Risk Management as a Dynamic and Continuous Process in the Life Cycle of a Typical Major Civil Engineering Project

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Abstract

While many construction industries acknowledge the importance of risk management policies but hardly do they implement a defined technique in risk management. Many construction practitioners employ linear risk management process by applying risk mitigation process as and when risk occur. When project managers and practitioners ignore the application of risk management in real time projects, the implications are almost usually observed in the projects through forced variations, scope change and high uncertainties. In a complex and major civil engineering project, the risk exposure environment changes and shifts constantly due to external factors, changing objectives and other multiple dynamic variables. Quite often, initially planned risk mitigation targets do not generate intended outcome due to inadequate application of risk assessment process. For this reason, the risk and uncertainty management must be continuous, holistic and real time throughout the project life cycle from inception to completion. The ultimate goal of risk management plan is to achieve the project objectives in terms of cost, quality and time. Thus, risk management in complex and major civil engineering projects must be applied in real time, continuously and with utmost importance.

Key words – *risk management, residual risks, uncertainty, work packages, risk register, risk report and review, threats, Work Breakdown Structures, change control*

Introduction

Risk is an upcoming performance of an activity for which outcome is very uncertain. It can be potential loss of time, resources and any other activities. (Schuyler, 2001) argues risk is constituent of threat and opportunity requiring strategies for better outcome. (Simon, 2009) defines risk management in constructions as a method of managing uncertainty where negative outcomes are minimized and positive outcomes are capitalized upon. The risk and uncertainty management must be continuous, holistic and conducted in real time to overcome the shifting forces and constant changes in project life cycle caused by external factors and changing objectives (Jaafari, 1999). The continuous and dynamic environment of construction projects creates high uncertainty of risks and its planned mitigation targets, therefore requires continuous assessment of its processes throughout the project duration (Eshan et al, 2009).

In this paper, the dynamic and continuous nature of the risk is analyzed in reference to a typical major civil engineering construction project life cycle discussing why and how risk management is necessary and implemented at all stages of the project life cycle. Every single engineering project has its own life cycle with its unique stages and levels throughout its duration. However, there is no single best approach in organizing stages in the project life cycle of any major civil engineering project. For the purpose of this paper and to effectively understand the risk management at different levels, the life cycle of a typical major bridge engineering project shall be broadly classified into four major stages: Pre-construction stage, Procurement stage (bidding and awarding stage), Construction stage and Closeout stage. Fig. 1 shows the life cycle of a typical major civil engineering project.

Major civil engineering construction project is a complex and systematic project involving variety of risks at all times of its life cycle from preparation to completion (Li et al., 2103). The objective of this paper is to understand why risks changes in every stage of project life cycle and how risk management can be applied at various levels throughout the project duration. A comprehensive template on risk management process in a project life cycle is proposed at the end of this paper to encourage construction practitioners to access project risks at a glance.

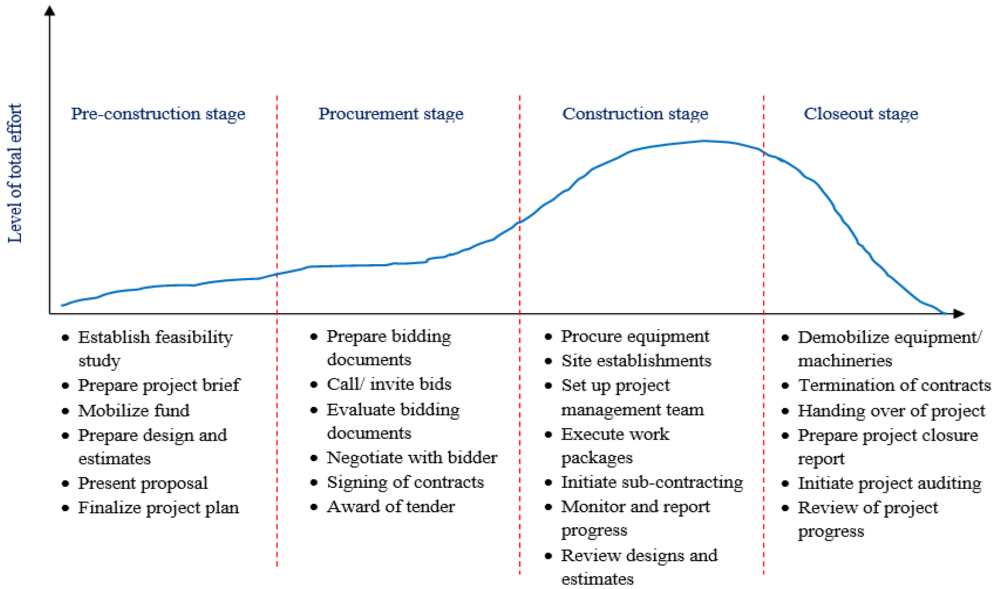

Fig. 1 *Life cycle of a typical major civil engineering project*

1. Pre-construction stage

Pre-construction stage includes all the activities before actual execution of the project where most important decisions of the project on cost, schedule and scopes are defined. Activities such as feasibility study, design and estimation, mobilization of funds, meeting with stakeholders and preparation of contractual documents takes place in this stage of the project life cycle. This stage is the most important stage of the project in terms of risk management because the degree of uncertainty is the highest (See Fig. 2).

1.1 Why risk management is implemented in this stage?

Any changes in the scope of the project in this stage is easier to incorporate and costs less than any following stages. The ability to change the scope of the project decreases continually as the project progresses (Fabrycky & Blanchard, 1991). Most of the project managers and organizers are keen to invest time and effort in risk management tools at the early stage of the project rather than during the execution when they are subject to mounting pressures (Raz & Micheal, 1999). Studies have shown that early identification and management of risks and opportunities have worked well for the success of any civil engineering project. Therefore, risk management is essential and important aspects of pre-construction process in order to obtain project objectives.

1.2 How risk management is implemented in this stage?

Risk Identification is the first and perhaps the most important step in risk management process as the failure to identify any particular risk ceases the implementation of any other steps in the risk management of that particular risk (Dinu & Ana, 2012). Since it is nearly impossible to manage all risks in this stage, the project may adopt to identity key and critical risks to be appraised as per previous experience. Dr. David Hillson suggests organizations to screen out inherent risks using a model developed by Simons, known as the "Risk Exposure Calculator" which can divide projects risk exposure into three categories namely safety zone, cautious zone and danger zone. This process helps project management committee to prioritize and focus on the area most at risk to save time and resources. Some very common method of risk identification used in mega projects are: brainstorming, risk database analysis, checklist analysis, risk questionnaire and risk survey.

Brainstorming being an open and free approach encourages collaborative effort to generate lists of risks. Inviting and engaging relevant stakeholders in brainstorming not only results in identification of key risks but also builds greater sense of project risk ownership and team commitment to manage risk for the duration of the project (Gazaryan, 2107). In the pre-construction stage risk database analysis could provide information describing risk associated with choosing project location, design consideration, political influence and financial issues, which could be evaluated and appropriate data for risk management could be adopted.

Qualitative and quantitative analysis of identified risks are performed to evaluate the impact of risks and opportunities in terms of its mitigation. Fairly simple and most commonly practiced, qualitative analysis predicts the risk event outcome using available data and generating numerical value (Shuttleworth, 2017). It is clear that, this method being simple can only prioritize the risks but cannot generate subjective assessment of risk occurrence and its potential severity for a very large civil engineering project. Quantitative analysis translates the probability and impact of risks into measurable quantity through contingency value to project time cost and schedule (Werner and Meyer, 2015). The use of Monte Carlo Simulation to generate random potential scenario and potential approximation of risk impact could be practiced in major civil engineering project of high value. In a major civil engineering project, it is quite natural that certain project variables effect the project outcomes usually in terms of cost or time to completion. The assessment of such effect is usually performed through sensitivity analysis where the risks are treated independently. The sensitivity analysis isolates the variables and records the range of possible outcomes and analyzes the various risks to the project by looking at all aspects of the project and their potential impact on the overall goal.

Risk mitigation plan is important process in the pre-construction stage to identify the risks that could either be avoided, transferred or shared. Some critical risks in design could be avoided by relaxing the objectives of the project and clarifying the requirement with proper communications. As major civil engineering projects are multidisciplinary in nature, series of conflicts between specialists of different disciplines may occur in the pre-construction phase mainly because works of all consultants are interdependent (Baydon, 2011). Organizing frequent meetings between conflicting parties to find a compromise that suits the best interest of the project can possibly avoid risks related to conflicts of interests. Technical risks such as design errors, owner's change orders and incomplete drawings seems evident particularly due to complex nature of the project. While employing specialists and reputed firm for the task may certainly reduce the risks, providing sufficient time for the design team, issuing well defined design brief and enforcing change control system is highly recommended (Dash, et al., 2005).

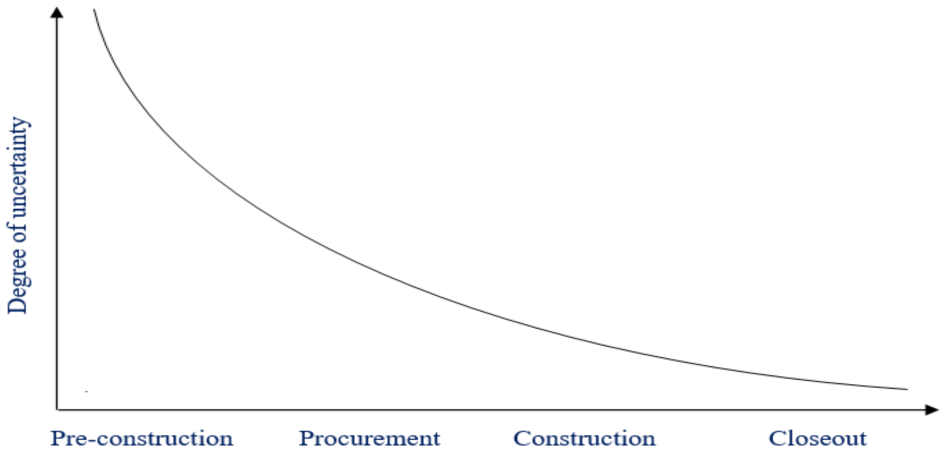

Fig 2 *Degree of uncertainty at different phases of project life cycle*

1.3 Strengths and weaknesses of the processes

In this stage potential risks of all other stages are identified so that proper assessment can be made and effective risk response technique could be adopted during subsequent stages. Availability of multiple stakeholders for decisions making in this stage facilitates wider generation of information and data to be critically applied during risk analysis. One of the biggest strengths of risk management in this stage is the opportunity to change with minimum cost and impact to the project.

Despite early efforts of planning and evaluation on projects, many basic information required to make decisions changes with time creating unknown exposure to risks and uncertainties making risk management more difficult (Jaafari, 1999). The use of sensitivity analysis doesn't yield mathematical logic and fails to focus on the interrelationship between underlying variables, which limits its application in significant projects. Similarly, the use of sophisticated software of risk analysis like Monte Carlo Simulation usually depends on data input assumptions which are generally defined by the user and may have considerable impact on the results of the simulation. Studies have shown that often due to insufficient data about the project in the pre-construction stage and substantial cost relative to the value of project, quantitative risk analysis are usually ignored by project

(Werner and Meyer, 2015). This weakness creates loss of opportunity in effective risk management processes and undermines the use of risk assessment software. It is quite natural that in the pre-construction stage of project life cycle, the involvement of contractor is very minimum. As a result, the contractor often does not get equipped with the risk assessment and mitigation measures defined in the pre-construction.

2. Procurement Stage (Bidding and award stage)

The procurement stage involves series of activities from sourcing, planning and managing of bids and tenders. This is a transition stage from design into construction. Highest level of integrity and consistency is expected in this stage to address potential risks of corruptions, accusations and conflicts of interest.

2.1 Why risk management is implemented in this stage?

The procurement phase of a typical major civil engineering project faces complex technologies, unusual legal or contractual agreements, sensitive environment, stringent regulatory or licensing conditions and unbalanced cash flows (Broadlef, 1999). Apparently, such challenging environment creates space for compliance risks arising due to corruptions, regulations and oversight. Failure to manage these risks pose threat to project's reputations, investor's trust and public accusations. Implementation of risk management is important in this stage to identity suitable approaches in finding a competitive contractor while also carefully applying all procurement norms through bidding process. Issues of oversights and errors by procurement personals while evaluating multiple and complex bidding documents may risk legal disputes between contractor and client.

2.2 How risk management is implemented in this stage?

Risk management in procurement phase involves series of steps. (Barden & Kenneth, 2010) recommends mapping of various procurement risks with various stages of procurement cycle and identity indicators for the suspected irregularities. SWOT analysis could to adopted to identify key risks associated with the procurement stage of project life cycle where the client or the owner is usually involved. Strength can examine the client's skills and core competencies, Weakness can show the areas of improvement and the Opportunities and Threats shall identify the strength and weakness of the client (Verma, 2017).

Identified risks are evaluated and categorized according to its source, severity and its probability of occurrence. It has been suggested that with the report from client's response on the SWOT analysis, a standard risk assessment review should be prepared on the basis of risk associated with client's procurement program into High Risk, Medium Risk and Low Risks (Enterprise Service, 2014). As per the severity of the risks identified, the client may want to decide on mitigating measures as per its capacity, time and cost.

Many risks related to contract and bidding documents can be effectively managed by organizing a consultative meeting with all prospective bidders which is more technically referred to as "Pre-bid meeting". In addition to responding all queries and concerns of the bidders, the pre-bid meeting facilitates interpretations of technical specifications and procurement aspects which would reduce the future risks of accusations and complains (Lynch, 2017). Use of online bidding system technically known as e-bidding or e-tendering could reduce risks related to bid submission and evaluation while also allowing more user-friendly, check and balance system and reducing time and effort compared to the conventional method of tendering. Sometimes as per nature of the project and in the interest of time, owners can simply transfer all his risks in procurement by opting a type of contract called "design/built projects" which is more comprehensively known as "turnkey projects". It has been suggested that turnkey projects reduce the liability of owners in terms of design, procurement and quality through single point of responsibility contract agreed with the contractor (Shapiro, 2000).

2.3 Strengths and weaknesses of the processes

Risk management processes in the procurement stage has lots of opportunities in terms of risk mitigation, risk reduction and risk transfer.

Considering the complexities of the project, the owner has the option to transfer risk to the contractor through design/built model of contract, while contractor has the opportunity to eliminate risks related to all bidding submissions. Opportunity also exists in this stage to possibly identity potential construction risks through proper review of the design and contract documents during the pre-bid meetings and incorporate necessary changes at minimum cost and damage to the project scope.

The primary weakness here is the limitations due to the procurement rules and regulations and specific country's law which restricts certain flexibilities while applying risk management processes. Also, the lack of specialists and competent personals with technical knowledge in procurement department may miss the technical aspects of the project during procurement processes which may later put the constructor into more risky situations.

3. Construction stage

This stage is the busiest and most complex phase of the project life cycle involving massive use of fund, technologies, manpower and time. The success of this stage usually depends on the outcome of the previous stages. Similarly, the risks in this stage largely depends on how risks are managed in the pre-construction and procurement stage. However, this stage itself encounters uncertainties and surprises which are difficult to be identified in the early stage of planning phase, hence requiring its own risk management processes.

3.1 Why risk management is implemented in this stage?

The success of any typical major civil engineering project depends largely on the management of the construction stage regardless of outcome of pre-construction and procurement phase. Huge consequences from loss of personal life to disqualification of contractor may occur if the risks in this phase are not properly monitored. It is generally observed that significant expenditures and time is lost while investing on unnecessary activities resulting due to circumstances under the control of the project team, which otherwise could have been avoided. This happens when the project team keeps themselves busy on their project scope avoiding risks management consciously or subconsciously.

3.2 How risk management is implemented in this stage?

The general method of risk identification is ineffective and inadequate for the complex construction environment of large project since there are too many uncertain factors during the course of construction. (Li, Zhang and Fu, 2013) suggests modular method of risk analysis in major civil engineering projects based on WBS-RBS (Work Break Down Structure-Risk Breakdown Structure) where construction phases of large projects are established and appropriate risk management techniques are applied at each Work Package (WP). In risk management, work package (WP) is the elementary unit of risk identification which makes the project manager to clearly, systematically and effectively identify the risks and establish the dynamic database of the risk source. This method of risk identification could simplify risk evaluation and risk mitigation processes as it provides systemized approach to risk source which otherwise becomes complex in a major civil engineering project. Risk evaluation with both qualitative and quantitative analysis is implemented in this stage of project life cycle to ascertain risk priority areas and potential impacts so that the project manager and his team could prioritize their effort and time on those risk with relatively high impact to the project.

One of the most common sources of risk in the construction phase is the introduction of design changes which leads to the disruption of schedules and resources, affects cost and time and ultimately hinder project performance. (Chapman & Ward, 2003) recommends establishment of standard project change control procedure and set up adequate coordination, communication and documentation of changes to minimize the risks of subsequent disputes between client and the contractor on the liability of cost and delay. The occurrence of force majeure events in construction is virtually unpredictable and has significant effects in projects and can have significant costs and delays (Chapman, 2014). Such risks shall be shared by both client and the contractor, but however, unfortunately, in many contracts the risk of force majeure is shifted to the contractor.

Some risks out of control for client and contractor could be simply transferred to third parties. Occupational risk related to health and safety in project are by law required to be eliminated, prevented or controlled and are generally given top priority in any civil engineering project. According to American Society of Safety and Engineering (ACSE), an independent team within the project shall be constituted as a separate Health and Safety Department to develop, monitor, regulate and report all health and safety activities in the construction. Often some risks can be simply accepted or retained by the contractor by developing a contingency plan to execute should the risk event occur.

In a typical major civil engineering project, the project team encounters plenty of surprises arising due to procurement and supply uncertainties. While such uncertainties are common and are usually unavoidable, the contractor may adopt the global practice to transfer the risk to the supplier through proper contract agreement. It would indicate that the general reaction to the global company's supply disruptions and interruptions, dual sourcing and using multiple suppliers can be an effective tool in dealing with unexpected supply breakdown (Yu, Hassheng et al., 2008). Similar system could also be adopted to prevent potential risks related to breakdown of equipment and machineries.

Since project elements and project risks are growing increasingly interdependent, it is sometimes observed that utilizing the creativity of project employees and accommodating their holistic views benefits in mitigating risks that might be unforeseen by the project manager (Williams, 1999). The author argues that though employee empowerment has certain conflict with the project risk management, the project team should be empowered to take actions cross-impacts of planned actions in the interest of the overall project. This is particularly suitable in mitigating risks beyond the reach of the project manager since subordinates shares the responsibility of risk management through empowerment.

3.3 Strengths and weaknesses of the processes

The use of contingency fund gives certain room of comfort to the project manager in terms of accepting or retaining certain risks deemed necessary in relative to the project overall cost. Given that a typical major civil engineering projects maintains separate health and safety department in the construction site, the occupational health and safety risks of workers are properly monitored and accounted. Also, the risk reporting and reviewing system generally adopted in this phase provides documented and substantial information on the risk management processes of the entire construction duration aiding in improved application of risk management processes in the similar future projects.

The effective application of risk management in construction phase is often largely dependent on the perspective of the project manager on risks. The process of risk management requires project managers to expose risks for the purpose of analyzing and reporting them which may create anxiety among stakeholders and may even result in the cancellation of the project in an extreme case (Kutsch and Hall, 2009). This according to the author, accounts for 'deliberate ignorance in risk' where project managers limit the degree to which they identify risks questioning the credibility of the risk management processes. Quite often, currently adopted modern risks assessment tools are not adequate to meet the increasing dynamic and continuous risks factors in complicated major civil engineering project. Some risk though identified as less severe in the initial stage of construction and given less priority may pose greater threat at the later stage. Therefore, the process of risk management in construction phase has certain weakness in terms of accurate prediction of change in the project variables leading to change in the impact of its risk.

4. Closeout stage

The closeout stage is the transition from the construction to the actual use of the constructed facility. The general trend suggests that the degree of uncertainty is lowest in this stage of the project life cycle as the scope of the project is almost under completion. However, the risk management processes still have significant function in this stage, though sometimes given less importance as the project activities comes to an end.

4.1 Why risk management is important in this stage

The closure stage of the project involves activities related to demobilization of equipment and machineries, termination of supplier's contract, communicating project handover to client, project closure report preparation, project auditing and releasing project resources. Such activities require proper and adequate plan to reduce potential risks arising from contractual lapses, documentation errors and stakeholders' influences. The approach of risk management in the closure phase of project provides visibility in terms of budget and timelines and allows an accurate performance tracking of the closing phase, which is always critical in terms of resources where the organization can't afford to waste any asset (Laser et al, 2010). The closeout stage of the project also encounters risks which are left after all planned risk responses had been implemented in the pre-construction and construction stage. These risks are referred to as residual risks. Sometimes unexpected risks arise due to the outcome of risk response implemented for the primary risks. Such risks are termed secondary risks. The residual and secondary risks generally unavoidable in large projects, often said to pose threat especially during operation and maintenance if not managed at the closeout stage of the project life cycle.

4.2 How risk management is implemented in this stage

The risk management processes in closeout phase of project follows similar procedures as of earlier phases of project life cycle, though intensity of its application may be relatively less. Some common risks identified in the closeout phase include loss of project income through waste of project assets, inefficient demobilization system and improper handing over documentations. In addition to risks of its own, some risks identified in the pre-construction, procurement and construction phases of the project life cycle though being managed in their respective phases continue to pose threat even in the closeout phase. Usually residual and secondary risks are those which are left even after implementation of contingency plan. Therefore, project generally maintains a backup plan commonly known as the ‘fallback plan' to combat such risks.

It is often observed that project encounter risk in the loss of strategic assets during the completion and at the closure of the project. Strategic assets are core competencies in the form of human knowledge and technological strengths that allow a firm to outperform others (Kam & Janice, 2002). Since project is a temporary endeavor, a firm may lose an experienced and competent project manager and his team after the completion of the project. This may pose risk of loss in strategic assets of the firm, and may impact the future endeavor. A proper strategic plan to retain the project team often in the form of increased incentives and recognition should be placed to avoid such risks. Another aspect of risks management in the closeout phase is the risk reporting and review system. Risks reporting and review tools such as risk assessment report, risk action report, risk communication plan and risk registers maintained continuously throughout the project duration is finally summarized to evaluate and analyze overall project risks. Such practice shall not only serve as a future reference but provide guidance on risks management processes for future major civil engineering projects.

4.3 Strengths and weaknesses of the processes

Since risk management processes is being continuously implemented in the earlier phases of the project life cycle, its intensity of use is relatively low, especially if the risk management is successful in the earlier stages. This strength ensures implementation of risk management processes in relatively lower cost, lesser effort and time in the closure stage when the project cannot afford to lose any time and effort. In addition, the final stage of the project life cycle holds significant records of all project activities including success and failure stories and risk management reports. Such information on risk management successes and failures provide valuable information to the project team in planning and preparing for future similar major project with better and effective proposals to risk management strategies.

It is evident that the cost and time of incorporating any changes in the scope of the project is maximum in this phase of project life cycle as the project is already under completion. This weakness prohibits any major changes to the project scope though identified as a potential future risk during risk assessment. Due to the project being nearing for completion, the attitude of project team may suddenly change towards risks in the closing phase. The project team tend to provide less importance to risk management believing the risk sources have either been eradicated or controlled. This weakness in the perception of project team results in poor or futile implementation of risk management processes in the closeout phase of a typical major civil engineering life cycle.

Table 1: *A typical framework to employ risk management processes with strengths and weakness in a civil engineering project*

Project life cycle	**Risk identification and mitigation**		**Strength and weakness of Risk Management Process**	
	Type of risks	**Proposed mitigation measures**	**Strength**	**Weakness**
Pre-construction stage	- Conflicts between specialists and consultants	- Frequent meetings, dialogues and communications	- Opportunity to change with minimum cost - Sufficient time to identify and analyze risks	- High exposure to risks - Complex and difficult to access risk behaviors - Less involvement of contractors
	- Design errors	- Issue well-defined design brief		
	- Owner's change order	- Enforce change control system		
	- Incomplete designs	- Sufficient time to the designers		
Procurement stage	- Communication risk	- Conduct pre-bid meeting	- Opportunity to transfer risk through Turnkey model - Identification of construction risks during pre-bid meeting with contractors	- Limitations due to procurement rules/ regulations - Inadequate technical knowledge by procurement personnel
	- Risks related to bid submissions	- Use online tendering (e-bidding/ e-tendering)		
	- Project complexity risk	- Use Design-Built (Turnkey)		
	- Corruptions/ allegations	- Discard single point of contact		
Construction stage	- Design changes	- Establish change control system	- Use of contingency funds	- Risk management largely

	- Liability risks	- Proper documentations	- Opportunity to use risk reporting and review forms - Availability of diverse project team members to mitigate risks occurrence - Opportunity to transfer some of the risks	dependent on PM's perspective - Deliberate ignorance of risks - Huge cost and time loss to correct some risks - Hiding of risks by project team - Risk fatigue due to dynamic and continuous appearance of risk
	- Force majeure	- Share the risk and transfer		
	- Occupational risk	- Strong independent OHS team		
	- Weather risk	- Accept and mitigate it		
	- Death and injury	- Insurance		
	- Construction errors	- Use contingency funds		
	- Supply disruption	- Use dual sourcing		
	- Risks beyond reach of PM	- Team empowerment		
Closeout stage	- Risks due to demobilization	- Proper planning and care	- Low intensity of risk event if managed well earlier - Lower cost, time and effort if successful earlier - Availability of risk registers	- Maximum cost to incorporate changes - Complacency by project team - Huge changes to lose cost in wastes
	- Termination of contracts	- Proper termination clauses		
	- Loss of strategic assets	- Retention plan and incentives		
	- Secondary and residual risks	- Employ fallback plan		
	- O&M risks	- Draft proper O&M documents		

Conclusion

The objective of this paper was to establish why and how risk management is dynamic and continuous processes in regard to a life cycle of a typical major civil engineering project. The life cycle of a project, for the purpose of this paper has been defined into four stages: pre-construction stage, procurement stage, construction stage and closeout stage.The principle of risk management from risk identification

to risk evaluation, risk mitigation, contingency management and risk response has been discussed at all phases of project life cycle including assessment of the strengths and weakness of the processes across all levels of the project duration. In order to achieve the project objectives and value of cost and time, the implementation of risk management shouldn't be restricted to a certain level of project duration, but rather given equal importance at all phases of project life cycle.

It is observed that the due to unknowns and uncertainties, the performance of risks deviates from its predicted behavior and therefore regular reviews and modifications of risk management processes is imperative throughout the project duration to reduce its impact. Also, the dynamic environment of a complex civil engineering project generates new risk sources and forces the change in the risk management process and diverges the planned target. These inevitable circumstances in project pushes for the continuous monitoring and implementation of the risk management processes throughout the project life cycle irrespective of perspective of client or the contractor.

While risks management is usually aimed in reducing the potential threat in the project and realizing the optimum benefit of cost and time, it encounters limitations generally in respect to its assessment methodologies which sometimes are subjective in its results. However, the fact that risk management is all about assessments and predictions of future uncertainties and threats, such limitations are out of control of any human inventions. Therefore, risk management though involves cost and effort, is considered as project manager's friend and ally and one of the ten knowledge areas in which a project manager must be competent, as stated in PMBOK.

This paper limits the study on the application of risk management processes only in typical major civil engineering projects involving highly complex and changing environment. It will be interesting to see the difference and intensity of risk management processes across medium and small-scale civil engineering projects and study the risk management application and its relative cost with project size and value.

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