads in an infrastructure project. The finish date corresponding to a certain probability of an activity can be also viewed as it can be a project manager concern. The histogram data are represented on the right of the histogram. The statistics represents the range were the hit column bars lye. This range is between 18/08/2012 till 01/09/2012 with an average of 23/08/2012 was most hits lye.

Tracing the tallest bar to the left, 210 times out of 1000 times hits landed on or before 23/8/2012. Different arrows at 50 % and 80 % probabilities or confidence level are set. Everything to the left of the 80 % intersection at the curve represents 80 % of the iterations. The scheduled date is that we will finish at 16/8/2012 as shown on the right bottom corner of the diagram. We have <1% of hitting this September date as shown on the right axis cumulative probability (yellow arrow). An option given by the probability distribution histogram is the highlighter which can shade and show the delta between the confidence level (80 %) and the date at which the program was scheduled. As illustrated on the highlighter in Fig 5.42 indicates that10 days are needed if an organization needs to be 80 % confident. So we need mitigation strategies in order to meet there scope.

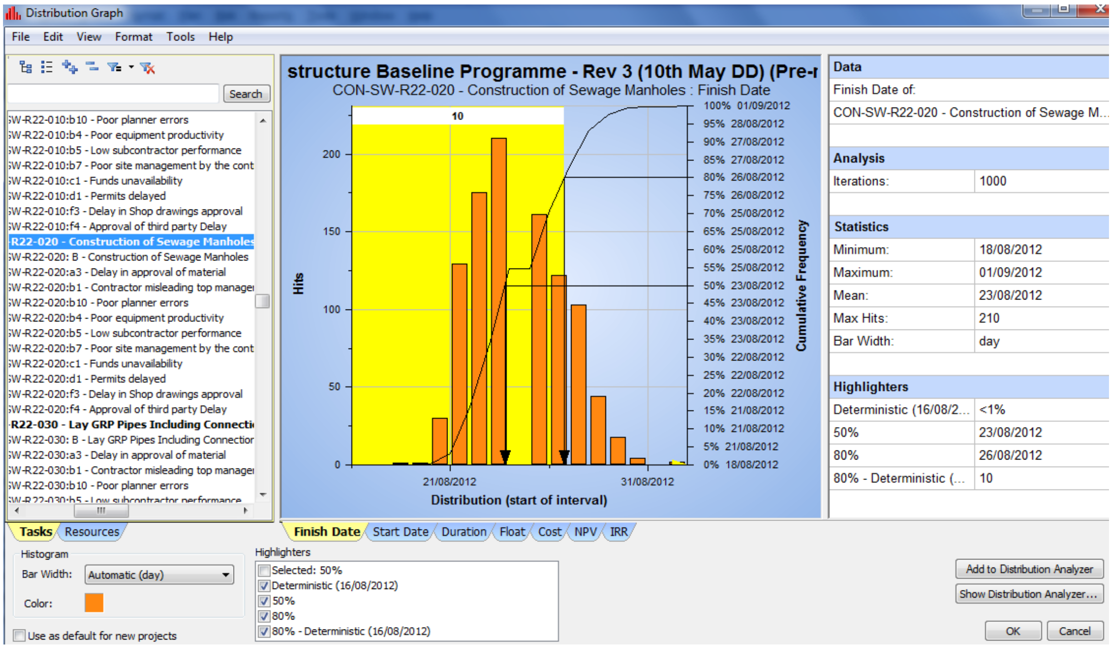


Fig 5.42 Construction of Sewage Manholes Activity Pre-mitigation Histogram

5.2.3.12.2 Pre-mitigation Probability Histogram for Cost

The completion of whole works histogram chart in Fig 5.43 has two y-axes. The left axis corresponds to the number of hits (blue bars).The right y-axis corresponds to the cumulative curve which highlights the confidence level or percentage value. The graphical data are represented on the right of the histogram. The statistics represents the cost range were the hit column bars lye. This range is between 78,588,337 L.E and 93,416,050 L.E with an average of 84,988,001 L.E were most hits lye. The bar width is also shown within 1,000,000 L.E were viewing in a different bar width is capable. The deterministic cost was 78,366,146 L.E. The histogram indicates that by a probability of less than one percent the project completion of whole works can finish by this cost. At 50 % probability, the project completion of whole works cost could be 84,899,134 L.E. At 80 % probability, the project completion cost of whole works could be 87,172,414 L.E. The distribution histogram allows project managers to know the probability to finish the whole works at a certain cost.

Tracing the tallest bar to the left, 158 times out of 1000 times the number of hits landed in between 83,899,134 L.E and 84,899,134 L.E. Different arrows at 50% and 80% probabilities or confidence level are set. These arrows can be placed for any confidence level suggested by an organisation. Everything to the left of the 80 % intersection at the curve represents 80 % of the iterations. An option given by the probability distribution histogram is the highlighter which can shade and show the delta between the confidence level (80 %) and the date at which the program was scheduled. As illustrated on the highlighter in Fig 5.43 indicates that an additional 8,806,268 L.E is needed if an organization needs to be 80 % confident. So we need mitigation strategies in order to meet there scope.

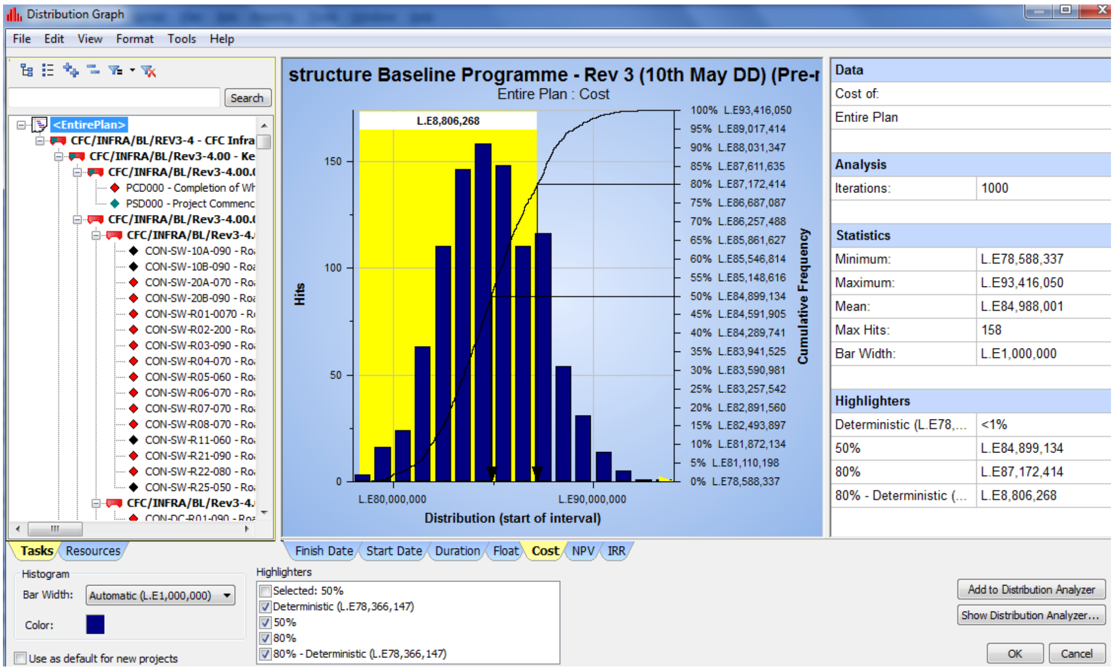


Fig 5.43 Entire Plan Cost Pre-mitigation Histogram

The construction of sewage manholes activity histogram chart in Fig 5.44 has two y-axes. The left axis corresponds to the number of hits (blue bars). The right y-axis corresponds to the cumulative curve which highlights the confidence level or percentage value. The graphical data are represented on the right of the histogram. The statistics represents the cost range were the hit column bars lye. This range is between 9,700 L.E and 128,272 L.E with an average of 62,675 L.E were most hits lye. The bar width is also shown within 10,000 L.E were viewing in a different bar width is capable. The deterministic cost was 9,701 L.E. The histogram indicates that by a probability of less than one percent the project completion of whole works can finish by this cost. At 50 % probability, the project completion of whole works cost could be 61,963 L.E. At 80 % probability, the project completion cost of whole works could be 81,093 L.E. The distribution histogram allows project managers to know the probability to finish the whole works at a certain cost.

Tracing the tallest bar to the left, 177 times out of 1000 times the number of hits landed in between 61,963 L.E and 62,963 L.E. Different arrows at 50% and 80% probabilities or confidence level are set. These arrows can be placed for any confidence level suggested by an organisation. Everything to the left of the 80 % intersection at the curve represents 80 % of the iterations. An option given by the probability distribution histogram is the highlighter which can shade and show the delta between the confidence level (80 %) and the date at which the program was scheduled. As illustrated on the highlighter in Fig 5.44 indicates that an additional 71,392 L.E is needed if an organization needs to be 80 % confident. So we need mitigation strategies in order to meet there scope.

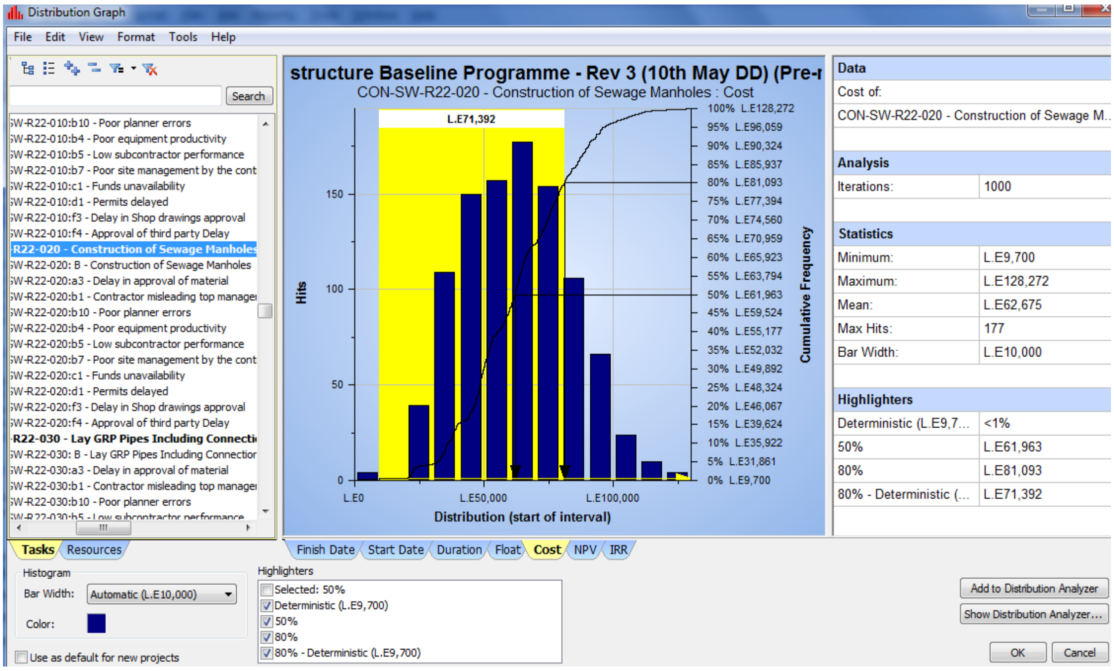


Fig 5.44Construction of Sewage Manholes Cost Pre-mitigation Histogram

5.2.3.12.3Pert-Master Tornado Chart Report

5.2.3.12.3.1Duration Sensitivity Duration Tornado Chart

This report will focus on generating and successfully presenting the tornado chart for project drivers. As shown in Fig 5.45 duration sensitivity bars represents logical predecessors driving the infrastructure project completion of whole works. The program will look at two tasks, the completion of whole works and each of the predecessor driving activities listed at the left of the tornado bars in Fig 45 below. The program will calculate the correlation of their duration. If each time the driver increases in duration, the duration to the milestone increases, then the correlation percentage is high. At the right side of the completion of whole works tornado diagram lays a list of tornado diagram data. These data include the definition of duration sensitivity, the analysis data and description of the sensitivity correlation.

The duration sensitivity defined by the program states that the duration sensitivity of a task is a measure of the correlation between it and the duration (or dates) of the project (or a key task or summary). The analysis data reminds the risk analyst that 1000 iterations are carried out to obtain the logical predecessors of the project completion work. The sensitivity calculations prove that the numbers beside the tornado bars represent the correlation. This correlation is between both the start date of the project completion of the whole work and the duration of its logical predecessors. These sensitivity calculations are done according to Pearson's product moment theory.

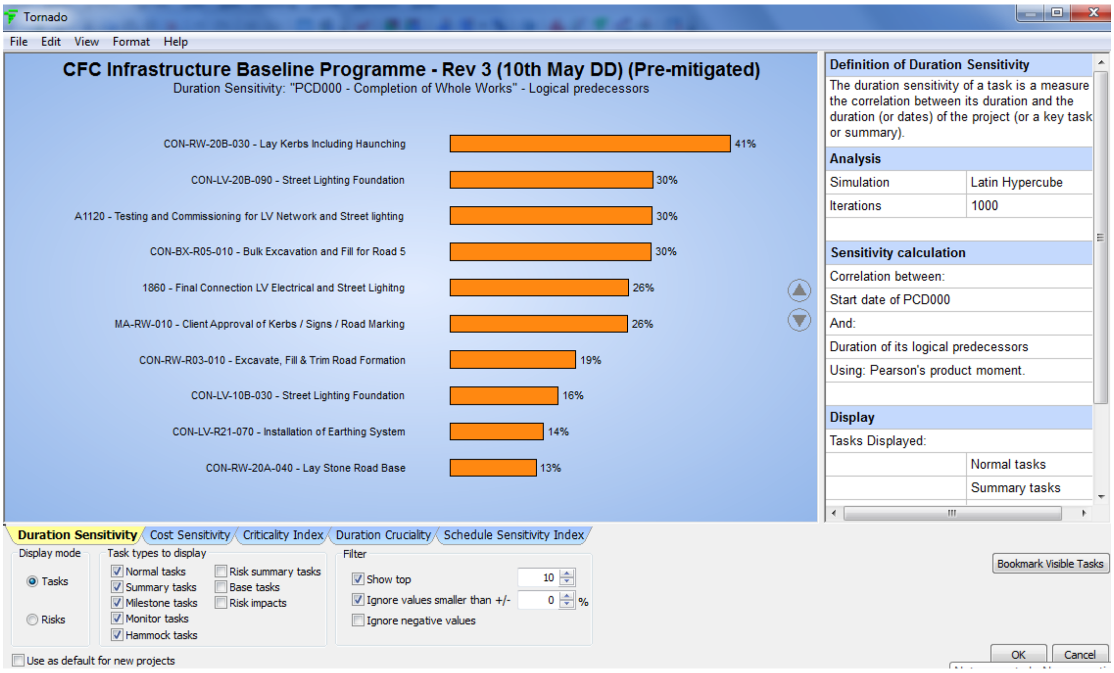


Fig 5.45 Duration Sensitivity Tornado Chart

5.2.3.12.3.1.1 Pearson's product moment theory

In statistics, the Pearson product-moment correlation coefficient (sometimes referred to as the PPMCC or PCC,[1] or Pearson's r, and is typically denoted by r) is a measure of the correlation (linear dependence) between two variables X and Y, giving a value between +1 and −1 inclusive . It is widely used in the sciences as a measure of the strength of linear dependence between two variables. It was developed by Karl Pearson from a similar but slightly different idea introduced by Francis Galton in the 1880s.

Pearson's correlation coefficient between two variables is defined as the covariance of the two variables divided by the product of their standard deviations. The form of the definition involves a "product moment", that is, the mean (the first moment about the origin) of the product of the mean-adjusted random variables; hence the modifier product-moment in the name. It is the most commonly used method of computing a correlation coefficient between variables that are linearly related.

5.2.3.12.3.2 Criticality Index Tornado Chart

As represented in Fig 5.46 critical activities which carry risk events is in red on the tornado chart. The criticality metric simply shows the percentage of iterations or simulations that an activity was on the critical path. Thus, these activities represent the critical activities were risk factors linked to them. If a risk analyst is reporting to a milestone or activity that is off the critical path, then the key drivers may show as 0% critical. The attempt of this chart is to show not only if the activity is a driver to a reporting milestone or activity, but whether it is on the overall network critical path. The numbers on the criticality chart are the number of iterations that an activity was on the critical path.

A project manager may highlight these critical activities as being the most critical project drivers as it has the greatest impact on the project completion. On the left hand side of Fig 5.46 critical activities drivers which are logical predecessors of the project completion work are represented. After carrying a simulation of 1000 iterations these are the most driving critical activities. List of tornado data is represented at the right of the project completion work tornado diagram. These data include definition of criticality index, analysis and calculation values description. The definition of criticality index by the Pert-Master program is the proportion of the iterations in which it was critical. The analysis result describes that the simulation is Latin Hypercube and that 1000 iteration were carried. The values beside the tornado bars are calculated for logical predecessors of the project completion of whole works.

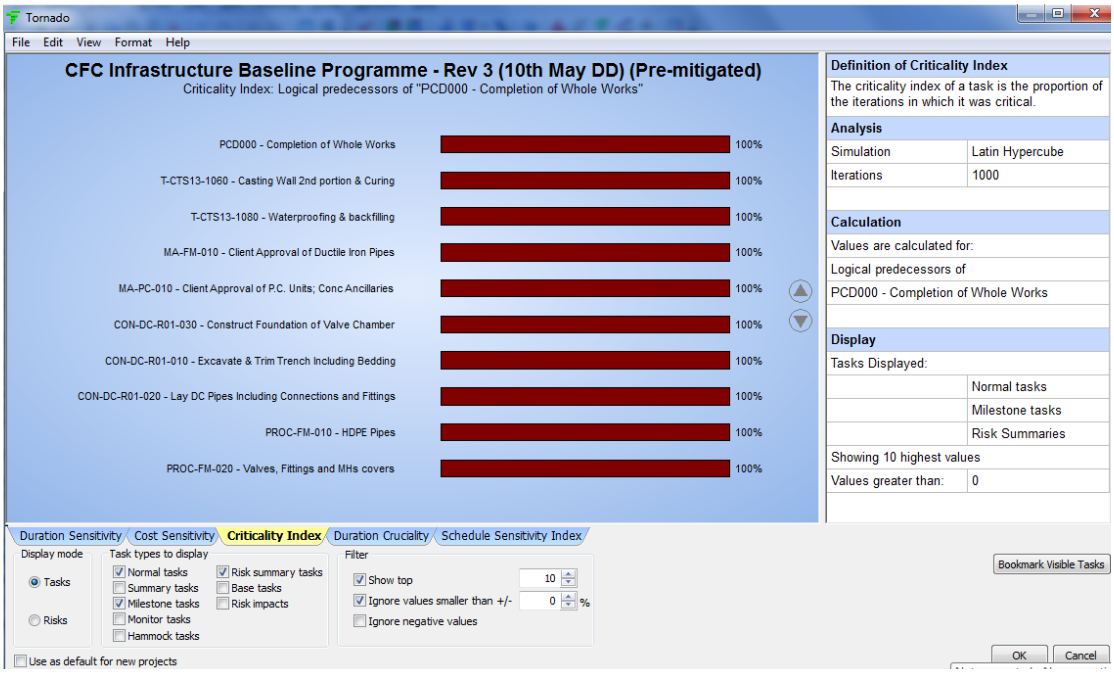


Fig 5.46 Criticality Index Tornado Chart

5.2.3.12.3.3 Cost Sensitivity Tornado Chart

The Per-Master program offers different display views. Either by representing the Tornado Diagram in terms of activity bars as above tornado or in terms of risk events. In this Tornado diagram the cost sensitivity is displayed in terms of risk factors. In this manner the highest risk factors or drivers which might affect the cost of project completion of whole works is represented. The previous Tornado Diagrams are used within the task mode. This will show a tornado chart of all activities and risk events. On the other hand risk mode used for cost sensitivity will show a tornado chart of risk events only.

Fig 5.47 represents a list of cost sensitivity tornado data is represented at the right of the project completion work tornado diagram. These data include, definition of cost sensitivity, analysis and sensitivity calculation values description. The definition of cost sensitivity by the Pert-Master program is a measure of the correlation between the occurrence of any of its impacts and the cost of the project (or a key task).

The analysis result in Fig 5.46 describes that the simulation is Latin Hypercube and that 1000 iteration were carried. The sensitivity calculation value beside the tornado bar is a correlation between cost of entire plan and existence of each risk. These values were calculated based on Pearson's product moment theory (Pearson's theory was described in this chapter). The numbers on the duration and cost sensitivity chart are a correlation metric. It shows how strong the correlation is between to activities to predict if one activity is driving the other. The previously made histogram told you where you are at. The tornado is telling you how to fix it. Use the data to run scenarios. The purpose of the analysis is to give proactive information to improve the probability of project success.

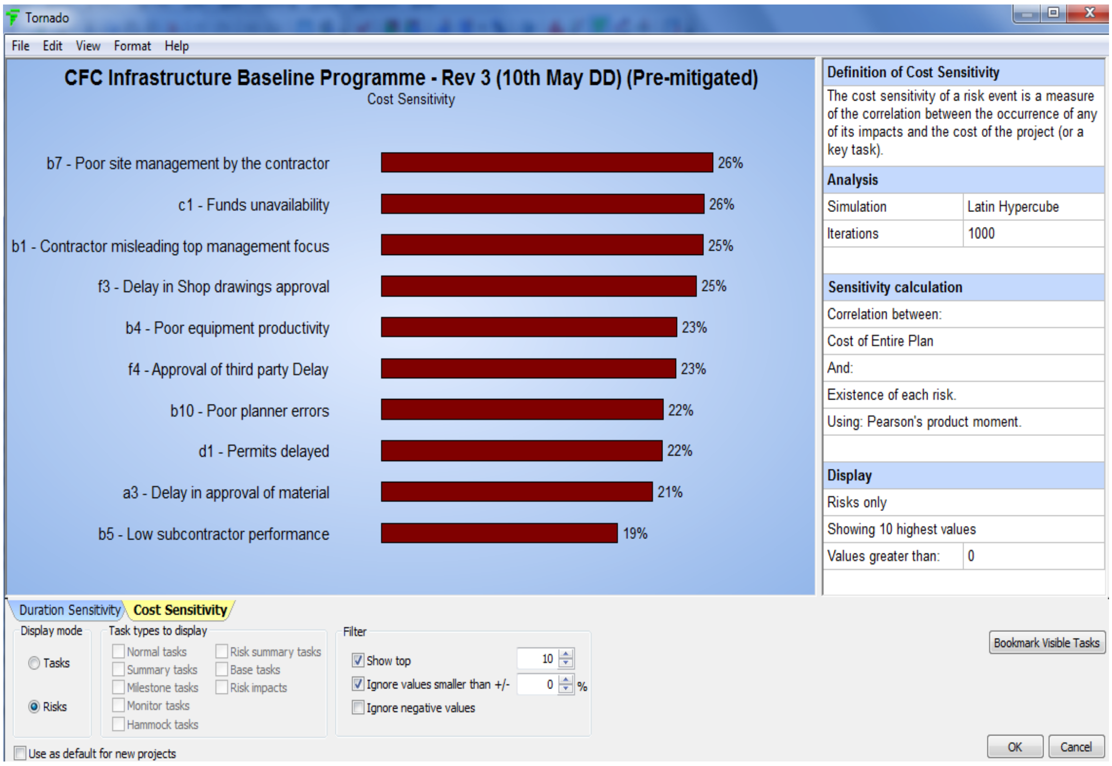


Fig 5.47 Cost Sensitivity Tornado Chart

5.2.3.13 Post-Mitigation Scenario Analysis

5.2.3.13.1 Introduction

The risk response plan was made including two scenarios both the pre-mitigation and the post-mitigation scenarios. The risk analysis made obtaining the cumulative histogram charts and tornado diagrams was made for the pre-mitigation scenario. The pre-mitigation scenario includes linking risk factors implemented in the risk register to the program but without suggesting and implementing any mitigation actions. The second scenario built in this risk analysis chapter is the post-mitigation scenario. After implementing the mitigation actions into the risk register, then linking risk factors to the schedule followed by implementing risk plan the post-mitigation scenario is now ready for carrying analysis on it.

The post-mitigation scenario thus includes risk factors implemented with mitigation actions and modified suggested post-mitigation scales by the risk response questionnaire participants. Thus the risk analysis result for the post-mitigation scenarios will differ than that results obtained from the pre-mitigation scenario modeling by another means. As suggested by the participants in the risk response questionnaires the impact scales of risk factors on linked program activities is changed either by reduction to a lower impact scale or remaining the same . For this reason, the risk analysis result in case of post-mitigation scenario for the tornado diagrams is changed. The logical predecessors or risk drivers of project finish completion all works will have lower contingency thus they is less capability in affecting the completion time and cost .This is clear also for the criticality risk drivers were the project manager may benefit from this.

A risk analyst by implementing mitigation actions and carrying out these post-mitigation risk analysis may benefit the project manager by giving him more than one scenario for reducing the impact of these risk factors if they do occur .On the other hand the probabilities of occurrence of these prioritized risk factors will not be changed . This is because the risk factors probability of occurrence scales suggested in the qualitative risk analysis stage by the participants. The participants agree that these probabilities scales will not be reduced as these risk factors are most probable to occur. For this reason the histogram results will not be changed in the post-mitigation scenario risk analysis results.

5.2.3.13.2 Post-mitigation Probability Histogram for Time

The completion of whole works histogram chart in Fig 5.48 has two y-axes. The left axis corresponds to the number of hits (orange bars).The right y-axis corresponds to the cumulative curve which highlights the confidence level or percentage value. The histogram bars give insight into not only the risk data but how the schedule logic and milestones are sequenced.

Spikes in the histogram, gaps in the data, large standard deviation, and the data skew may highlight how the risk ranges are trending, constraints that are causing issues, problematic non-working periods. At the left of the histogram lie program activities. Each column bars (hit) represent a calendar day at the base as shown in the bottom left corner. The histogram bars will represent monetary or time ranges. A bar on the histogram chart can represent the iterations that landed in a certain day period. The bars can be changed based on user preference.

The graphical data are represented on the right of the histogram. The statistics represents the range were the hit column bars lye. This range is between 25/09/2013 till 26/10/2013 with an average of 09/10/2013 was most hits lye. The bar width is also shown in days were viewing in a different bar width is capable. The deterministic date 11/09/2013 indicates that by a probability of less than one percent the project completion of whole works can finish at this date. At 50 % probability, the project completion of whole works could be finished at 09/10/2013. At 80 % probability, the project completion of whole works could be finished at 14/10/2013. The distribution histogram allows project managers to ask about the probability to finish the whole works at a certain date. It also allows the project managers to know the date by which the whole works is completed at a proposed probability.

Tracing the tallest bar to the left, 83 times out of 1000 times hits landed on or before 9/10/2013. Different arrows at 50 % and 80 % probabilities or confidence level are set. These arrows can be placed for any confidence level suggested by an organisation. Everything to the left of the 80 % intersection at the curve represents 80 % of the iterations. The scheduled date is that we will finish at 11/9/2013 as shown on the right bottom corner of the diagram. We have less than 1% of hitting this September date as shown on the right axis cumulative probability (yellow arrow). An option given by the probability distribution histogram is the highlighter which can shade and show the delta between the confidence level (80 %) and the date at which the program was scheduled. As illustrated on the highlighter in Fig 5.48 indicates that 33 days are needed if an organization needs to be 80 % confident. So we need mitigation strategies in order to meet there scope.

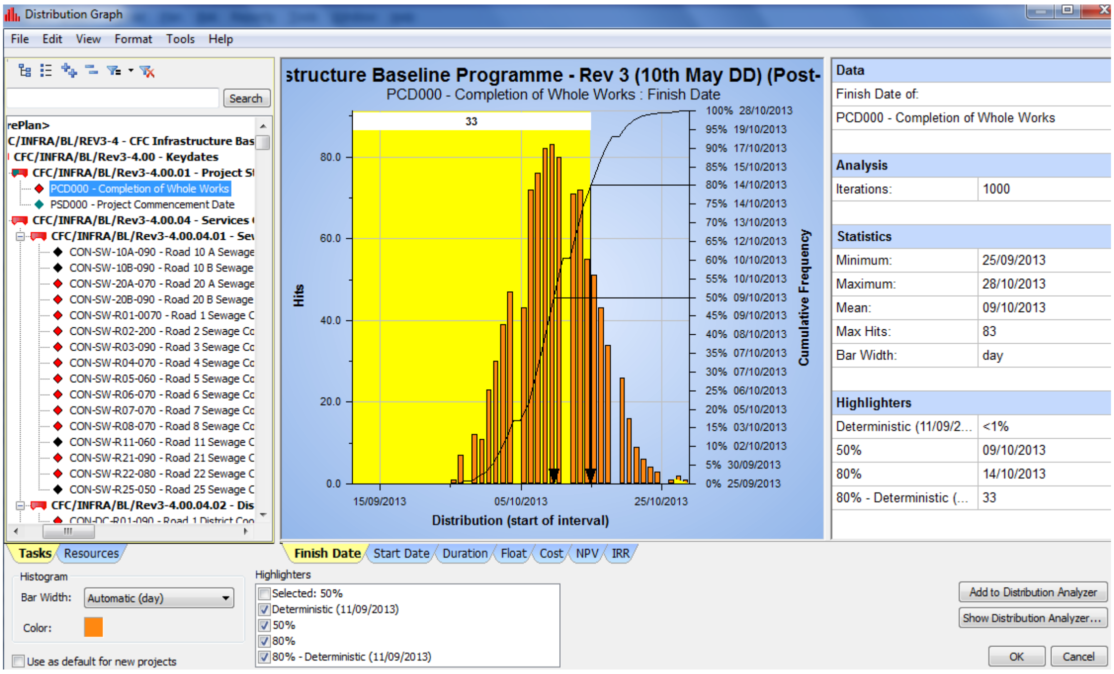


Fig 5.48 Completion of Works-Finish Date Post-mitigation Histogram

As represented in Fig 5.49 the cumulative level histogram can be also viewed for construction of sewage manholes activity within sewage network in road 22. Risk factors were linked before during the quantitative risk register to all sewage networks activities in all roads in an infrastructure project. The finish date corresponding to a certain probability of an activity can be also viewed as it can be a project manager concern. The histogram data are represented on the right of the histogram. The statistics represents the range were the hit column bars lye. This range is between 15/08/2012 till 01/09/2012 with an average of 23/08/2012 was most hits lye.

Tracing the tallest bar to the left, 202 times out of 1000 times hits landed on or before 23/8/2012. Different arrows at 50 % and 80 % probabilities or confidence level are set. Everything to the left of the 80 % intersection at the curve represents 80 % of the iterations. The scheduled date is that we will finish at 16/8/2012 as shown on the right bottom corner of the diagram. We have less than 1% of hitting this September date as shown on the right axis cumulative probability (yellow arrow). An option given by the probability distribution histogram is the highlighter which can shade and show the delta between the confidence level (80 %) and the date at which the program was scheduled. As illustrated on the highlighter in Fig 5.49 indicates that10 days are needed if an organization needs to be 80 % confident. So we need mitigation strategies in order to meet there scope.

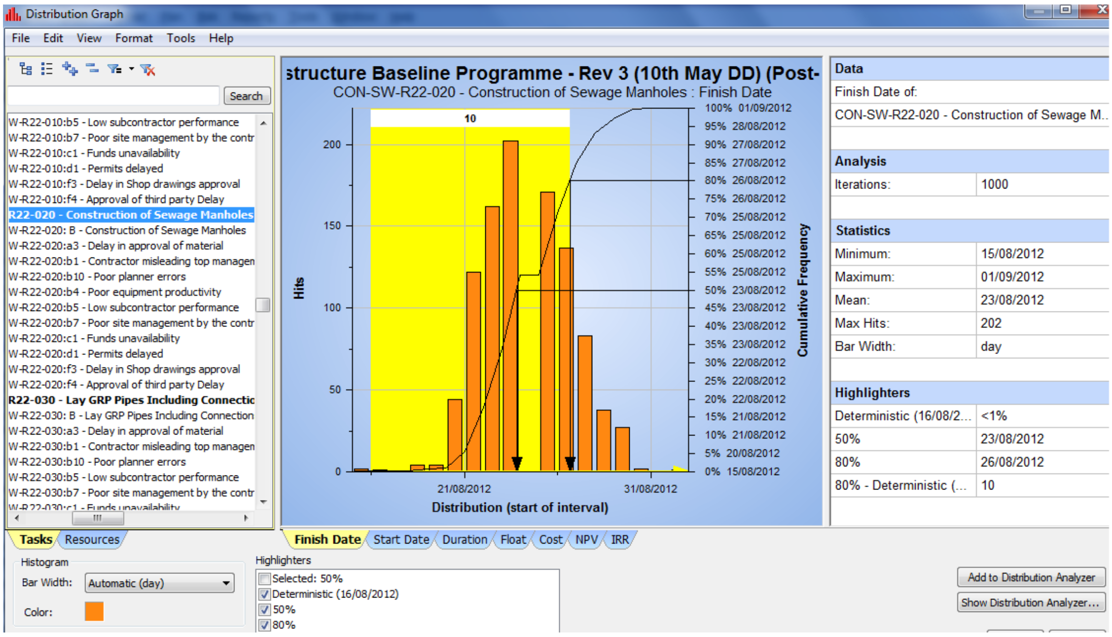


Fig 5.49 Construction of Sewage Manholes Activity Post-mitigation Histogram

5.2.3.13.3Post-mitigation Probability Histogram for Cost

The completion of whole works histogram chart in Fig 5.50 has two y-axes. The left axis corresponds to the number of hits (blue bars).The right y-axis corresponds to the cumulative curve which highlights the confidence level or percentage value. The graphical data are represented on the right of the histogram. The statistics represents the cost range were the hit column bars lye. This range is between 78,385,202L.E and 85,529,801L.E with an average of 81,349,220L.E were most hits lye. The bar width is also shown within 1,000,000L.E were viewing in a different bar width is capable. The deterministic cost was 78,366,146L.E. The histogram indicates that by a probability of less than one percent the project completion of whole works can finish by this cost. At 50 % probability, the project completion of whole works cost could be 81,283,803L.E. At 80 % probability, the project completion cost of whole works could be 82,303,825L.E. The distribution histogram allows project managers to know the probability to finish the whole works at a certain cost.

Tracing the tallest bar to the left, 317 times out of 1000 times the number of hits landed in between 81,283,803L.E and 82,283,803L.E. Different arrows at 50% and 80% probabilities or confidence level are set. These arrows can be placed for any confidence level suggested by an organisation. Everything to the left of the 80 % intersection at the curve represents 80 % of the iterations. An option given by the probability distribution histogram is the highlighter which can shade and show the delta between the confidence level (80 %) and the date at which the program was scheduled. As illustrated on the highlighter in Fig 5.50 indicates that an additional 3,937,678 L.E is needed if an organization needs to be 80 % confident. So we need mitigation strategies in order to meet there scope.

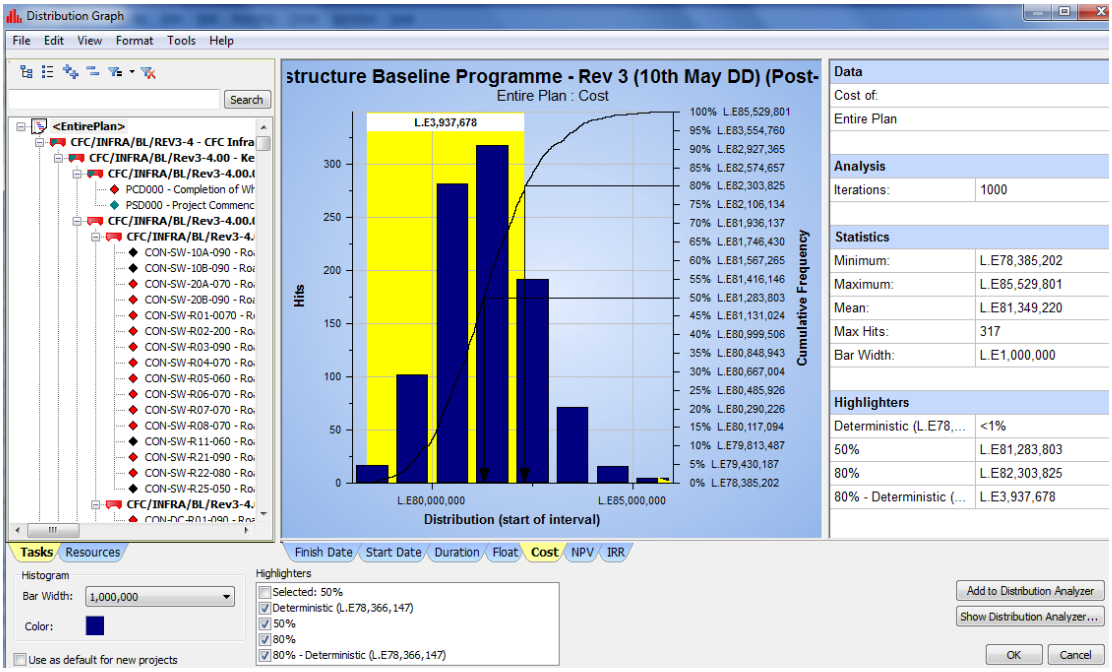


Fig 5.50 Entire Plan Cost Post-mitigation Histogram

The construction of sewage manholes activity histogram chart in Fig 5.51 has two y-axes. The left axis corresponds to the number of hits (blue bars). The right y-axis corresponds to the cumulative curve which highlights the confidence level or percentage value. The graphical data are represented on the right of the histogram. The statistics represents the cost range were the hit column bars lye. This range is between 9,700L.E and 63,328L.E with an average of 29,543L.E were most hits lye. The bar width is also shown within 10,000L.E were viewing in a different bar width is capable. The deterministic cost was 9,701L.E. The histogram indicates that by a probability of less than one percent the project completion of whole works can finish by this cost. At 50 % probability, the project completion of whole works cost could be 30,320L.E. At 80 % probability, the project completion cost of whole works could be 38,486L.E. The distribution histogram allows project managers to know the probability to finish the whole works at a certain cost.

Tracing the tallest bar to the left, 377times out of 1000times the number of hits landed in between 30,300L.E and 40,300L.E. Different arrows at 50% and 80% probabilities or confidence level are set. These arrows can be placed for any confidence level suggested by an organisation. Everything to the left of the 80% intersection at the curve represents 80% of the iterations. An option given by the probability distribution histogram is the highlighter which can shade and show the delta between the confidence level (80%) and the date at which the program was scheduled. As illustrated on the highlighter in Fig 5.51 indicates that an additional 28,786L.E is needed if an organization needs to be 80% confident. So we need mitigation strategies in order to meet there scope.

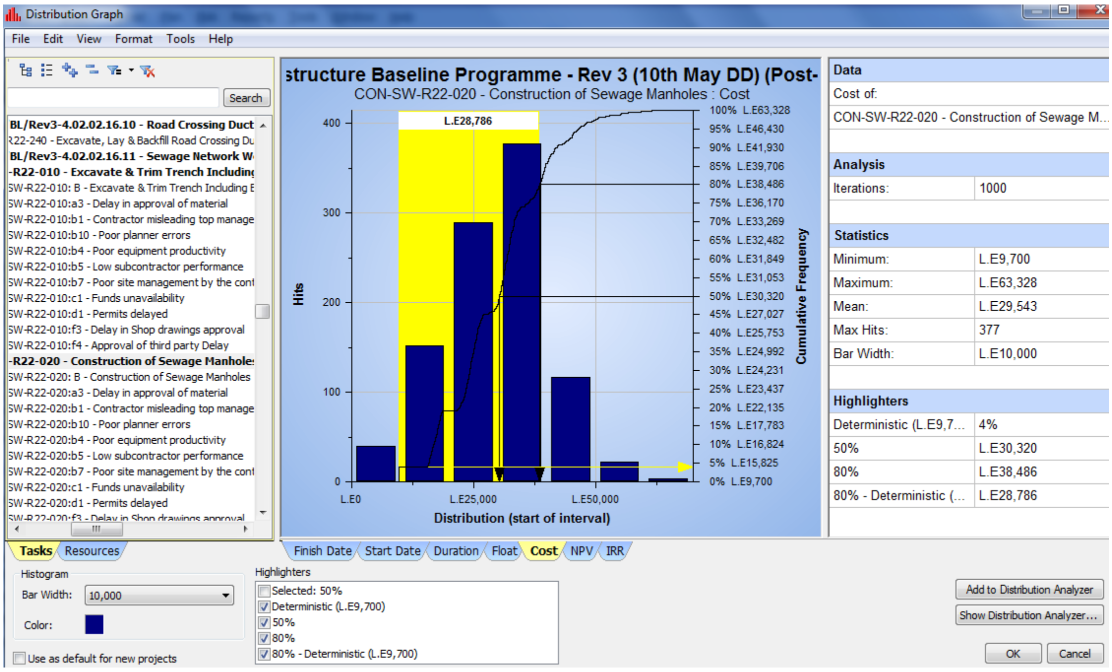


Fig 5.51 Construction of Sewage Manholes Cost Post-mitigation Histogram

5.2.3.13.4 Duration Sensitivity Tornado Diagrams

Before viewing risk analysis Tornado Diagrams report, risk analysis run should be made. Running risk analysis is made for also 1000 iterations in order to take all possible scenarios between the maximum and minimum ranges of each activity in the schedule. Fig 5.52 represents the Tornado Diagram for the duration sensitivity for project completion of all works. On the left hand side of the diagram lays the logical predecessors or the risk drivers of the project completion date. These risk drivers are represented on bars were they are the highest ten predecessors which can have an impact on the project completion of whole work cost and time.

A risk analyst should take a corrective action when he knows that according to the placed schedule dates and according to the Tornado Diagram results that the highest driving predecessor which could impact the project completion works time and cost is bulk excavation and fill for road 5 activity. This indicates that the program should be fixed with aid of site meetings to modify any misleading durations. The represented risk drivers are the highest 10 drivers in the schedule which might impact the project completion work. On the right hand side of Fig 5.52 the Tornado data are represented. This data includes the definition of duration sensitivity. Analysis is made using Latin hypercube simulation after 1000 iterations. Also the data represented gives indication that the numbers beside the risk drivers bars represent the correlation between the start date of the project completion of whole works and the duration of its logical predecessors using Pearson's product moment.

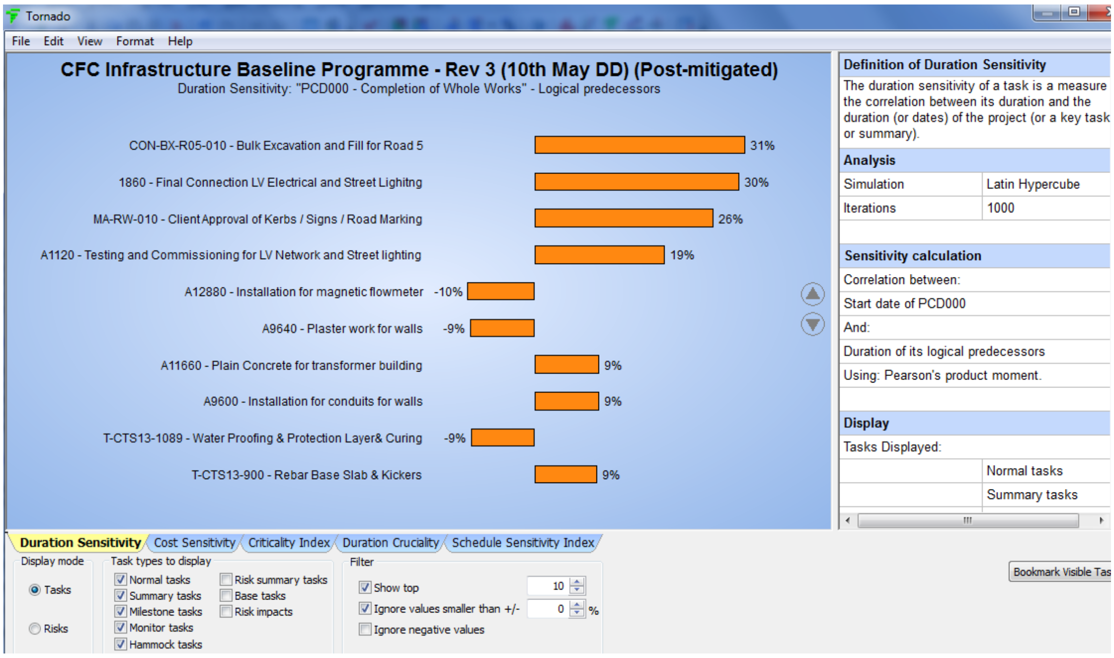


Fig5.52 Duration Sensitivity Tornado Diagram

5.2.3.13.5Criticality Index Tornado Chart

As represented in Fig 5.53 critical activities which carry risk events is in red on the tornado chart. The criticality metric simply shows the percentage of iterations or simulations that an activity was on the critical path. Thus, these activities represent the critical activities were risk factors linked to them. If a risk analyst is reporting to a milestone or activity that is off the critical path, then the key drivers may show as 0% critical. The attempt of this chart is to show not only if the activity is a driver to a reporting milestone or activity, but whether it is on the overall network critical path. The numbers on the criticality chart are the number of iterations that an activity was on the critical path.

A project manager may highlight these critical activities as being the most critical project drivers as it has the greatest impact on the project completion. On the left hand side of Fig 5.53 critical activities drivers which are logical predecessors of the project completion work are represented. After carrying a simulation of 1000 iterations these are the most driving critical activities. List of tornado data is represented at the right of the project completion work tornado diagram. These data include definition of criticality index, analysis and calculation values description. The definition of criticality index by the Pert-Master program is the proportion of the iterations in which it was critical. The analysis result describes that the simulation is Latin Hypercube and that 1000 iteration were carried. The values beside the tornado bars are calculated for logical predecessors of the project completion of whole works.

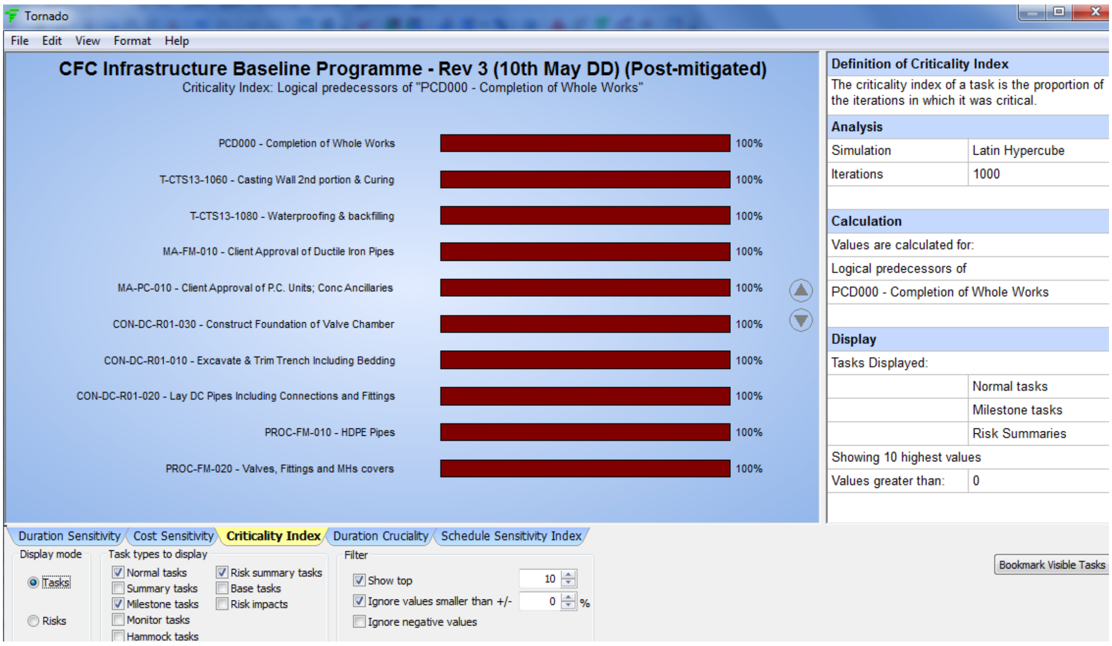


Fig 5.53 Criticality Index Tornado Chart

5.2.3.13.6 Cost Sensitivity Tornado Chart

At the right of the project completion work tornado diagram in Fig 5.54. These data include, definition of cost sensitivity, analysis and sensitivity calculation values description. The definition of cost sensitivity by the Pert-Master program is a measure of the correlation between the occurrence of any of its impacts and the cost of the project (or a key task). The sensitivity calculation value beside the tornado bar is a correlation between cost of entire plan and existence of each risk. The represented risk drivers are the highest 10 drivers in the schedule which might impact the project completion work. The highest risk factors driving an increase in the cost of completion of the project are represented. The highest risk factor affecting completion cost is Poor Equipment Productivity. For this reason the Tornado Diagram is changed in the post-mitigation scenario than that in the pre-mitigation scenario. Thus risk drivers or logical predecessors obtained will have lower risk correlation results.

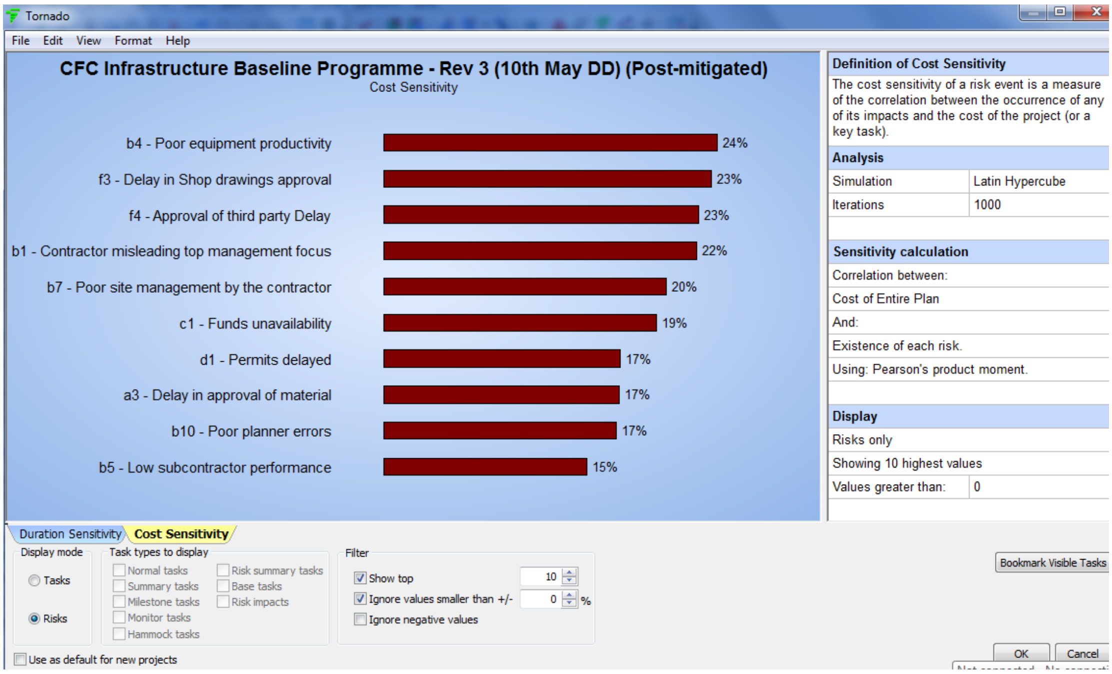


Fig 5.54 Cost Sensitivity Tornado Chart

5.2.3.14 Pre-mitigation and Post-mitigation Results Comparison

The quantitative risk analysis will use Monte Carlo analysis simulation to build up a cumulative probability histogram. This histogram will assist the organization to carry out the project or not. It will highlight the required time and cost to reach a confident level. The Pert-Master tool is used to illustrate the sensitivity analysis tornado chart. The tornado charts will reflect the logical predecessors or drivers of a certain variable or task. This chart will give an organization activities of most driving for cost and time for a certain variable. Pearson's statistical model may be used for calculating the correlation between two variables which can be linearly related was the base of ranking the risk drivers. A risk analyst can realize the entering mitigation actions and concentrating on obtaining reasonable durations and costs for project completion drivers.

Pre-mitigation analysis results will analyze the prioritized risk factors prior to inserting any mitigation actions. Post-mitigation analysis results will analyze the prioritized risk factors after inserting mitigation actions. Mitigation actions are implemented based on a field questionnaire. Fifty participants gave their opinions about adding mitigations to improve the qualitative impact scales. Two scenarios is analyzed in this study, the Pre-mitigation and Post-mitigation scenarios. Two results were obtained for each scenario. Confidence Level Histogram and Tornado Charts results are compared prior and after implementing mitigations.

The cumulative confidence level histogram is carried out for both cost and time objectives. The cumulative distribution for time is carried for the completion of whole works and construction of sewage manhole activity. The histogram will reflect several criteria including hit column bars date range, hit column average date, deterministic date, date of 50% confidence, date of 80% confidence, maximum no. of hits, duration for maximum no. of hits and needed days of 80% confident. It is evident that no realized changes in probability results for time objective between pre-mitigation and post-mitigation results.

Statistical results for the completion of whole work histogram of time objective is discussed. The completion period is from 24/09/2013 to 26/10/2013 and the average completion date is on 09/10/2013 which shows the most iteration hits lye. The bar width is shown in days and can be viewed in different manners. At 50% probability, the project completion of whole works may be finished at 09/10/2013. At 80% probability, the project completion of whole works may be finished at 14/10/2013. The distribution histogram will allow project managers to ask about the probability to finish the whole works at a certain time. It also may allow the project managers to know the time by which the whole works is completed at a proposed probability.

By tracing the tallest bar to the left, 86 times out of 1000 times hits the bar will land on or before 9/10/2013. The scheduled date will show the completion date on 11/09/2013 as shown on the right bottom corner of the diagram. We have less than 1% of hitting this September date as shown on the right axis cumulative probability (yellow arrow). An option shown by the probability distribution histogram is the highlighter which shaded the delta between the confidence level (80 %) and the date at which the program is scheduled. Thirty three days is required if an organization needs to be 80% confident. That mean we need mitigation strategies in order to meet there scope.

Comparing the cumulative distribution for cost is also done for the completion of whole works and the construction of sewage manhole activity. The histogram will reflect several criteria including hit column bars cost range, hit column average cost, deterministic cost, amount needed to be 50% confidence, amount needed to be 80% confidence, maximum no. of hits, cost for maximum no. of hits and needed days to be 80% confident. It is clear that no realized change will occur in probability results for time objective unlike cost confidence level histogram. The difference is clear for cost objective in several criteria's.

Starting with the completion of whole works cost histogram. Before implementing mitigation actions Bars Cost Range is between 78,588,337L.E and 93,416,050L.E. After implementing mitigations Hit Column Bars Cost Range is between 78,385,202L.E and 85,529,801L.E, this means that the range between the minimum and maximum completion cost is reduced by an amount of 203,135L.E to 7,886,249L.E. This reduction is due to implementing corrective actions. The average cost is most of the number of hits lied is reduced from 84,988,001 L.E to 81,349,220L.E with a reduction amount of 3,638,781L.E.

The cost which can make an organization 50% confident prior implementing mitigations was 84,899,134 L.E this cost have been reduced to 81,283,803L.E for after mitigations are implemented. The cost which can make an organization 80% confident prior implementing mitigations was 87,172,414 L.E this cost have been reduced to 82,303,825 L.E after mitigations are implemented. It is clear that the deterministic or budget cost previously set at a cost of 78,366,146L.E. As illustrated in the results this value will not be changed for both scenarios. Despite that, the deterministic cost is used as a base of comparison. This is met by comparing this amount with the cost which could make an organization to be 80% confident. Prior implementing mitigation actions, 8,806,268L.E was the amount needed in order to keep an organization 80% confident. This value was reduced to 3,937,678L.E with a reduction of 4,868,590L.E after mitigation actions are implemented. This value represents the delta between the deterministic cost and the 80% confidence level required to meet by an organization.

For the pre-mitigation scenario the maximum number of hits made was 158hits out of 1000 iterations carried. The cost corresponding to 158hits was between 83,899,134L.E and 84,899,134L.E. The maximum number of hits made for post-mitigation scenario was 317 hits out of 1000 iterations carried. The cost corresponding to 317hits was between 81,283,803L.E and 82,283,803L.E. Reduction in the value of the cost corresponding to the maximum number of hits proves that implementing mitigation actions has a great effect as an efficient step of risk management.

The second confidence level histogram made was for constructing sewage manholes activity in road 22. Before implementing mitigation actions Hit Column Bars Cost Range was between 9,700L.E and 128,272L.E. After implementing mitigations Hit Column Bars Cost Range became between 9,700L.E and 63,328L.E. This means that the range between the minimum and maximum completion cost have been reduced. This reduction was due to implementing corrective actions. The average cost was most of the no. of hits lied was thus reduced from 62,675L.E to 29,543L.E after implementing mitigation actions.

The cost which can make an organization 50% confident prior implementing mitigations was 61,963L.Ethis cost have been reduced to 30,320L.Efor after mitigations are implemented. The cost which can make an organization 80% confident prior implementing mitigations was 81,093L.Ethis cost have been reduced to 38,486L.Eafter mitigations are implemented. It is clear that the deterministic or budget cost previously set at a cost of 9,701L.E. As illustrated in the results this value will not be changed for both scenarios. Despite that, the deterministic cost is used as a base of comparison. This is met by comparing this amount with the cost which could make an organization to be 80% confident. Prior implementing mitigation actions, 71,392L.Ewas the amount needed in order to keep an organization 80% confident. This value was reduced to 28,786L.Ewith a reduction of 42,606L.E after mitigation actions are implemented. This value represents the delta between the deterministic cost and the 80% confidence level required to meet by an organization.

For the pre-mitigation scenario the maximum number of hits made was 177hits out of 1000 iterations carried. The cost corresponding to 177hits was between 61,963L.E and 62,963L.E. The maximum number of hits made for post-mitigation scenario was 377 hits out of 1000 iterations carried. The cost corresponding to 377hits was between 30,300L.E and 40,300L.E. Reduction in the value of the cost corresponding to the maximum number of hits proves that implementing mitigation actions was a good solution to help meeting an organization decision goal.

There are three types of tornado diagrams used, duration sensitivity, criticality sensitivity and cost sensitivity diagrams. The duration sensitivity chart will focus on generating and successfully presenting the tornado chart for project drivers. As shown on the chart duration sensitivity bars represents logical predecessors driving the infrastructure project completion of whole works. The program will look at two tasks, the completion of whole works and each of the predecessor driving activities listed at the left of the tornado bars.

The criticality tornado chart illustrates critical activities which carry risk events are in red on the tornado chart. The criticality metric simply shows the percentage of iterations or simulations that an activity was on the critical path. Thus, these activities represent the critical activities were risk factors linked to them. The attempt of this chart is to show not only if the activity is a driver to a reporting milestone or activity, but whether it is on the overall network critical path. The numbers on the criticality chart are the number of iterations that an activity was on the critical path.

The cost sensitivity chart illustrates the highest risk factors or drivers which might affect the cost of project completion of whole works is represented. The previous Tornado Diagrams are used within the task mode. This will show a tornado chart of all activities and risk events. On the other hand risk mode used for cost sensitivity will show a tornado chart of risk events only. The chart illustrates a list of cost sensitivity tornado data is represented at the right of the project completion work tornado diagram. These data include, definition of cost sensitivity, analysis and sensitivity calculation values description. The definition of cost sensitivity by the Pert-Master program states that the cost sensitivity of a risk event is a measure of the correlation between the occurrence of any of its impacts and the cost of the project (or a key task).

The program will calculate the correlation of predecessor's duration and/or cost. If each time the driver increases in duration and/or cost, the duration and/or cost of milestone increases, then the correlation percentage is high. The correlation percentages concerned with pre-mitigation scenario tornado diagrams is reduced after implementing mitigation actions. This proves that applying good responsive actions towards a project identified risk factors can make logical predecessors less driving the project completion and any sewage activity cost and time objectives.

5.2.4 Risk Analysis Output

The output of both quantitative risk analysis and risk response plan is an updated risk register as represented in Fig 5.55, the figure illustrates probabilities and impacts scales of project objectives before and after implementing mitigation response actions. Fig 5.55 represents risk factors shown together with their risk IDs. Three stages including the pre-mitigation scales, the mitigation title and the post-mitigation scales are represented. The pre-mitigation stage was implemented from the qualitative risk analysis output. Both mitigation title and post-mitigation scales are taken from participants opinions after carrying a field survey during the construction of sewage projects.

In the pre-mitigation column shown in Fig 5.55, the impacts on both project objectives including time and cost objectives are registered. These pre-mitigation scales were previously conducted from the updated qualitative risk register in chapter four. The right side of the updated risk register reflects the post-mitigation scales. These scales are either reduced to a lower scale or have the same scales. This change in scales is due to implementing corrective response actions towards prioritized risk factors. It is clear that the risk score for these risk factors have been reduced.

Risk Register

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Qualitative Quantitative

Risk			Pre-Mitigation (Data Date = 22/06/2012)				Mitigation		Post-mitigation			
ID	T/O	Title	Probability	Schedule	Cost	Score	Response	Title	Probability	Schedule	Cost	Score
b4	T	Poor equipment productivity	M	M	M	10	Reduce	Use more experienced project team , p...	M	L	L	5
f3	T	Delay in Shop drawings approval	M	H	M	20	Reduce	Discuss any problems with the consult...	M	L	L	5
a3	T	Delay in approval of material	M	M	M	10	Reduce	Try to discuss use other material , Con...	M	L	L	5
b5	T	Low subcontractor performance	M	M	M	10	Reduce	Use more Subcontractor , Use warning...	M	L	L	5
d1	T	Permits delayed	M	M	M	10	Reduce	Good comunication for contractor wit...	M	L	L	5
f4	T	Approval of third party Delay	M	M	M	10	Reduce	Perform regular meetings to discuss t...	M	L	L	5
b10	T	Poor planner errors	M	M	M	10	Reduce	Use more experienced planner who de...	M	L	L	5
b7	T	Poor site management by the contractor	M	M	M	10	Reduce	Consultant ca send warnings to the co...	M	L	L	5
c1	T	Funds unavailability	M	L	M	10	Reduce	Increase cash available before constru...	M	L	L	5
b1	T	Contractor misleading top management focus	M	M	M	10	Reduce	Project team must set regular weekly ...	M	L	L	5

Fig 5.55 Updated Risk Register

5.3 Conclusion

This chapter represents the risk analysis simulation process. In order to carry the risk analysis process perfectly, an efficient program tool was used called the Pert-Master Primavera risk analysis tool. Throughout this chapter, two sewage risk management processes were carried. These are the quantitative risk analysis and the risk response actions processes. Both processes were carried through this chapter in order to obtain an efficient risk analysis. This efficient risk analysis is met by using this pert-master program and that’s why this program has been chosen. Before carrying risk analysis the program has the advantage of carrying different checks. These checks are done in order to check the validity of the program prior carrying risk analysis. The Primavera Risk Analysis program gives the risk analyst the advantage to correct any schedule planner mistakes. Correcting these errors will allow the risk analyst to obtain accurate risk analysis results. One of the errors corrected in this Chapter is the open ended activities could affect the risk analysis process.

The output of qualitative risk analysis process was a list of 10 prioritized risk factors. Prioritized risk factors are analyzed and have given risk response actions towards them. This is done by implementing the updated risk register conducted from qualitative risk analysis into the Pert-Master program. Sewerage project schedule was used linking sewage construction activities to their corresponding risk factors. Results of the analysis were compared before and after the mitigation process. Both mitigation title and post-mitigation scales are taken from participants opinions after carrying a field survey during the construction of sewage projects. Pre-mitigation scenario by which risk factors are implemented without taking into consideration the implementation of suggested mitigation actions. While post- mitigation scenario has mitigation actions implemented to them.

Different form of the analysis results were obtained and compared. The distribution histogram bars was tested about giving the probability to finish the whole works at different dates as well as the date by which the whole works is completed at a proposed probability. Were corrective action could be taken based on information given to the top management. The Tornado Diagram results that the highest driving predecessor could be reviewed. It can reflect to a risk analyst what risk drivers or logical predecessors could be viewed for a corrective action.

The cumulative confidence level histogram was made for both cost and time objectives. The cumulative distribution for time is done for the completion of whole works and the construction of sewage manhole activity. The histogram reflects several criteria including hit column bars date range, hit column average date, deterministic date, date to be 50% confidence, date to be 80% confidence, maximum no. of hits, duration for maximum no. of hits and needed days to be 80% confident. It is clear that no realized change occurred in probability results for time objective.

Table 5.6 indicates the number of working days at a suggested probability needed to be added to the estimated scheduled time. The deterministic completion date is on 11/09/2013 with project duration of 1,075 days. At 50% probability, the project completion of whole works could be finished at 09/10/2013. Thus, at a probability of 50%, twenty eight days or 2.6% of the project duration is required to be added to the completion scheduled date. At 80% probability, the project completion of whole works could be finished at 14/10/2013.Thirty three days must be added to the schedule completion date of 11/09/2013. The required percentage represents the percentage of the required days to be added to the project duration.

Table 5.6 Required Number of Days

Cases	Completion Date	Risk Premium Days	Percentage of Schedule Time
Schedule Date	11/09/2013	-	-
50% Confidence	09/10/2013	28 Days	2.6%
80% Confidence	14/10/2013	33 Days	3.1%

As represented in Table 5.7, the deterministic or budget cost is 78,366,146L.E.The cost which can make an organization 50% confident is 84,899,134 L.E. This means that an amount of 6,532,988 L.E is needed to be added to the estimated cost. The cost which can make an organization 80% confident is 87,172,414 L.E. This means that an amount of 8,806,268 L.E is to be added to the estimated cost. Table 5.7 indicates the percentage required to be added to meet the estimated cost.

Table 5.7 Pre-mitigation Required Amount

Cases	Completion Cost	Risk Premium Cost	Percentage of Estimated Cost
Budget Cost	78,366,146 L.E.	-	-
50% Confidence	84,899,134 L.E.	6,532,988 L.E	8.3%
80% Confidence	87,172,414 L.E.	8,806,268 L.E	11.2%

Table 5.8 represents the required amount to meet the estimated cost after implementing mitigation actions. The deterministic cost is 78,366,146L.E. The cost which can make an organization 50% confident is reduced to 81,283,803L.E. This means that an amount of 2,917,657 L.E is needed to be added to the estimated cost. The cost which can make an organization 80% confident is reduced to 82,303,825L.E. This means that an amount of 3,937,679 L.E is needed to be added to the estimated cost. Table 5.8 also indicates the percentage required to be added to meet the estimated cost after adding mitigations.

Table 5.8 Post-mitigation Required Amount

Cases	Completion Cost	Risk Premium Cost	Percentage of Estimated Cost
Budget Cost	78,366,146 L.E.	-	-
50% Confidence	81,283,803 L.E.	2,917,657 L.E	3.7%
80% Confidence	82,303,825 L.E.	3,937,679 L.E	5.0%

Table 5.9 illustrates the amount required to be added to the estimated cost before and after mitigation implementation. Percentages present the reduction made in the amount required to be added to the budget cost after adding different mitigations.

Table 5.9 Savings Comparison Before and After Mitigations

Cases	Risk Premium Before Mitigation	Risk Premium After Mitigation	Percentage of Estimated Cost
50% Confidence	6,532,988 L.E	2,917,657 L.E	4.6%
80% Confidence	8,806,268 L.E	3,937,679 L.E	6.2%

There are three types of tornado diagrams used, duration sensitivity, criticality sensitivity and cost sensitivity diagrams. The duration sensitivity chart will focus on generating and successfully presenting the tornado chart for project drivers. As shown on the chart duration sensitivity bars represents logical predecessors driving the infrastructure project completion of whole works. The program will look at two tasks, the completion of whole works and each of the predecessor driving activities listed at the left of the tornado bars.

The criticality tornado chart illustrates critical activities which carry risk events are in red on the tornado chart. The criticality metric simply shows the percentage of iterations or simulations that an activity was on the critical path. Thus, these activities represent the critical activities were risk factors linked to them. The attempt of this chart is to show not only if the activity is a driver to a reporting milestone or activity, but whether it is on the overall network critical path. The numbers on the criticality chart are the number of iterations that an activity was on the critical path.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Summary

It is important to use efficient cost estimate and time schedule for the construction of sewage networks projects. This is to be done in order to avoid both cost overrun and losing control on the schedule construction time. The objective of this study is of twofold, first is to identify risk factors that may impact both cost and time of sewage construction. Second, is to analyze these risk factors and improve the maturity of both cost estimate and project time schedule. This improvement could be achieved by reducing the effect of risk factors. By taking this mitigation action, risk factors are reanalyzed and improvements are represented.

- **I**n order to meet the study objectives, risk management process were carried on sewage networks projects were the following work sequence was used:-

- **R**isk identification stage targets to obtain a list of identified risk factors related to the sewage project activities. In order to do that, different papers were viewed obtaining a list of risk factors.

- **Q**ualitative risk analysis was done by obtaining both probabilities of occurrence and impact scales of different risk factors through a questionnaire.

- **Q**uantitative risk analysis and Risk response plan processes are then followed. Mitigation actions towards the prioritized risk list are given through field questionnaires. Both prioritized risk factors list and mitigation actions are implemented into the risk program. Risk Analysis results are compared before and after mitigation actions implementation.

6.2 Conclusion

- **U**sing a survey a total number of 50 risk factors related to different risk categories were identified by the end of the risk identification process.

- **R**isk categories include technical quality performance risks, external risks related to project organization, financial risks, environmental risks, management risks and external risks related to public regulations.

- **T**he qualitative risk analysis process carried results in a prioritized list of 10 risk factors. Experts suggested the probability of occurrence and impact scales of prioritized risk factors. Using risk score method and probability impact matrix, risk factors are ranked to be further analyzed quantitatively with the aid of a case study.

- **Q**uantitative analysis for the most important 10 risk factors 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 scenario were prioritized risk factors are linked to the schedule and mitigation actions are implemented to them.

- **T**he Monte Carlo analysis simulation results into probability distribution histogram and tornado diagrams. For time no change in results was observed and 3.1% of the project duration to be added to the completion date of 14/10/2013 for an organization to be 80% confident. 2.6% of the project duration to be added to the completion date of 14/10/2013 for an organization to be 80% confident.

- **A**ccording to the Monte Carlo results for cost objective, analysis results were also compared before and after applying mitigation actions. Before mitigation, for an organization to be 80% confidence 11.2% of the completion cost to be added to the estimated completion cost. After mitigation, 5.0% are to be added to the project estimated completion cost. Thus, 6.2% of the total completion cost will not be added to the completion cost if an organization decides to be 80% confident and mitigate the list of most effective risk factors.

- **B**efore mitigation, for an organization to be 50% confidence 8.3% of the completion cost to be added to the estimated completion cost. After mitigation, 3.7% are to be added to the project estimated completion cost. Thus, 4.6% of the total completion cost will not be added to the completion cost as a result of adding mitigation actions.

- **T**here are three types of tornado diagrams used, duration sensitivity, criticality sensitivity and cost sensitivity diagrams. The following was concluded:

- **B**efore implementing mitigations, the project completion duration tornado indicates the highest five predecessors driving the time of project completion. These are laying curbs, street lightning foundations, testing and commissioning of LV network, bulk excavation and fill for road 5 and final connection LV electrical and street lightning.

- **A**fter mitigation implementation, the highest five driving predecessors are bulk excavation and fill for road 5, final connection LV electrical and street lightning, client approval of curbs and signs, testing and commissioning of LV network and Installation of flow meter. Any misleading durations must be revised and fixed.

- **T**he criticality tornado chart illustrates critical activities which carry risk events and has the highest impact on project completion cost and time. Before mitigation the highest activity was casting water tank walls. No change in criticality tornado results as after mitigation the highest driving activity remains casting water tank walls.

- **T**he cost sensitivity tornado chart represents the highest risk factors driving an increase in the project completion cost. Before mitigation the highest five risk factors were poor site management by the contractor, funds unavailability, contractor misleading top management focus, delay in shop drawings approval and poor equipment productivity.

- **A**fter mitigation the highest five risk factors became: poor equipment productivity, delay in shop drawing approval, delay in approval of third party, contractor misleading top management focus and poor site management by the contractor. This difference in the results indicates that the impact of some of the risk factors by driving the project cost of completion has been reduced.

6.3 Recommendation

- **T**he main objective of any contractor constructing sewage network projects is to obtain an economic construction cost and time. This could be met using the critical risk factors obtained in this study.

- **T**he identified risk factors as well as their impacts and probability should be continuously evaluated to account for any future change in these factors or their impacts.

- **T**he contractor could use scales of impacts and probabilities of occurrence of the most effective risk factors for any future risk analysis.

- **T**he most effective risk factors on cost objective include the following 10 risk factors: Poor equipment's productivity, Delay in shop drawing approval, Poor planning errors, Funds unavailability, Delay in material approval, Low subcontractor performance, Third party delay approval, Poor site management by the contractor, Permits delayed and change in tax regulations.

- **P**rioritized risk factors for time include the following 10 risk factors: Delay in shop drawing approval, Poor equipment's productivity and efficiency measures, Poor site management in the contractors organization, Poor planning errors, Misleading management focus, Delay in material approval, Lack of construction management, Low subcontractor performance, Funds unavailability and Permits delayed.

- **C**ontractors could use the analysis output used in the Case Study applied in this thesis. Contractors can apply corrective mitigation actions towards the identified list of risk factors using several mitigations suggested in this study.

- **A**pplying mitigations on the most effective risk factors leads to a reduction in the percentage to be added to the completion time or cost. The higher confidence level required by an organization the higher the percentage to be added to the completion cost or completion time.

- **A**s a result of the case study, at different confidence levels, different percentage of project duration is required to be added to the base schedule. The higher the confidence level chosen by an organization, the more working days to be added to the base schedule.

- **I**t was observed from the case study, before adding mitigations, at a confidence level percentage of the estimated cost is needed to be added to the estimated cost. After applying mitigations the percentage to be added to the estimated cost is decreased as a result of applying mitigations and decreasing the probability and impact scales of the most effective risk factors.

- Through the case study, three types of tornado diagrams are used. Using Pearsons Product Moment, correlation is used between variables of total duration and cost with sewage construction activities. The most driving predecessor activities for total cost and time are observed.

- **C**ontractors could use Tornado diagrams to indicate the most driving activities impacting both construction cost and time. Contractors must try to track these drivers and improve their durations or even be sure that during construction there durations will not be delayed.

- **D**uring the construction of sewage system contractors must monitoring and control of existing risk factors. Risk factors which might appear during construction to the risk register must be added.

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APPENDICES

Appendix A: Data Collection.

-Participants Names.

Appendix B:Questionnaires

1- Risk Identification Questionnaires.

2- Qualitative Risk Analysis Questionnaires.

3- Risk Response and Post mitigation Questionnaires