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Computing Cost and Time Contingency for Box Culverts Construction Projects using Integrated Risk Management Technique

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Abstract*: *Construction and rehabilitation of water control structures in Egypt considered as an important project, as it influences the usage of water resources in Egypt which become limited resources due to water scarcity existed in the last decades. Also these projects helps in the optimization of water resources, Moreover it helps in the growth of agricultural and industrial sector. Project Risk Management (RMP) is considered as a vital and important tool in decision making, thus RMP used as a planning management system to detect risks affecting project deliverables; such as cost and time target. This research shows how to optimize the deliverables for construction of box culverts in Egypt, through a well-defined risk management framework and real case study for a certain project executed in the last decade. Finally, this study shows how to calculate cost and time contingency for these projects through an integrated risk management technique. Finally this study shows hazard risk identification and assessment for these type of projects. The conclusion of this study show that the cost contingency needed to resolve different risk factors arise in the shown case study is to increase the estimated budget with average value 11.50 percent on the total estimated budget, as well as the time contingency is found with average value 16.00 percent to be added over the total original baseline schedule of the construction project.

Keywords: Risk, Risk Management, Cost Contingency, Time Contingency, Construction of Box Culverts in Egypt.

I. INTRODUCTION

Risk is the state of uncertainty, as an event or condition that, if it occurs, has a positive or negative effect on projects deliverables. Managing risk is an integral part of sound management and risk management helps to achieve projects objectives **(Omar et al., 2020) [4].** Moreover, Business Risk can be defined as the inherent chances for either profit or loss associated with a particular endeavor which approved that risk occurs due to limited knowledge, and due to projects consequences versus targets **(Rashid, 2009) [1].** Also, Business risk is the probability that an actual return of an investment will be less than the expected return. The continuing process to identify, analyze, evaluate and monitor risk to alleviate the adverse effect of loss **(Saeed, 2018) [8]**. Projects are exposed to both internal risks (financial, design, contractual, construction, personal, involved parties and operational risks) and external risks (economic, social, political, legal, public, logistical and environmental risks). All the risks may influence cost, or time of the project in both negative and positive ways (**Choudhry et.al, 2018) [7]**. Risk concerns the deviation of one or more results, or of one or more future events from expected value. Technically, the main purpose of RMP is solving problems that suffer due to deviation of project deliverables, as to create an alternatives to proper functioning under conditions **(Pooworakulchai, 2018) [5].**

The Egyptian water resources system is composed to many interacting components and intermingles with social, economic and environmental systems, which are also complex and uncertain. Fresh water resources include River Nile flow, precipitation and groundwater from both renewable and non-renewable aquifers **(Gunidy, 2015) [11].** There is a large number of hydraulic control structures in the Nile valley and the Nile Delta, which play an important role for controlling, distribution and allocation of water, but these structures suffers different stages of degradation. The main problems in these structures is hydraulic inefficiency resulting from leakage and dysfunctional of gate operating. Also these structures suffer from structural instability resulting from the erosion of their foundations and differential settlement caused by high traffic loads. With the increasing trend of replacing barrages in Egypt, especially those built before the High Dam in 1971, there is a need to reduce their construction costs. Barrages/regulators and box culverts are structures used to control water levels along irrigation canals. The main elements of a these structures consist of a floor, abutments, piers, and a bridge. The cost of these structures depends primarily on its floor and secondarily on its abutments, piers, and bridge.

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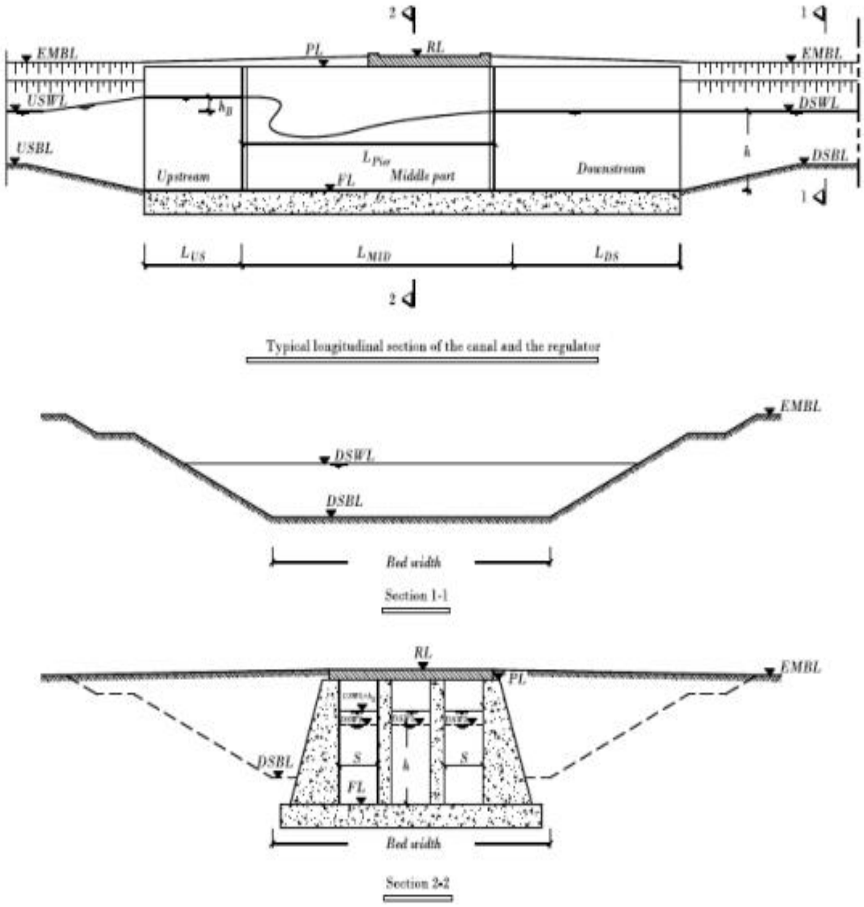

Fig.1 Barrage and canal sections showing the hydraulic parameters (*Ashour et al., 2009) [2].*

II. PROBLEM STATEMENT AND RESEARCH SCOPE

Project participants mostly take their judgment and control their project activates by their intuitions and experience and randomly data handled inside projects, not by performing systematic RMP. This leads to not achieve project deliverables **(Zabaal, 2007) [3].** The aim of this research is to optimize the deliverables of box culvert construction project through a risk management framework and accurate calculation of cost and time contingency of these projects. This research depends on case study, and to show how to compute cost and time contingency using integrated risk management technique, as data is classified into the following:

- **Background information:** The technical information about box culverts as water structure constructed in Egypt for the last decade.

-**Description of the real projects:** As describing full analysis about the risk management process of a certain project, as real project is discussed; showing cost and time analysis for this project, also describing the different risks occurred, finally shows how to measure cost and time contingency needed.

III. METHODLOGY

The main methodology of data formulation and its analysis is meeting with project participants, to provide benchmark for this study. The following flow chart **figure (2)** shows the study methodology:

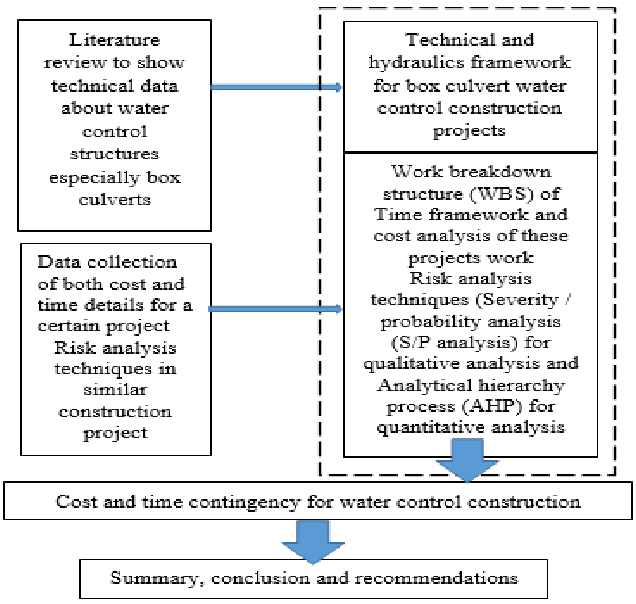

Fig .2. Study methodology flow chart

A.Technical data about construction of box culvert

Culvert is a hydraulic structure which may be fully or partially submerged in water stream. Culverts mostly change the natural flow of water. It can be used to divert, disrupt or completely stop water flow.

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Moreover culverts can be built on any water stream for a specific function. Culverts are water structures that allows water to flow under a road, rail way road, or similar obstruction from one side to the other side. As may be typically embedded so as to be surrounded by soil **(Nanni et al., 2001) [9]**. And **figure (3)** shows how box culvert is used in the intersection between water stream (channel) and a highway road.

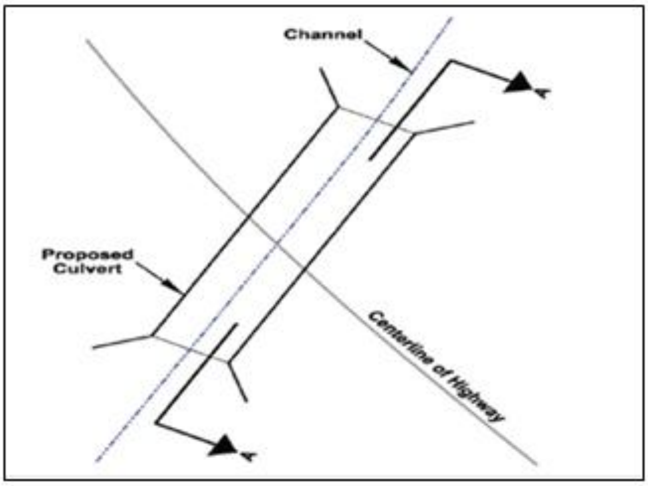

Fig.3. Roadway cross culvert length

Culverts design depends on hydraulic technical data, which should contain the culvert length, loading analysis, and other items that lead to the completed culvert plans and its dimension. Box culverts may be made of reinforced concrete frames as closed system which support vertical or lateral earth pressure to be passive or active and part of load may be vehicles load. Culverts either single or multi-cell based on the hydraulic requirements.

Culverts life time depends on the material that used to resist corrosion, as culverts having high initial cost can have a longer service life and also can have lower total operation and maintains (O&M) cost. The (O&M) cost includes maintenance costs, operational cleaning cost and risks associated with flooding. Moreover, future maintenance requirements can also save money in the long run. Maintenance costs for culverts may result from channel erosion at the inlet of water stream and its outlet, also erosion, deterioration of the culvert invert, sedimentation and embankment repair in case of overtopping.

B. Case study for a box culvert construction project.

Background for the project and discussing cost and time breakdown

The following **Table-1 and Figure (4)** shows cost and time breakdown allover project life cycle for Box culvert project with number of three vents, each vent width equals three meters and with height of vent is about 2.50m. This box culvert exists in Alexandria city , as canal width equals 12meters, This project executed in 2016 with total project budget **9 100 000 L.E. (9Million 100 Thousand L.E.) with duration about 294days (9.8 Months).**

Moreover, this realistic water structure construction project in Egypt began in **5/2016**, as the project began in its conceptual and feasibility studies phase and finished in **3/2017** after rediverting water stream to the main stream and accomplish handover of the project [6].

Table – 1: Cost and Time Breakdown for a Box culvert construction project in Egypt:

Project Phases (Milestones activities)	Cost (1000 LE)	Time (days)
Conceptual and feasibility studies.	**(350)**	**(179)**
Technical feasibility studies	150	30
Economic feasibility studies	100	30
Project decision (Bid or no-bid) & Revising Project Framework with Stakeholders	50	20
Issuing frame work of the project and it feature	50	100
Engineering phase	**(530)**	**(115)**
Choose site location and conduct hydraulic studies /Site Survey analysis	30	5
Perform Soil analysis and Geotechnical analysis and issuing reports	200	10
Issuing Final detailed Drawing and Specification	300	100
Construction phase (I)	**(3550)**	**(79)**
Mobilization and Site preparation	100	7
Construction of temporary Canal	200	9
Build buffers for Canal Diversion	125	10
Diversion of main stream	50	15
Construction of dewatering system	200	10
Excavation by using mechanical tools	125	5
Piling system	2000	5
Soil Test in Site and Reports	50	60
Foundation of pile Cap	700	10

Continue Table – 1: Cost and Time Breakdown for a Box culvert construction project in Egypt:

Project Phases (Milestones activities)	Cost (1000 LE)	Time (days)
Construction phase (II)	**(4450)**	**(126)**
Plain concrete execution for footings (Zone I)	200	20
Reinforced Concrete execution for foundation & Ret. Walls(Zone I)	1000	30
Plain concrete execution for footings (Zone II)	200	20
Reinforced Concrete execution for foundation & Ret. Walls(Zone II)	1000	30
R.C. Slabs	600	50
Concrete Tests in Site and Report	50	60
Pitching Work and Leveling and Backfilling	350	15
Side Walks and Bridges super-structures	250	25
hydraulic and technical checks	100	15
Erecting of Gates and Screening	500	15
Re-Divert to the main stream	100	20
Handover and Project Completion	**(100)**	**(10)**

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IV. ANAYLSIS AND DISCUSSION

A.Risk identification and qualitative assessment for a box culvert s project

Risk identification is considered as a critical step in the risk management process, risk identification is an organized, through approach to finding real risks associated with a project. Risk identification determines which risks might affect the project and their characteristics at each project phase. In this study, Participants in risk identification and assessment activities are **(6) personnel** whom are: Project managers for (Owner reprehensive - Consultant & Contractor) and project site engineers for contractors.

Risk probability assessment investigates the likelihood that each specific risk will occur, risk impact assessment investigates the potential effect on a project objective. Notice that the influence of risk factors (RF) on the matrices are assigned in **table –2**

Table-2: Numerical qualitative risk analysis matrix for the project cost. Where: "Red Color shows important high risk factors, Yellow Color shows high risk factors, Green Color shows medium risk factors":

Severity / Probability	Increase in budget and duration				
	From 0 to 3% (1)	From 3% to 10% (2)	From 10% to 20% (3)	From 20% to 30% (4)	More than 30% (5)
Rare (1)	1	2	3	4	5
Unlikely (2)	2	4	6	8	10
Possible (3)	3	6	9	12	15
Likely (4)	4	8	12	16	20
Certain (5)	5	10	15	20	25

Table- 2 shows the frequency of each RF occurs as: (Rare) from zero to one time all over the project, (Unlike hood) two times through the project, (Possible) three times through the project, (Likely) four times through the project, (Frequently) five or more through the project. Finally the risk factors are classified into:

-If the magnitude of risk is from (15 to 25) for Red color, it means that this RF is important high risk factors as those should be avoided or to be controlled by some engineering or administrative control measures, also these risk factors should be subjected to frequent assessment.

-If the magnitude of risk is from (6 to 12) for Yellow color, it means that the risk is high risk factors, so it has to be monitored but less priority than important high risk factors.

-If the magnitude of risk is from (1 to 6) for Green color, it means that the risk is medium so to be monitored and controlled by a lower cost engineering and administrative control.

And the tables below (3) & (4) shows the risk factor identified and assessed through project participants as the risk factors are nine risk factors affecting on both cost and time targets.

Table -3: Risk identification and qualitative assessment concerning cost target of Box culvert water structure project:

Factors	Q1	Q2	Q3	Q4	Q5	Q6	µ
Unexpected changes in cash flow	10	10	12	8	12	8	10.00
Over-Design for components of the project	8	8	10	6	12	8	8.67
Assigning non-applicable constructability method	10	8	10	6	12	8	9.00
Site accessibility problems	15	15	17	13	15	17	15.33
Geotechnical and soil analysis troubles issues	12	12	14	10	12	14	12.33
Labor productivity lower than required	12	15	17	13	15	17	14.83
Material transportation delay	8	8	10	6	8	10	8.33
Change orders at construction phase	4	20	22	18	20	22	17.67
Bad weather conditions	12	15	17	13	15	17	14.83

Table - 4: Risk identification and qualitative assessment concerning time target of Box culvert water structure project:

Factors	Q1	Q2	Q3	Q4	Q5	Q6	µ
Unexpected changes in cash flow	10	8	10	4	12	8	8.67
Over-Design for components of the project	8	8	8	4	12	8	8.00
Assigning non-applicable constructability method	12	8	12	12	16	8	11.33
Site accessibility problems	15	15	18	20	22	24	19.00

Continue Table -4: Risk identification and qualitative assessment concerning time target of Box culvert water structure project:

Factors	Q1	Q2	Q3	Q4	Q5	Q6	µ
Geotechnical and soil analysis troubles issues	12	12	14	10	10	12	11.67
Labor productivity lower than required	12	15	17	13	20	22	16.50

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Material transportation delay	12	12	14	10	10	12	11.67
Change orders at construction phase	8	20	22	18	20	22	18.33
Bad weather conditions	12	20	22	20	22	24	20.00

Thus the RF "Changes orders at construction phase "is highest influence with perspective to cost target, where this factor depends on number of change orders done in the project and if there is change orders effect on the critical path of the project or not, as handling this point is so important to not have conflicts when the project is executed. Moreover change order has a lot of other terminology; such as change proposal at engineering phase and variation order at construction phase.

"Bad weather condition " RF is highest influence with perspective to time target in this case study , as this factor depend on a well forecasting of the weather through over the project construction and take into consideration where scheduling of the project. Also site accessibility problems risk factor influence both budget and duration of the project, as this factor depends on the location of the site, the route of entrance to the site, type of activities and equipment's used in execution in this site. This factor can be controlled by a well discussion of routes and entrances to the work site, to study the possible accessibility or to make suitable routes for equipment and labors to enter to site.

Geotechnical and soil analysis troubles issues is a medium influence risk factor for both cost and time target , as soil – analysis investigation reports and studies is one of the important studies that must be accomplished in the engineering phase where early duration of project cycle and continual updated , thus to define all the features and criteria of the soil and then design all the footings and sub-structure of the project executed , so any change in the expected feature of this soil would give change in the design of the structure, which may lead to higher cost or delaying in the project duration due to change in recommendation of the soil or change in the statically system of the structure.

And the sensitivity analysis for the means values showing the influences concerning budget and duration of the project is shown in **figure (5):**

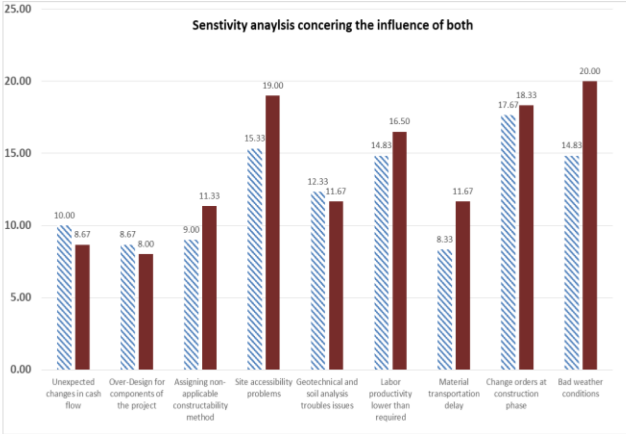

Fig .5. Sensitivity analysis concerning the influence of both cost (in hatched) and time target (in solid) – box culvert construction project

B. Quantitative risk analysis (QRA) by AHP for a box culvert project

The methodology of QRA is using Analytical hierarchy process (AHP) to measure cost and time contingency for the case study shown. AHP developed by Thomas L.Saaty based on pair wise compression as it is consider as a multi-criteria decision-making approach [10]. These comparisons are used to obtain the weights of importance of the decision criteria, and the relative performance measures of the alternatives in terms of each individual decision criterion. The assigned scale in this case study from 1 to 9 is adopted. In that scale, a score of 1 indicates equal importance and a score of 9 indicates that an element is extremely important than the other. Meanwhile, reciprocals to these scores (i.e. 1/2, 1/3...1/9) represent the counter importance relationships for assigning numerical scale values, survey forms are designed.

Moreover, for calculating cost contingency the methodology is formulated by the following steps:

- The First step is calculating the effectiveness (Eff.) for each project phase , to use this Eff. factor in the AHP cycle , table (5) shows the breakdown of the project, as the project is simply classified into main three phases as shown (Conceptual &feasibility studies and Engineering phase Construction phase (I) - Construction phase (II) and handover.
- The second step is beginning with the AHP analysis model for the three phases of the project with the mathematical model shown in tables (6), (7), and (8).

Table-5: Risk effectiveness in each project phase concerning cost target:

Project phases (Box- Culvert water)	**Cost (LE) *1000**	**Eff.**
Conceptual and feasibility studies & Engineering phase	880	0.0979
Construction phase (I).	3550	0.3953
Construction phase (II) & handover	4550	0.5066
Total Project cost	**8 980**	

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Table -6: Pairwise compression and AHP analysis (concerning cost target) for RF at conceptual &feasibility studies and engineering phase:

Conceptual and feasibility studies & Engineering phase (Normalize criteria weight)	Unexpected changes in cash flow	Over-Design for components of the project	Assigning non-applicable constructability method	Site accessibility problems	Geotechnical and soil analysis troubles issues	Labor productivity lower than required	Material transportation delay	Change orders at construction phase	Bad weather conditions
Unexpected changes in cash flow	1.00	2.00	3.00	2.00	2.00	4.00	4.00	2.00	4.00
Over-Design for components of the project	0.50	1.00	2.00	3.00	2.00	4.00	3.00	2.00	5.00
Assigning non-applicable constructability method	0.33	0.50	1.00	2.00	0.50	4.00	5.00	3.00	5.00
Site accessibility problems	0.50	0.33	0.50	1.00	0.20	1.00	1.00	1.00	1.00
Geotechnical and soil analysis troubles issues	0.50	0.50	2.00	5.00	1.00	4.00	3.00	1.00	1.00
Labor productivity lower than required	0.25	0.25	0.25	1.00	0.25	1.00	0.20	0.20	0.20
Material transportation delay	0.25	0.33	0.20	1.00	0.33	5.00	1.00	1.00	1.00
Change orders at construction phase	0.50	0.50	0.33	1.00	1.00	5.00	1.00	1.00	4.00
Bad weather conditions	0.25	0.20	0.20	1.00	1.00	5.00	1.00	0.25	1.00
	4.08	5.62	9.48	17.00	8.28	33.00	19.20	11.45	22.20

										Normalize	Eff.	Qualitative influence from S*P Matrix	Value of each risk factor
Unexpected changes in cash flow	0.2449	0.3561	0.3163	0.1176	0.2414	0.1212	0.2083	0.1747	0.1802	0.2226	0.098	10.00	0.2181283
Over-Design for components of the project	0.1224	0.1780	0.2109	0.1765	0.2414	0.1212	0.1563	0.1747	0.2252	0.1727	0.098	8.67	0.1467194
Assigning non-applicable constructability method	0.0816	0.0890	0.1054	0.1176	0.0604	0.1212	0.2604	0.2620	0.2252	0.1372	0.098	9.00	0.1210268
Site accessibility problems	0.0612	0.0593	0.0211	0.0588	0.0402	0.1515	0.0521	0.0873	0.0450	0.0666	0.098	15.33	0.0998418
Geotechnical and soil analysis troubles issues	0.1224	0.0890	0.0351	0.0588	0.1207	0.1515	0.0521	0.0873	0.1802	0.0896	0.098	12.33	0.1083129
Labor productivity lower than required	0.0612	0.0356	0.0211	0.0588	0.1207	0.1515	0.0521	0.0218	0.0450	0.0654	0.098	14.83	0.0949945
Material transportation delay	0.0612	0.0593	0.0211	0.0588	0.0402	0.1515	0.0521	0.0873	0.0450	0.0666	0.098	8.33	0.0542519
Change orders at construction phase	0.1224	0.0890	0.0351	0.0588	0.1207	0.1515	0.0521	0.0873	0.1802	0.0896	0.098	17.67	0.1552221
Bad weather conditions	0.0612	0.0356	0.0211	0.0588	0.1207	0.1515	0.0521	0.0218	0.0450	0.0654	0.098	14.83	0.0949945
												Σ	1.093492044

Table -7: Pairwise compression and AHP analysis (concerning cost target) for RF at Construction phase (I):

Construction phase (I). (Normalize criteria weight)	Unexpected changes in cash flow	Over-Design for components of the project	Assigning non-applicable constructability method	Site accessibility problems	Geotechnical and soil analysis troubles issues	Labor productivity lower than required	Material transportation delay	Change orders at construction phase	Bad weather conditions
Unexpected changes in cash flow	1.00	2.00	2.00	1.00	0.50	0.50	0.50	2.00	2.00
Over-Design for components of the project	0.50	1.00	1.00	0.50	1.00	1.00	2.00	1.00	0.50
Assigning non-applicable constructability method	0.50	1.00	1.00	1.00	0.20	2.00	0.50	0.50	0.20
Site accessibility problems	1.00	2.00	1.00	1.00	2.00	3.00	2.00	1.00	0.50
Geotechnical and soil analysis troubles issues	2.00	1.00	5.00	0.50	1.00	0.33	2.00	1.00	0.50
Labor productivity lower than required	2.00	1.00	0.50	0.33	3.00	1.00	2.00	2.00	1.00
Material transportation delay	2.00	0.50	2.00	0.50	0.50	0.50	1.00	0.50	0.50
Change orders at construction phase	0.50	1.00	2.00	1.00	1.00	0.50	2.00	1.00	1.00
Bad weather conditions	0.50	2.00	5.00	2.00	2.00	1.00	2.00	1.00	1.00
	10.00	11.50	19.50	7.83	11.20	9.83	14.00	10.00	7.20

										Normalize	Eff.	Qualitative influence from S*P Matrix	Value of each risk factor
Unexpected changes in cash flow	0.1000	0.1739	0.1026	0.1277	0.0446	0.0508	0.0357	0.2000	0.2778	0.1044	0.395	10.00	0.4127666
Over-Design for components of the project	0.0500	0.0870	0.0513	0.0638	0.0893	0.1017	0.1429	0.1000	0.0694	0.0857	0.395	8.67	0.2938492
Assigning non-applicable constructability method	0.0500	0.0870	0.0513	0.1277	0.0179	0.2034	0.0357	0.0500	0.0278	0.0779	0.395	9.00	0.2769988
Site accessibility problems	0.2000	0.0435	0.1026	0.0638	0.0446	0.0508	0.0714	0.0500	0.0694	0.0783	0.395	15.33	0.4747936
Geotechnical and soil analysis troubles issues	0.0500	0.0870	0.1026	0.1277	0.0893	0.0508	0.1429	0.1000	0.1389	0.0938	0.395	12.33	0.4570503
Labor productivity lower than required	0.0500	0.1739	0.2564	0.2553	0.1786	0.1017	0.1429	0.1000	0.1389	0.1573	0.395	14.83	0.9224183
Material transportation delay	0.2000	0.0435	0.1026	0.0638	0.0446	0.0508	0.0714	0.0500	0.0694	0.0783	0.395	8.33	0.2579929
Change orders at construction phase	0.0500	0.0870	0.1026	0.1277	0.0893	0.0508	0.1429	0.1000	0.1389	0.0938	0.395	17.67	0.6549943
Bad weather conditions	0.0500	0.1739	0.2564	0.2553	0.1786	0.1017	0.1429	0.1000	0.1389	0.1573	0.395	14.83	0.9224183
												Σ	4.673282219

Table -8: Pairwise compression and AHP analysis (concerning cost target) for RF at Construction phase (II) and handover:

Construction phase (II) & Handover. (Normalize criteria weight)	Unexpected changes in cash flow	Over-Design for components of the project	Assigning non-applicable constructability method	Site accessibility problems	Geotechnical and soil analysis troubles issues	Labor productivity lower than required	Material transportation delay	Change orders at construction phase	Bad weather conditions
Unexpected changes in cash flow	1.00	2.00	2.00	1.00	0.50	0.50	0.50	2.00	2.00
Over-Design for components of the project	0.50	1.00	0.50	1.00	1.00	1.00	2.00	1.00	0.50
Assigning non-applicable constructability method	0.50	2.00	1.00	1.00	0.20	2.00	0.50	0.50	0.20
Site accessibility problems	1.00	1.00	1.00	1.00	2.00	3.00	2.00	1.00	0.50
Geotechnical and soil analysis troubles issues	2.00	1.00	5.00	0.50	1.00	3.00	2.00	1.00	0.50
Labor productivity lower than required	2.00	1.00	0.50	0.33	0.33	1.00	1.00	2.00	1.00
Material transportation delay	2.00	0.50	2.00	0.50	0.50	1.00	1.00	1.00	0.50
Change orders at construction phase	0.50	1.00	2.00	1.00	1.00	0.50	1.00	1.00	1.00
Bad weather conditions	0.50	2.00	5.00	2.00	2.00	1.00	2.00	1.00	1.00
	10.00	11.50	19.00	8.33	8.53	13.00	12.00	10.50	7.20

										Normalize	Eff.	Qualitative influence from S*P Matrix	Value of each risk factor
Unexpected changes in cash flow	0.1000	0.1739	0.1053	0.1200	0.0586	0.0385	0.0417	0.1905	0.2778	0.1035	0.395	10.00	0.4093228
Over-Design for components of the project	0.0500	0.0870	0.0263	0.1200	0.1172	0.0769	0.1667	0.0952	0.0694	0.0924	0.395	8.67	0.3167176
Assigning non-applicable constructability method	0.0500	0.1739	0.0526	0.1200	0.0234	0.1538	0.0417	0.0476	0.0278	0.0829	0.395	9.00	0.2948972
Site accessibility problems	0.2000	0.0435	0.1053	0.0600	0.0586	0.0769	0.0833	0.0952	0.0694	0.0904	0.395	15.33	0.5475407
Geotechnical and soil analysis troubles issues	0.0500	0.0870	0.1053	0.1200	0.1172	0.0385	0.0833	0.0952	0.1389	0.0871	0.395	12.33	0.4243133
Labor productivity lower than required	0.0500	0.1739	0.2632	0.2400	0.2344	0.0769	0.1667	0.0952	0.1389	0.1625	0.395	14.83	0.9528312
Material transportation delay	0.2000	0.0435	0.1053	0.0600	0.0586	0.0769	0.0833	0.0952	0.0694	0.0904	0.395	8.33	0.2975221
Change orders at construction phase	0.0500	0.0870	0.1053	0.1200	0.1172	0.0385	0.0833	0.0952	0.1389	0.0871	0.395	17.67	0.6080792
Bad weather conditions	0.0500	0.1739	0.2632	0.2400	0.2344	0.0769	0.1667	0.0952	0.1389	0.1625	0.395	14.83	0.9528312
												Σ	4.804055524

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And the calculation of cost contingency is adopted by superposition of the three tables shown above, and by the following equation:

$$\textit{Cost contingency in (percent)} = 0.80\ (Sc) + (S.V.) \qquad (1)$$

As the result shows Summation of Influences affecting cost target (Sc) in tables (7) , (8) and (9) equal to **(10.57)** and also standard deviation (S.V.) is equal **(3.45)** , so equation (1) gives a cost contingency equal **(11.91perecnt)** , as this contingency needed to be add on the original estimated budget of the project.

Moreover, for calculating time contingency the methodology is formulated by the following steps:

- The First step is calculating the effectiveness (Eff.) for each project phase , to use this Eff. factor in the AHP cycle , table (9) shows the time breakdown of the project , as the project is simply classified into main three phases as shown (Conceptual &feasibility studies and Engineering phase – Construction phase (I) - Construction phase (II) and handover.
- The second step beginning the AHP analysis model for the three phases of the project with the mathematical model in shown in tables (10), (11), and (12).

Table-9: Risk effectiveness in each project phase concerning time target:

Project phases (Box- Culvert water)	**Duration (Days)**	**Eff.**
Conceptual and feasibility studies & Engineering phase	132	0.449
Construction phase (I).	84	0.2857
Construction phase (II) & handover	78	0.2653
Total Project duration	**294**	

Table- 10: Pairwise compression and AHP analysis (concerning time target) for risk factors at Conceptual & feasibility studies and Engineering phase:

Home

Conceptual and feasibility studies & Engineering phase (Normalize criteria weight)	Unexpected changes in cash flow	Over-Design for components of the project	Assigning non-applicable constructability method	Site accessibility problems	Geotechnical and soil analysis troubles issues	Labor productivity lower than required	Material transportation delay	Change orders at construction phase	Bad weather conditions
Unexpected changes in cash flow	**1.00**	1.00	0.50	2.00	1.00	1.00	1.00	2.00	4.00
Over-Design for components of the project	1.00	**1.00**	2.00	3.00	2.00	4.00	3.00	2.00	5.00
Assigning non-applicable constructability method	2.00	0.50	**1.00**	2.00	0.50	4.00	5.00	3.00	5.00
Site accessibility problems	0.50	0.33	0.50	**1.00**	0.20	1.00	1.00	1.00	1.00
Geotechnical and soil analysis troubles issues	1.00	0.50	2.00	5.00	**1.00**	1.00	3.00	1.00	1.00
Labor productivity lower than required	1.00	0.25	0.25	1.00	1.00	**1.00**	1.00	0.20	0.20
Material transportation delay	1.00	0.33	0.20	1.00	0.33	1.00	**1.00**	1.00	1.00
Change orders at construction phase	0.50	0.50	0.33	1.00	1.00	5.00	1.00	**1.00**	4.00
Bad weather conditions	0.25	0.20	0.20	1.00	1.00	5.00	1.00	0.25	**1.00**
	8.25	**4.62**	**6.98**	**17.00**	**8.03**	**23.00**	**17.00**	**11.45**	**22.20**

										Normalize	Eff.	Qualitative influence from S/P Matrix	Value of each risk factor
Unexpected changes in cash flow	0.1212	0.2166	0.0716	0.1176	0.1245	0.0435	0.0588	0.1747	0.1802	0.1161	0.449	8.67	0.4516479
Over-Design for components of the project	0.1212	0.2166	0.2864	0.1765	0.2490	0.1739	0.1765	0.1747	0.2252	0.1968	0.449	8.00	0.7070423
Assigning non-applicable constructability method	0.2424	0.1083	0.1432	0.1176	0.0622	0.1739	0.2941	0.2620	0.2252	0.1755	0.449	11.33	0.8929674
Site accessibility problems	0.1212	0.0722	0.0286	0.0588	0.0415	0.0435	0.0588	0.0873	0.0450	0.0640	0.449	19.00	0.5459927
Geotechnical and soil analysis troubles issues	0.0606	0.1083	0.0477	0.0588	0.1245	0.2174	0.0588	0.0873	0.1802	0.0954	0.449	11.67	0.4999322
Labor productivity lower than required	0.0303	0.0433	0.0286	0.0588	0.1245	0.2174	0.0588	0.0218	0.0450	0.0730	0.449	16.50	0.5404665
Material transportation delay	0.1212	0.0722	0.0286	0.0588	0.0415	0.0435	0.0588	0.0873	0.0450	0.0640	0.449	11.67	0.3352587
Change orders at construction phase	0.0606	0.1083	0.0477	0.0588	0.1245	0.2174	0.0588	0.0873	0.1802	0.0954	0.449	18.33	0.7856077
Bad weather conditions	0.0303	0.0433	0.0286	0.0588	0.1245	0.2174	0.0588	0.0218	0.0450	0.0730	0.449	20.00	0.655111
												Σ	5.414026333

Table- 11: Pairwise compression and AHP analysis (Concerning time target) for risk factors at Construction phase (I):

Construction phase (I) (Normalize criteria weight)	Unexpected changes in cash flow	Over-Design for components of the project	Assigning non-applicable constructability method	Site accessibility problems	Geotechnical and soil analysis troubles issues	Labor productivity lower than required	Material transportation delay	Change orders at construction phase	Bad weather conditions
Unexpected changes in cash flow	**1.00**	2.00	2.00	1.00	0.50	0.50	0.50	2.00	2.00
Over-Design for components of the project	0.50	**1.00**	1.00	1.00	1.00	1.00	2.00	1.00	0.50
Assigning non-applicable constructability method	0.50	1.00	**1.00**	1.00	0.20	2.00	0.50	0.50	0.20
Site accessibility problems	1.00	1.00	1.00	**1.00**	0.50	3.00	2.00	1.00	0.50
Geotechnical and soil analysis troubles issues	2.00	1.00	5.00	2.00	**1.00**	3.00	2.00	1.00	0.50
Labor productivity lower than required	2.00	1.00	0.50	0.33	0.33	**1.00**	0.50	2.00	1.00
Material transportation delay	2.00	0.50	2.00	0.50	0.50	2.00	**1.00**	1.00	0.50
Change orders at construction phase	0.50	1.00	2.00	1.00	1.00	0.50	1.00	**1.00**	2.00
Bad weather conditions	0.50	2.00	5.00	2.00	2.00	1.00	2.00	0.50	**1.00**
	10.00	**10.50**	**19.50**	**9.83**	**7.03**	**14.00**	**11.50**	**10.00**	**8.20**

										Normalize	Eff.	Qualitative influence from SP Matrix	Value of each risk factor
Unexpected changes in cash flow	0.1000	0.1905	0.1026	0.1017	0.0711	0.0357	0.0435	0.2000	0.2439	0.1056	0.286	8.67	0.2615422
Over-Design for components of the project	0.0500	0.0952	0.0513	0.1017	0.1422	0.0714	0.1739	0.1000	0.0610	0.0982	0.286	8.00	0.2244879
Assigning non-applicable constructability method	0.0500	0.0952	0.0513	0.1017	0.0284	0.1429	0.0435	0.0500	0.0244	0.0704	0.286	11.33	0.227866
Site accessibility problems	0.2000	0.0476	0.1026	0.0508	0.0711	0.1429	0.0870	0.1000	0.0610	0.1002	0.286	19.00	0.544146
Geotechnical and soil analysis troubles issues	0.0500	0.0952	0.1026	0.1017	0.1422	0.0357	0.0870	0.1000	0.2439	0.0893	0.286	11.67	0.2976344
Labor productivity lower than required	0.0500	0.1905	0.2564	0.2034	0.2844	0.0714	0.1739	0.0500	0.1220	0.1600	0.286	16.50	0.7542471
Material transportation delay	0.2000	0.0476	0.1026	0.0508	0.0711	0.1429	0.0870	0.1000	0.0610	0.1002	0.286	11.67	0.3341247
Change orders at construction phase	0.0500	0.0952	0.1026	0.1017	0.1422	0.0357	0.0870	0.1000	0.2439	0.0893	0.286	18.33	0.4677111
Bad weather conditions	0.0500	0.1905	0.2564	0.2034	0.2844	0.0714	0.1739	0.0500	0.1220	0.1600	0.286	20.00	0.9142389
												Σ	4.025998278

Table- 12: Pairwise compression and AHP analysis (Concerning time target) for risk factors at Construction phase (II) & handover:

Construction phase (II) & Handover - (Normalize criteria weight)	Unexpected changes in cash flow	Over-Design for components of the project	Assigning non-applicable constructability method	Site accessibility problems	Geotechnical and soil analysis troubles issues	Labor productivity lower than required	Material transportation delay	Change orders at construction phase	Bad weather conditions
Unexpected changes in cash flow	**1.00**	1.00	1.00	1.00	0.50	0.50	0.50	2.00	2.00
Over-Design for components of the project	1.00	**1.00**	0.50	1.00	1.00	1.00	2.00	1.00	4.00
Assigning non-applicable constructability method	1.00	2.00	**1.00**	1.00	0.20	2.00	0.50	0.50	0.20
Site accessibility problems	1.00	1.00	1.00	**1.00**	2.00	3.00	2.00	1.00	0.50
Geotechnical and soil analysis troubles issues	2.00	1.00	5.00	0.50	**1.00**	3.00	2.00	1.00	0.50
Labor productivity lower than required	2.00	1.00	0.50	0.33	0.33	**1.00**	1.00	2.00	1.00
Material transportation delay	2.00	0.50	2.00	0.50	0.50	1.00	**1.00**	1.00	0.50
Change orders at construction phase	0.50	1.00	2.00	1.00	1.00	0.50	1.00	**1.00**	1.00
Bad weather conditions	0.50	0.25	5.00	2.00	2.00	1.00	2.00	1.00	**1.00**
	11.00	**8.75**	**18.00**	**8.33**	**8.53**	**13.00**	**12.00**	**10.50**	**10.70**

										Normalize	Eff.	Qualitative influence from SP Matrix	Value of each risk factor
Unexpected changes in cash flow	0.0909	0.1143	0.0556	0.1200	0.0586	0.0385	0.0417	0.1905	0.1869	0.0887	0.265	8.67	0.2040465
Over-Design for components of the project	0.0909	0.1143	0.0278	0.1200	0.1172	0.0769	0.1667	0.0952	0.3738	0.1011	0.265	8.00	0.2146258
Assigning non-applicable constructability method	0.0909	0.2286	0.0556	0.1200	0.0234	0.1538	0.0417	0.0476	0.0187	0.0952	0.265	11.33	0.2862449
Site accessibility problems	0.1818	0.0571	0.1111	0.0600	0.0586	0.0769	0.0833	0.0952	0.0467	0.0905	0.265	19.00	0.4562859
Geotechnical and soil analysis troubles issues	0.0455	0.1143	0.1111	0.1200	0.1172	0.0385	0.0833	0.0952	0.0935	0.0906	0.265	11.67	0.2805291
Labor productivity lower than required	0.0455	0.0286	0.2778	0.2400	0.2344	0.0769	0.1667	0.0952	0.0935	0.1456	0.265	16.50	0.637475
Material transportation delay	0.1818	0.0571	0.1111	0.0600	0.0586	0.0769	0.0833	0.0952	0.0467	0.0905	0.265	11.67	0.2801756
Change orders at construction phase	0.0455	0.1143	0.1111	0.1200	0.1172	0.0385	0.0833	0.0952	0.0935	0.0906	0.265	18.33	0.4408315
Bad weather conditions	0.0455	0.0286	0.2778	0.2400	0.2344	0.0769	0.1667	0.0952	0.0935	0.1456	0.265	20.00	0.772697
												Σ	3.57291126

And the calculation of cost contingency is adopted by superposition of the three tables shown above, and by the following equation:

Time contingency in (percent) = 0.80 (S_t) + (S.V.) **(2)**

As the result shows Summation of Influences affecting time target (***St***) in tables (10) , (11) and (12) is equal to **(13.91)** and also standard deviation (***S.V.)*** is equal **(4.86)** , so equation (2) gives a time contingency equals **(15.99 percent)** , as this contingency needed to be added on the baseline time schedule of the project.

V. HAZARD IDENTIFICATION AND RISK ASSESSMENT

Hazard identification and risk assessment is an important issue affecting the project success. And should be integrated by the above RMP to achieve project objective. Moreover, there are some definitions concerning safety risk management issues as follows:

Hazard: Anything (e.g. condition, situation, practice, behavior) that has the potential to cause harm, including injury, disease, death, environmental, property and equipment damage. A hazard can be a thing or a situation.

Hazard Identification (HAZID): This is the process of examining each work area and work task for the purpose of identifying all the hazards which are "inherent in the job". Work areas include but are not limited to machine workshops, laboratories, office areas, agricultural and horticultural environments, stores and transport, maintenance and grounds, reprographics, and lecture theatres and teaching spaces.

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HAZOP: is to conduct a meeting for complying the proposed design with operation and safe conditions

The tables (14) & (15) and (16) show how to identify hazard risks in construction of box culverts as to show HAZID process and risk assessment **in table (14),** also they show how to control this risk using exiting and additional controls and how to calculate residuals influence value after controlling hazard risk arise in the project as these points shown in **tables (15) & (16).** **Also, table (13)** shows hazard risk matrix which adopted in this type of construction project in Egypt.

Table-13: Numerical hazard qualitative risk analysis matrix

Severity / Probability	Concerning Injury and asset loss				
	A	B	C	D	E
Rare (1)	1	2	3	4	5
Unlikely (2)	2	4	6	8	10
Possible (3)	3	6	9	12	15
Likely (4)	4	8	12	16	20
Certain (5)	5	10	15	20	25

Where:

- **A** is the hazard severity leads to injury to be resolved by first aid or asset loss is less to 300K Egyptian pound.
- **B** is the hazard severity leads to minor injury or asset loss is less than 400K Egyptian pound.
- **C** is the hazard severity leads to major injury or asset loss is less than 500K Egyptian pound.
- **D** is the hazard severity leads to single fatality or asset loss less than 600K Egyptian pound.
- **E** is the hazard severity leads to Multi- fatality or asset loss more than 600K Egyptian pound.

Table-14: Hazard risk identification and assessment for box culvert construction projects:

Activates & Sub-activates	**Source of Danger (SOD)**	**Hazard ID. (HAZID)**	**Basic risk rank (BRR) (S,P)**
For construction phase:			
Mobilization.	Heavy loads.	Dropping heavy loads from height.	- (3, 4) Med.
	Electrical sources.	An electrical shock causes injury or fatality of workers.	(2, 4) Med.
	Mechanical equipment.	Vehicles collision with personnel or with other vehicles.	
	Moving vehicles.	Stay in pinch point or position leads to injury of a personnel.	- (3, 4) Med.
	Flammable material.	Failure of mechanical parts and may cause damage of equip. or human injury	-
	Slipping from liquid.		(1,4) Low
	Rotatory machine.		
	Unsafe equipment or tools.		(1,4) Low
	Water jet.		

Continue Table-14: Hazard risk identification and assessment for box culvert construction projects:

	Lack or appetence of oxygen.	Failing soil or rocks from of excavation intend that from an excavator or loader may cause damage of equip. or human injury.	(3, 4) Med.
Dewatering system.	Negative heights.	Failure in generator electrical insulation.	
	Harmful H_2S.	Noise pollution form generator may harm workers for higher exposure.	(2, 4) Med.
	Harmful insects.	Confined Space entry.	
	Free fall of material due to gravity.	Soil failure.	(3, 4) Med.
Excavation and temporary path rerouting.	Equipment noise pollution.	Breathing H_2S	(3, 4) Med.
Piles and foundation.		Sparks lead to fire ignition (fire hazard).	(3,5) high
Concrete work.	Sources of ignition.	Harms in respiratory system of personnel due to breathing cement fumes and vapor.	(2, 5) med.
	Sharp Heavy physical objects.		(3, 5) high.
Sidewalks and bridge.	Free fall of material due to gravity.		(3, 3) med.
Pitching and backfilling.	Sharp edges.		
Backfill the temporary path and finishes.	Cement breathing.		

Table-15: Hazard existing and additional control of box culvert construction project:

Activates &Sub-activates	**Existing Controls** (proactive "pr." / reactive"re.") - (Infrastructure "I." / Equipment "Eq." / human "H.") - (Administrative "Ad." / Engineering "Eng.")	**Additional Controls**
Mobilization.	Issuing and monitor site layouting *(I-pr.-Ad.).* Issuing and monitor lifting Plan *(I.-pr.-Ad.).* Install warning signs *(I.-pr.-Ad.).* Issuing and monitor site traffic plans *(I.-pr.-Ad.).* Review equipment certificate *(Eq.-pr.-Ad.).* Asses escape plan from site *(I.-re.-Ad.).* Review Personnel and work competency *(H.-pr.-Ad.).* Training of first Aid *(H.-pr.-Ad.).*	- Assigning more insulation for electrical parts. -Wearing protective personnel equipment "PPE" for electrical hazard. - Updating site layouting and concentrating to mitigate new pinch point according to project progress
Dewatering system.	Review all geotechnical analysis study and used approved shoring system *(I.-pr.-Eng.).* Use an appropriated excavation width for trenches with approved design *(I.-pr.-Eng.).*	Continual update of lifting and emergency plans including escape plans and site injury mitigation. Discussion of loading analysis and design during construction of foundation and piling including vibration and lateral load for trucks and loaders and excavators.
Excavation and temporary path rerouting.	Appropriate maintenance workshop and available spare parts *(Eq.-pr.-Ad.).*	More discussion of accident scenarios during construction to mitigate or eliminate these accidents.
Piles and foundation.	Wearing protective personnel equipment "PPE" & site clinic and Ambulance *(H.-pr.-Ad.)*	Safe guards and handrail.
Concrete work.	Review workers and contractor and tool competency towards activates accomplish and complying with HSE *(H.-pr.-Ad.).* Safety induction and awareness *(H.-pr.-Ad.).*	Install sparks arrestors. Decrease exposure time of noise for workers and use earmuffs for workers.
Sidewalks and bridge.	Ensuring Implementation of equipment preventive maintenance (*Eq.-pr.-Ad.).*	Use gas detectors to avoid exposure to harmful gases
Pitching and backfilling.	Use ready mix concrete in site (*Eq.-pr.-Eng.).*	
Backfill the temporary path and finishes.	Wearing protective personnel equipment "PPE" & site clinic and Ambulance *(H.-pr.-Ad.).*	

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Table -16: Hazard analysis and values of residual risk rank for box culvert construction project:

Activates& Sub-activates	Hazard ID. (HAZID)	Residual risk rank (RRR) (S,P)
Mobilization.	- Dropping heavy loads from height. - An electrical shock cause injury or fatality of workers. - Vehicles collision with personnel or with other vehicles. - Stay in pinch point or position leads to injury of a personnel. - Failure of mechanical parts and may cause damage of equip. or human injury	(2,4) Med. (1,4) Med. (2,4) Med. (1,4) Low (1,4) Low
Dewatering system.	Failing soil or rocks from of excavation intend that from an excavator or loader may cause damage of equip. or human injury. Failure in generator electrical insulation. Noise pollution form generator may harm workers for higher exposure. Confined Space entry.	(3, 4) Med. (1, 4) Med.
Excavation and temporary path rerouting.	Soil failure.	(2, 4) Med.
Piles and foundation.	Breathing H_2S	(2, 4) Med.
Concrete work.	Sparks lead to fire ignition (fire hazard). Harms in respiratory system of personnel due to breathing cement fumes and vapor.	(2, 5) Med.
Sidewalks and bridge.		(2, 5) med.
Pitching and backfilling.		(3, 4) med.
Backfill the temporary path and finishes.		(3, 3) med.

VI. CONCLUSION

This study underline the significance of accomplishing a successful risk management process for box culvert construction project. As these projects are having interrelated activities and specific risk factors. Also these specific risk factors are mostly affecting cost and time targets, thus give obligation of identifying these risk factors and showing their influences on both estimated budget and duration.

And the main conclusion shows in this study is as follows:

- ✓ This study shows how to perform a RMP for box culvert construction project and also how to use data come out from this process to achieve project deliverables.
- ✓ According to the case study shown , the cost contingency needed to resolve different risk factors arise in the shown case study is to increase the estimated budget by **11.50 percent** on the total estimated budget of the project , and time contingency **16.00 percent** to be added over the total original baseline schedule.
- ✓ This study shows in a tubular from the hazard risk identification (HAZID) framework and its assessment, as to help to perform the project in safe condition without accidents, as health safety and environment (HSE) is an important issue in construction projects.

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