Construction Project Risk Management for Performance Improvement (Polgahawela-Pothuhera-Alawwa Integrated Water Supplying Project)

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ABSTRACT

Construction risk management can be defined as the avoidance or the reduction of possible harmful incidents or actions in a construction project. It can be one of the most important factors in a construction project. Depending on the nature of the project, types of risks can be very wide in its range. Understanding the risk factors and the proper management of them, can lead a project to be completed on schedule, avoiding budget overruns whilst ensuring the safety and welfare of all the project participants. This research aims to identify the risks and their possible impacts on a specific construction project. The selected project is the construction of the Polgahawela-Pothuhera-Alawwa Integrated Water Supplying scheme located in the North-Western province of Sri Lanka. Risks categorized under the different sectors such as financial management, technical, quality, health, and safety, environment, social, legal and political were considered in the research but limited to the construction phase of the project. The methodology for this study is based on ISO 31000, which includes risk identification, risk analysis, risk evaluation and risk mitigation. To identify the relevant risks of the project, a structured interview using a questionnaire was conducted among selected project participants. In making the assessments founded on the responses received, weighted credits were assigned based on the academic and professional qualifications of the respondents. The responses were utilized in this manner to develop a listing of risk and its consequences. This highlighted the more severe risks enabling recommendations to be made to mitigate and manage such risks. The risk management process together with knowledge from previous literature was used in making recommendations to mitigate and manage risk towards project performance improvement. It should be noted that the findings could be of benefit to future contractors associated with similar projects.

KEYWORDS: *Risk, Water Supplying, Probability of occurrence, Consequence*

1 INTRODUCTION

Currently, in Sri Lanka, hundreds of construction projects are being carried out by both government and private sectors. Risk is one of the major factor that effects on each and every single project irrespective of their project value or scale. Any uncertain or unexpected incident that can be harmful or badly effect the performance of a project can be concerned as a risk. However there is a shortage of researches which have been conducted focusing a particular province in the country and especially no research have been conducted based on a project located in North-Western province of Sri Lanka. Moreover the risks of a water supplying project in Sri Lanka have not yet been researched. Since water projects are spread in a wide range unlike many other projects, risk warrants more attention.

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The technical aspects involves in all civil, structural, mechanical and electrical works, and also the working environment includes an extremely large perimeter when compared to many other projects. ISO 31000 is the worldwide accepted standard for risk management (Sousa, et.al, 2012). Therefore methodology was prepared in accordance with this standard. From Impact and Probability in Risk (Assessment - apppm, 2021), it was revealed that the probability vs consequences matrix, which is used in this study, is one of the standard and common method for evaluation of risks. Certain researches evaluates risk factors which are faced especially by water and sewerage systems construction projects (Rybka, Bondar-Nowakowska and Polonski, 2016). Risk management techniques stands more as strategies than frameworks or systems. Hence it was followed when proposing the mitigation strategies (Dikmen I., Birgonul M.T. and Arikan A.E. 2004). The literature survey depicts that the effectiveness of mitigation the risks, depends on proper identification, analysis and evaluation. However there are numerous gaps in this field, especially in Sri Lanka risk management has not been properly researched yet. There is a blank of an efficient risk management framework that suits to the country.

Aim of this research was to develop risk identification and mitigation system for the performance improvement of Polgahawela-Pothuhera-Alawwa Integrated Water Supplying Project (PPAIWSP). There were four major objectives;

- To identify the possible risks for a particular construction project
- To analyze the identified risks
- To evaluate the impact of each possible risk
- To propose mitigation methods for performance improvement

This research project is conducted to improve risk management of Polgahawela-Pothuhera-Alawwa Integrated Water Supplying Project (PPAWISP), located in North Western province of Sri Lanka. The project, which is budgeted for USD 108 million, consists of pipe laying of 320km total length, a weir across Ma Oya River, a water intake structure, and a water treatment plant with a capacity of 29000m 3 per day. The data collection of the research was done through a questionnaire and system boundary includes only the construction stage.

2 METHODOLOGY

The data which were collected, are mainly qualitative representations and they were primarily collected through rating based questionnaire system. The basic methodology was prepares in accordance with the ISO31000 standards.

Risk Identification

Risk factors that are possibly impacting on the project were revealed through interviews on live and online media participating experienced professionals representing both client and contractor.

Risk Analysis

The identified risk factors were then analyzed based on questionnaire type survey. A rating based questionnaire was prepared to assess each risk factor, with respect to consequence and the probability of occurrence. The consequence shall be the severity of the occurrence while the probability shall be the likelihood for a particular uncertainty to be occurred. Each risk section was responded by the specialists of the field and credits were offered based on the professional qualification of the respondent as in the Table 1

Table 1. Credits offered to each respondent category

Occupation (respondents)	Credits
Chief engineer, Deputy project manager, Site manager, Senior consultant engineer, HSE manager, QA/QC manager	2
Civil/site engineer, QA/QC engineer, Engineering assistant, Quantity surveyor, HSE officer	1
Junior site engineer, Technical officer Material technician, Trainee	0.5

Risk Evaluation

The collected data were then transferred to probability vs consequence matrix format to identify the risks which falls under most critical categories.

Risk Mitigation

The factors which were located in the red zone of the matrix (table 2) were considered as severe risks. The issues that might cause the particular risks were predicted and studied thoroughly. Then proposals were brought out to control those issues and to minimize the probability of occurrence of a risk by referring to the previous literature.

3 RESULTS AND DISCUSSION

3.1 Results of the risk evaluation

Financial risks
F1- Corruptions in payment chains
F2- Variations in material rates
F3- Delays in payments for subcontractors
F4- Delays in payments for contractors

Health & safety risks
H1- Electrocution
H2- Chemical hazards
H3- Injuries from machineries
H4- Collapses in pipe trenches
H5- Falling from heights
H6- Scaffolding failure
H7- Fire hazards

Technical & quality risks
T1- Insufficient quality assurance testing
T2- Insufficient supervision and inspection
T3- Damages to underground telecommunication line
T4- Faulty or incomplete drawings
T5- Poor material selection
T6- Errors in construction procedures
T7- Delays in design reviews

Management risks
M1- Contractual disputes
M2- Labor shortage
M3- Lack of skilled and unskilled staff
M4- Poor communication
M5- Bankrupt or leaving sub- contractors
M6- Material un-availability

Legal, political and social risks
L1- Political interruptions
L2- Public protests in land acquisition
L3- Public protests against pipe laying in road shoulders
L4- Legal obstructions in material transportation
L5- Changes of government policies interfering the project

Environmental & climatic risks
E1- Ground water level increases causing pipe laying difficulties
E2- Obstructions from environmental organizations
E3- River water pollution and threat to aquatic life
E4- Extreme weather conditions/ storms
E5- Flooding
E6- Increasing of river water level disturbing the weir construction

Table 2: Probability of occurrence Vs Consequence matrix

Probability → / **Consequence ↓**	Improbable	Remote	Occasional	Probable	Frequent
Negligible					
Minor		F1,H1,L1, L2	H2,H3	H4,H5,L3, E1	
Moderate		H6,M1,T1, L4, E2	F2,F3,M2, T2,L5,E3	M3,T3, E3	M4
Critical		M5,T4	M6,T5,T6, T7,E4	E5	
Catastrophic		H7	F4		

Low Risk
Medium Risk
High Risk

3.2 Discussion

Financial risks

Construction projects are highly exposed to the financial risks and changing nature of the economic aspects. In this study, four financial risk factors were identified as the most probable uncertainties. In summary, the evaluation results reveal that delays in payments for the contractor is the project's highest financial risk. The results illustrate that the variation in material rates is a medium risk as per the responses. Yet, the perspective of the respondents might have differed from the actual scenario here. Variation in material rates is the most critical and severe risk for a construction project, and it is linked to inflation, foreign currency exchange rates, etc. Therefore temporal rate variability is considered as a high risk in this study despite the responses. Main contractor is in control of delays in payment for sub-contractors, hence the risk is manageable. Corruptions in payment chains were identified to be the lowest risk. The recommendations are given to mitigate the high risks in finance identified in this study.

- Delays in payments for contractor:
  - An intelligent contract payment security system (SMTSEC) is proposed to be implemented in the project, decreasing the issues in payment for the project participants while converting the payment procedures more transparent. Here, both client and contractor initially agree on security payment conditions and those data are computerized through SMTSEC system. The system then provide the monthly payment amount by reviewing project cash flow and the updates of the project. Thereby, time efficiency of payment schedules can be improved (Ahmadisheykhsarmast and Sonmez, 2020)
- Variation in material rates:
  - It is more important to estimate the inflation that may prevail during the project and accommodate it at the tendering stage. And also the inflation and other economic rates should be monitored throughout the project. A model which can forecast the material price variation for previous similar projects would be the best solution to avoid project cost overrun (Musarat et al., 2020).

Health and safety risks

Health and safety risks are highly subjective, and many possible safety risks act on construction projects. Electrocution was identified as the lowest risk, which might have responded in such a way due to lesser weightage of mechanical and electrical work during the study's stage. According to the respondents, chemical hazards and injuries from equipment and machinery, even though has a considerable probability, will result in minor consequences. The collapses in pipe trenches were identified to have a higher probability and minor consequence. Yet it is considered as a severe risk because failures of channels are mostly fatal, and the possibility to survive is very low, and multiple workers may get trapped once (Chalupka, 2011). Similarly, falling from heights is one of the significant uncertainty which can cause fatal injuries or deaths of workers (Nadhim et al., 2016). The majority of the respondents have identified the impact of fire hazards as immensely high yet categorized in the medium-risk range due to its low probability. Scaffolding failure is evaluated as a medium risk; however, it is recommended to reduce the risk further since the upcoming stages of the project will need to engage in more high elevation constructions. Suggestions are provided for high risks; collapses of trenches, falling from heights, and scaffolding failures.

- Collapses of trenches
  - Providing training and refreshing courses on trench safety would be the best option because most trench accidents occur due to underestimating risk, overconfidence, time pressure, or economic pressure, which are preventable.
  - They are making the regulations on shoring stricter and clearly state the rules on specifications.
  - They encourage innovative techniques such as advanced trench box technologies, alternative methods to measure depths, etc.
    (Ruttenbur et al., 2019)
- Falling from heights
  - Taking proactive measures such as arranging short courses, seminars and training programs on-site is identified as the most effective solution.
  - Redesigning of construction procedures and site to reduce the complexity

- Ensuring the health condition of the employees through identification of hypertension, heart diseases, excessive fatigue, sleepiness, depression, etc. (Nadhim et al., 2016)

- Scaffolding failures
  - Employ an external contractor for scaffold erecting who may pay extreme attention to scaffolding safety and ensure no structural flaws.
  - Establish a rapid four-factor inspection method' which will ensure the safety of; planking, railing, access, and tying off to buildings.
    (Halperin and McCann, 2004)

Technical and quality risks

Technical and quality risks can cause a severe impact on project schedules, standards of the project, etc. Insufficient quality assurance testing was revealed to be having a moderate possible consequence while the probability is relatively lower. The obvious specifications in quality assurance testing might have reduced the risk probability. The design and build type contract might have reduced the drawing issues (Ling and Chong, 2005). Insufficient supervision and inspection and damages to the underground telecommunication lines are rated as a medium risk. Poor quality material selection is one of the vital risks. The cost spent on materials in a construction project is approximately 60% of the total budget; therefore, extreme attention must be paid to selecting materials (Sitota, Quezon and Ararsa, 2021). Errors in construction procedures is another severe risk that may result in immense consequence on both cost and time of the project. The delays in design reviews in obtaining approvals for modifications or variations, is also a high risk. The recommendations are proposed to mitigate high risks; poor material selection, errors in construction procedures and delays in design reviews.

- Poor material selection
  - Preparation or modification of the specification providing full details on each material referring to the standard codes and tightening the regulation ensuring the consistency with documents throughout the material selection procedure.
  - Certification of the materials via independent third party institution which should be a recognized or approved body by a relevant authority
    (Sitota, Quezon and Ararsa, 2021)
- Errors in construction procedures
  - Documentation of the construction procedures by ISO: 9001 or relevant code while improving the quality management system of the project
  - A probabilistic model of hazardous situation development is proposed to be implemented, which can reduce human errors as much as possible because human errors cause the majority of the constructions.
    (Baiburin, 2017)
- Delays in design reviews
  - Most delays are possible due to the high expectation of clients from the design and build contractor. Appoint expertise on the design management roles and maintain communication and cooperation with the client/consultant would minimize the delays in reviews and approvals.
    (Ling and Chong, 2005)
- It is highly recommended to implement a high efficient quality management system to reduce all risks related to quality aspects.
  For an example, check list can be identified as efficient and low cost QMS which can reduce most of the risks in construction (Mane, et al, 2015).

Management risks

Management risks are crucial in any construction project, which may lead the project to devastating failures. Contractual disputes may cause moderate impact, but the probability of occurrence has been identified to be relatively more minor. Since this is an international project, the disputes are comparatively less possible. Bankrupting a subcontracting company or leaving the subcontractors can have a critical impact; however, this risk also has a remote probability of occurrence. The labor shortage is another medium-range risk, while the lack of skilled and unskilled technical staff is illustrated as a high risk. The overall construction sector of Sri Lanka has a shortage of 400,000 workers (Sri Lanka's construction sector struggles with securing enough local talent, 2021), which affect each project more

or less. Material scarcity and unavailability is another critical risk. Import restrictions, rapid depletion of resources, increase in demand, poor transportation networks, etc., cause shortages in construction materials such as; steel, lumber, cement, electrical appliances, copper, etc. Poor communication was identified as high risk with an excessive probability of occurrence. Mitigation proposals are brought forward for the high risks; material unavailability, lack of skilled and unskilled technical staff, and poor communication.

- Material unavailability
  - Most material un-availabilities are due to poor material management, incorrect or delayed orders, and logistic defects. Before finalizing the orders, it is recommended to allocate extra time or rounds for clarifying the quantities and type of materials and always compare the orders with construction drawings.
  - If rare, high demanded or scarce materials are needed, ensure that stocks are always available for a considerable period and constantly investigate the availability of those materials in the market through contacting the suppliers. (Netscher, 2021)
- Lack of skilled and unskilled technical staff
  - This risk's responsibility is mainly held at the national level, which should establish a standard educational system including training and certification in the construction industry.
  - At the project level, ensuring attractive and appropriate salaries and benefits for skilled workers, implementing strategies to motivate workers, and employing multi-skilled technical workers would considerably reduce the risk.
  - (Kumara, 2017)
- Poor communication
  - Arranging programs to improve the cooperation between laborers and officers/supervisors, take necessary actions to minimize on-site conflicts and bullies, reduce noise levels that can interrupt voice commands and introduce creative and attractive communication techniques and strategies would reduce the risk of poor communication (Olanrewaju, Tan and Kwan, 2017).

Legal, political and social risks

Construction projects, especially launched to provide an essential utility to the public in a particular area, are integrated with the local society. Hence, it is crucial to assess the possible uncertainties arising from the community and local political institutes and the legal system. Political interruptions in deciding distribution zones have been rated as a low risk. The project is foreign-funded and directly handled through the central government, therefore, forces of local political authorities are impossible (Seneviratne A., personal interview, 2021). Public protests against land acquisition and compensation processes were identified as less probable. However, protests against pipe laying in road shoulders has been rated as a risk with high probability. The low quality backfilling, barricading access roads for a long time, damages to newly built roads, etc., might have lead the public to protests. Legal obstructions in material transportation is another issue that is mainly related to soil, sand, and coarse aggregates. But as this construction is a government project, the legal interruption is relatively low. Changes in government policies also identified to be a medium risk. Considering the comparatively high probability of public protests against pipe laying in road shoulders, recommendations are given to mitigate this risk;

- Public protests against pipe laying in road shoulders
  - Accelerate the pipe laying process and repair the access road and entries as soon as possible. Using the 'Micro Tunneling' technology wherever possible would do least disturbance to the public.

Environmental and climatic risks

The project contains components such as weir across Ma Oya River, which can impact on the environment easily. Obstructions from environmental organizations is a risk that has a moderate consequence but may occur remotely. River pollution is an obvious possible risk during the construction of weir by adding cement materials, chemical compounds, and other hazardous or poisonous materials into water. Groundwater level increases is another medium-range risk that can disturb pipe laying in trenches. Extreme weather conditions or storms may decelerate the performance of the project; therefore it is rated as a high risk. Flooding and river water rise was identified as the most severe risks. Both can

cause a critical impact on the project while river water increase has an even probability of occurrence. The high risks, flooding, river water increase and extreme weather conditions are considered in proposing risk mitigation methods.

- Flooding
  - Analyze and estimate the flood frequency and severity and predict the impending or possible floods using advanced technologies or software (example: HEC-HMS). Then it is possible to arrange the construction activities in an order which can reduce the potential risk.
- Increasing of river water level disturbing the weir construction
  - The construction of a strong cofferdam was identified as the best solution to mitigate this risk. Instead of the existing earthen cofferdam, it is recommended to construct a rock fill cofferdam that can endure higher velocity of the water.
- Extreme weather conditions/storms
  - High attention must be paid to this risk factor in the project planning stage. A risk management system integrated with extreme weather conditions predicts data, would reduce the risk. (Wedawatta, 2011)

4 CONLUSION

The improper risk management adversely impact on construction projects. Countries like Sri Lanka continually experience project failures due to unsuccessful risk management. Especially in large scale projects such as water treatment and supplying projects, the mitigation of risks becomes highly complicated. This study investigated the risks associated with Polgahawela-Pothuhera-Alawwa Integrated Water Supplying Project. A survey was carried out through a questionnaire with participation of project professionals, thereby severe risks were identified under six main categories as;

Financial – Delays in payments for sub-contractors and variation in material rates
Health & safety – Trench collapses, falling from heights and scaffolding failures
Technical & quality – Poor material selection, errors in construction procedures, and delays in design reviews
Management – Material unavailability, lack of skilled and unskilled technical staff, and poor communication
Legal, political & social – Public protests against pipe laying in road shoulders
Environmental & climatic – Flooding, increasing of river water level and extreme weather condition

It is emphasized that severity of risks should be determined with respect to both consequence and probability of occurrence. The most suitable risks mitigation strategies were proposed for each of those factors by referring the literature. In summary the paper reveals high risks of the acting on the selected water supplying projects along with recommendations to mitigate them. The results may be applicable to similar scale water projects which are located all over the country. It is recommended to conduct a risk analysis for any contractor before starting a similar project. And also continuous updating of the analysis would be significantly supportive. Future studies which can explore risks related to all stages of the project are suggested.

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