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RISK MANAGEMENT IN DEEP EARTHWORK/EXCAVATION (A CASE STUDY OF THE 6 BASEMENTS EARTHWORK/EXCAVATION FOR CIVIL BUILDING IN VIETNAM)

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Abstract

Basement has become very popular for modern civil construction in Vietnam as 60% of the civil building of the country has more than two basements. However, many projects find it extremely risky to execute earthwork, especially with the depth of more than three basements. It is therefore very important for developers, designers, and constructors to study risk management in deep basement earthwork/excavation.

Risk happens in all aspects of an earthwork project, the problems could lead to cost overhead or waste of time, and it can even result in physical hazard to worker, including injuries, serious damages or even death. From the demand for knowledge of earthwork risk management, this study develops an advance framework to control risk in an earthwork projects. It consists of risk counter in all stages of the project. This study covers four earthwork stages, including 'Acquiring, Ignition, Execution and Closure'.

There is a gap between theories and practice in Vietnam because of the lacking formal risk management system in deep excavation work. Therefore, this research outlines some of the risk management theory but mainly focus on analyzing the practice of a real life project, which contains the excavation of six basements. As a result from this study, some recommendations will be given to improve the knowledge of Risk Management System for Deep Basement Earthwork/Excavation.

Keywords: *Excavation, Earthwork, Risk Management, Earthwork Management, Deep Basement Excavation, Risk Management System, Earthwork Risk, Excavation Risk.*

1. Introduction

1.1 Background

Most of the high-rise buildings relate to earthwork and excavation for the foundation, water drain and basement. Deep excavation poses the greatest risk and is more likely than some other excavation-related incidents to result in worker fatalities (Safe Work Australia, 2012). One cubic yard of soil can weigh as much as a car and an unprotected hole can be an early grave. In fact, a basement can go from 6 up to 35 meters depth underground so deep basement excavation failures are extremely dangerous because they occur quickly and very hard for worker to escape especially when collapse is extensive. Thus, earthwork presents serious risks to all workers involved.

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Earthwork work generally means work involving the removal of soil or rock from a site to form an open face, hole or cavity, using tools, or machinery in which risk can arise from various sources. Risk management is therefore increasingly becoming an extensive component an earthwork projects in a pursuit to efficiently deal with unexpected events and ambivalence.

The damaging consequences imposed by risk and uncertainty could harm an organization tremendously in term of financial and reputation. As a result, it is extremely important for an earthwork organization to implement formal risk management system to ensure the project meet quality, safety and under budget.

Risk can come in many forms in a deep excavated project such as physical, financial, political, environmental, and social. Many earthwork organizations therefore aim at implementing formal risk management systems in order to take control over risks and potential hazards. Risk management involves identifying, assessing and responding to risk as it is crucial to corporate as an united team from the earliest possible phases. As a result, identify and efficiently deal with risks when they occur (Potts, 2008).

1.2 Problem statement

Basements are generally are more difficult to excavate as the depth increases, hence more expensive. In the central area, moreover, the high price of the land and limited parking space force the owner to build multi-story basements and underground parking garages. This is becoming very common in central Vietnam where larger basement problems have been addressed by local government as they are the cause of significant disruption and disturbance for the neighbors.

Increasing number of hazardous relating to earthwork for the past three decades is significant due to the utilization of heavy equipment on construction sites (Mohamed, 2015). Variety of fatal hazards exist on heavy construction sites that cause suffer for the workers, mainly physical harms such as get hit by vehicle, fall down the hole, etc.

The benefits of risk management are the knowledge of the identified risks arises within a project. It supports decisions through specific analysis and historical data that could be reinforcement for future assessment. Unfortunately, many earthwork organizations are not accept the importance of risk management implementation as an essential factor that helps complete the project.

The lack of formalized procedures often leads to an inefficient implementation of risk management. In fact, the procedures need to be continuity in the different project phases and enhance interaction between contractors. In pursue of effective risk management, an earthwork organization has to familiar with risk responsibilities, risk management capabilities and risk conditions. For years, the earthwork industry has had a poor reputation for managing risk resulting in delays and a failure to achieve quality, safety and cost objectives (Banaitene and A. Banaitis, 2012).

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The study in academic literature relating to risk management within the construction industry is vast, however, not many formal studies about risk management for earthwork, particularly deep basement excavation presented in practice.

1.3 Objective of this study

The first objective of this master thesis is to study the theory of risk management in construction as well as exploring the theoretical application in relation to risk management.

The second objective is to investigate the perception and practical implementation of risk management using a real life deep basement excavation project.

The third objective is to develop risk management frameworks for deep basement excavation so that an earthwork organization can apply for future project.

2. Literature review

2.1 Risk management theory

Nature disaster could happen so even the best planner can go failure through the fault of no one. The change of economic and financial condition could also lead to disaster performance. The contract administrator could identify some of the biggest risk can happen in the project and come up with strategies to deal with those risks if they arise. The strategies should allow some flexible time and budget so the contractor could recover from the risks that constrain the success of the project (Papageorge, 1988).

The conditions of the contract need to be monitored carefully to identify the risks that could occur during the construction. In fact, nature disaster, financial difficulties, and hazard are common risks that a contract often encounters. Prepare counter strategies and plan for possible action to avoid additional cost or missing the deadlines (Bonander & Ulriksson, 2016).

In fact, Gajewska and Ropel (2011) identify the risk management plan as follow:

- Risk management plan
- Identify risks
- Perform qualitative risk analysis
- Perform quantitative risk analysis
- Plan risk responses
- Monitor and control risks: Risks can be monitored on a continuous basis to check if any change is made. New risks can be identified through the constant monitoring and assessing mechanism

“The aim is not to obtain perfect predictions of future events, rather it is the recognition of potential risk sources with high impact on a particular project, should they occur. It is impossible to identify all potential risks and the purpose should not be to do so” (Smith et al., 2006)

To maximize the efficiency of risk management, the *risk management plan* (RMP) should be continuously developed during the entire project. In this way, risks will be discovered and managed throughout all the phases (Smith et al. 2006).

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The *identification of risk* is known as the most important part in risk management (Banaitene & Banaitis, 2012).

"Qualitative methods for risk analysis are based on descriptive scales, and are used for describing the likelihood and impact of a risk. These relatively simple techniques apply when quick assessment is required" (Cooper et al. 2005). *"Quantitative methods for risk analysis* need a lot of work for the analysis to be performed.

Risk response "indicates what action should be taken towards the identified risks and threats. The response strategy and approach chosen depend on the kind of risks concerned" (Winch, 2002).

Risk monitoring is "vital since all information about the identified risks is collected and monitored" (Winch, 2002).

Smith et al. (2006) provide an understandable definition of risk management system and how it is used in practice. Risk management system is not a tool to predict the future; it is used for facilitating the project to help generate better decisions based on the information from the investment. The fore, the decisions is more accurate and result in effective performance. In theory, risk management system is defined as a process with procedures which involves the systematic application of management policies and processes to the form the system of identifying, analyzing, responding, monitoring and communicating risks (Cooper et al., 2005).

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2.2 Earthwork theory

"Risk management for earthwork involves thinking more broadly about risk and uncertainties, not just spotting work-related hazards". The engineers need to take into account the reason of any harmful event, the level of impact and the likelihood of occurrence. Then, form a system that could eliminate or minimize the risk (Worksafe NZ, 2016).

The contractor need to make sure that the worker only enter the site when they ware protection and aware of the deep excavate hazards. Many hazards relate to earthwork such as falling loads, dusty air, and mobility of heavy equipment harzard.

The dangerous of an excavation collapse make it extremely important to manage risk in the earthwork project. "The consequences are significant as the falling earth can bury or crush any person in its path resulting in death by suffocation or internal crush injuries" (OSHA, 2015).

It often takes 3 to 6 months to complete excavating a basement of a house depending on the size of the property and the complexity of the work. The excavator digs down then moves the waste to the surface for transport and dump. The foundation need to be designed and form along with the excavation (Mohamad, 2017).

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The impacts of the earthwork on surround neighbors need to be taken into account. In fact, soil removal in a big project takes time and often generates a significant traffic volume. Additionally, it usually causes damage to roads and pavements nearby. An earthwork project normally works 24/7 and only rest on public holidays. The civilians around the site will have to endure noise, vibration and dust for at least few months (Craper, Fell and Gammoh, 2013). Therefore, it is necessary to meet all the neighbors and give them comfort condition before start working.

3. Case study

3.1 Project description

This paper implements a project that has one of the deepest basements in Vietnam. The project is one of the finest civil buildings established in Hanoi in 2018 and looking forward to be handed over in the end of 2020. It's located on the corner of the most bustling area in the fastest developing district of Ha Noi, within a walking distance to a number of historical attractions and parks. It contains 6 basements with 35 commercial floors, comprising of around 500 high quality luxury residential apartments and commercial suites, this building is surrounded by many shops, restaurants, supermarkets, and also has a very convenient public transport connecting system. This project is designed to be eco-friendly and smart. It compromises a full use of nature sun light and wind to provide a better living environment to the residences. The building offers various options from 57 m2 apartment to 142 m2 penthouses to fit customer's demand. Additionally, the building is close to many facilities and conveniences such as Big C mega super market, Grand Plaza Hotel, National Convention Center, Ocean Mall, Nhan Chinh market, Hanoi- Amsterdam High School, etc. This is absolutely an outstanding high-class project and the success of the investors can be secured.

Table 3.1: Project Detail

Project Name	N/A
Owner	N/A
Project Location	Le Van Luong st – Thanh Xuan dist – Hanoi – Vietnam
Land	8004 m2
Building Area	128.685 m2
Building	35 Floors (500 appartments) – 5 basements
Design Contractor	P&T Group International Ltd (Singapore)
Main Contractor	N/A
Basement Contractor	N/A
Total Investment (USD)	80,000,000
Start date	March 2018
Planned finish date	December 2020

3.2 Scope of work and deliverable

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Table 3.2: Scope of work

Name	Description	Quantity	Duration
Excavation	- Dick deep to 21m compare to the surface - Load the soil on the truck for dumping	200000 m3	8 months
Soil transportation	- Make the temporary road for the truck to move inside the site - Clean the trucks and make sure they are clean before they get out of the site and move on the road	200000 m3	8 months
Clean the road around the site	- Worker pick up leftover dirt and soil dropped by the truck on the road around the site - Hire water truck to clean the road after each day of soil transportation		
Organise soil dumping area	- Use bulldozer to level the dumped soil - Make temporary road for the truck inside dumping area - Provide water and electricity for the worker	200000 m3	8 months
Levelling	- Make the surface of each basement nice and smooth for the concrete floor - Compact the floor with the compaction of K80	10 workers	8 months
Backfill the foundation with sand	- Excavate the soil of foundation - Backfill with sand after finish concreting	5000 m3	1 month
Concrete demolish	- Demolish the concrete pile - Cut the small pile	30000 m3	8 months
Concrete transportation	- Use excavator to load the concrete on the truck - Transport the concrete to dumping area	30000 m3	8 months
Clean the barrier wall	- Worker clean the soil and concrete on top of the wall - Excavator clean the soil and concrete on the wall - Use brick to cover the bad area	8 workers	2 months
Cut and collect the used steel	- Cut the left over steel from after demolish the concrete pile - Collect the steel and put them in steel area	5 workers	
Paperwork	- Execute all the related paper work - Calculate the amount of work and acceptance paper		

To define the deliverables, we should include clear standards for the acceptance of each deliverable, in order to minimize the chances of disputes. The following are deliverability of this project:

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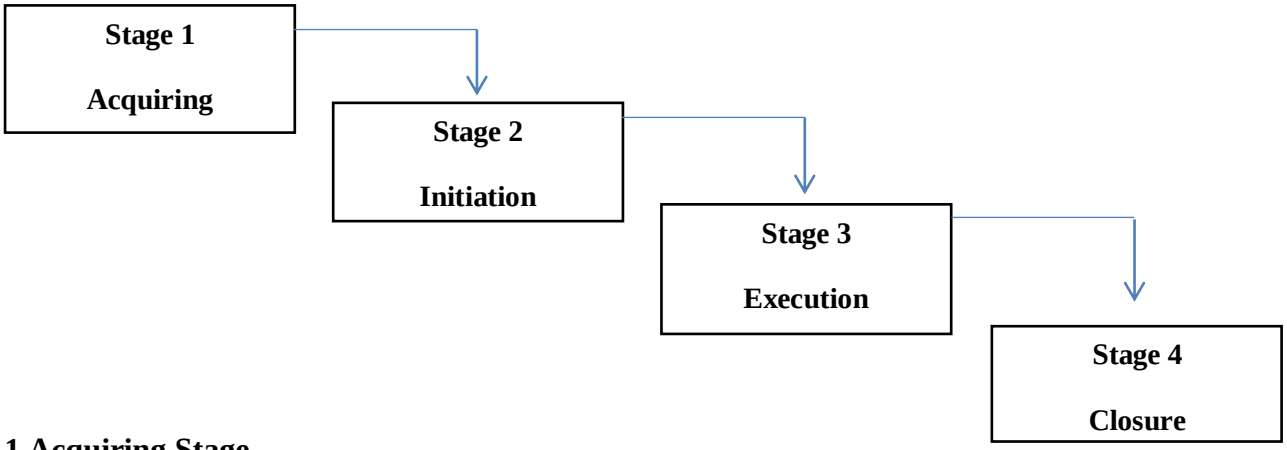
Table 3.3: Deliverable

Name	Deliverable	Acceptance requirement	Required document
Excavate 1st floor	Excavate to 7m deep from the ground code and transport 50000 m3 of waste soil. It require 4 big excavation and 50 trucks	The dimension including level has to meet up drawing with acceptance tolerance	Excavation work acceptance report
Excavate 2nd to 6th floors	Excavate to 18m deep from the ground code and transport 150000 m3 of waste soil. It requires 3 long hand excavator, 2 short hand excavator, 2 bulldozer and 80 trucks	The dimension including level has to meet up drawing with acceptance tolerance	Excavation work acceptance report
Leveling and grouding	Making the ground nice and smooth for concreting work	Acceptance of safety and technical office	Grounding acceptance report
Concrete pile demolish	Demolish 350 concrete pile. Using 1 demolisher and 5 workers	Record of technical office	Pile acceptance report
Temporary road	Using waste bricks to make solid temporary road at site	Acceptance of technical office	Temporary road technical report

3.3 Risk in each stage of the project

This study divides an earthwork project into 4 stages. Each stage contains common industrial risk where problems are analyzed and discussed.



3.3.1 Acquiring Stage

The top three factors that determine if a contractor can be successful at this stage are ‘Marketing, Relationship management and Bidding”. These factors however propose unexpected risks if they are not handled with experience.

An earthwork organization needs to consult the marketing professional to create a branding system. Then make sure the brand system is used throughout the company. The system should

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enhance the integrated branding. In other words, all the logo or slogan sent out to public need to consistent and repeat the same message that a company wants to deliver. For example, FECON is branding very well as they consistently put their logo on walls, worker's shirt, and machinery, etc. The slogan "Listening to Earth" is sent through the systems.
An excavation company should identify the company's brand and mission, then create a website that will entice the potential customer to pick up the phone and call for enquires. Make sure the information on the website is up to date

Implement internal marketing system where pictures of company are constantly taken and stored. Put the pictures with stories on website and online to get more awareness then manage the feedbacks and transfer them to enquiries.

3.3.2 Initiation Stage

This stage is form by 4 main activities that help an earth contractor to prepare before start executing the job. The activities are 'contract negotiation, resource preparation, site receive, and external factor preparation'. Each activity propose various risks which will be explained and analyze as follow

Increase in productivity, efficiency and safety has been largely demanded in the earthwork construction environment, resulting in the need to optimize every task related to this process. To achieve this, it is crucial to have extra resources. This includes the site conditions and equipment specifications, which leads to minimize costs and maximize productivity. At the same time, it ensures the completion of the work within acceptable time and cost estimates, following the sustainable principles. Thus, effective planning in these constructions is essential, including the optimization of available resources or selection of the best equipment fleet for the work at hand.

The implementation of earthwork can benefit greatly from good preparing resource to avoid specific site challenges and constraints. The planning could consider whether we have back up for uncertain situation. This project follows the following strategies:

Table 3.4: Resources Risk Solution

Problem	Solution
Human resource risk	- Have back up employee - Hire shift base employee - Employee need to give notice at least 7 days before taking leave - Recruit enough people before the work start - Have reward for employee who did not take leaves during the work
Machinery risk	- Always have back up machine - Be close to the mechanic who repair the machine - Check the machine condition and ensure good quality before the work start - Check all the machine at least once a week to see if any problem - Get the operator to report the condition of the machine after each shift
Financial risk	- Prepare at least 15% of contract value as back up cash - Have bank guarantee - Make a cash flow plan for the whole project

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Table 3.5: Solution for Right of Access

Risk	Solution
Site Altitude	- The engineer need to check the altitude frequently - The altitude need to be recorded and signed by at least 2 parties - The altitude need to be measure by machine and ensure the reliability
Site boundary	- Take clear mark for the boundary - Use fence to surround the site - Apply map at all time
Site Condition	- Make sure the site condition is recorded and signed by at least 2 parties - Inform the employer and owner immediately if there are any problems
Building Permit	- Double check the building permit before start working - Keep a copy of building permit for the local authorities
Date of site receive	- Make sure the date of site receive is not the date of starting to count schedule - The date of site receive need to be recorded and signed by at least 2 parties

3.3.3 Execution stage

This stage is when the contractor starts excavating and soil transporting at the site. There are no doubts many risks arise throughout the project. There are 5 major risks in a deep basement excavation, which are:

Table 3.6: Risks in Execution Stage

Risk	Definition	Likelihood (Low – High)	Impact Level (Low – High)	Risk Level (Low – High)
Delay risk	Many uncertainties arise in an earthwork project that causes the work behind schedule. Those uncertainties happen is called risk in delay management	High	High	High
Safety risk	Hazardous in an earthwork project is extremely dangerous. According to the law, no work should take place until the excavation is safe. It is crucial to have a good safety management system	Medium	High	High
Quality risk	There are many risks that arise in quality management as some of the quality benchmark is not in specification but come from experience of the contractor.	Medium	High	High
Efficiency risk	It is easy to get cost overhead in an earthwork project as there are many risks that increase the cost. The contractor need an efficiency management system to secure profit	High	High	High
Cash flow risk	It is dangerous to have a negative cash flow. Worker will stop working and subcontractor will stop providing service. An earthwork contractor constantly face the risk of getting negative cash flow	Medium	High	High

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Table 3.7: Delay Risk Solution

Risk	Solution
External factor	Inform the employer and owner to take care of the external issue. And request for extension due to the problem
Change in scope of work	Request for extension base on the calculated delay. In some case, ask for more money
Change in working method	Request for extension base on the calculated delay. In some case, ask for more money
Machinery problem	Fix the machine as quickly as possible. Have some back up machine to make sure the delay is under control. Show the employer that you are doing your best to fix the problem and stick with the schedule
Human resource problem	Have strict sick leave regulation so people respect the job. Hire back up people to make sure there are replacement
Site condition	Take picture of the site condition and inform the owner or employer. Ask for extension if needed
Political problem	Show owner and employer the evident that political event or changes are affecting the work speed. Ask for extension

The safety of a steep slope is hard to measure quantitatively. The geotechnical engineer determine the cut and slopes from mainly experience and observation. The specification need to add the vicinity which enhances stability. The height and steep level of slope need to formally address in each basement and instruct the site engineer constantly.

3.3.4 Closure Stage

Excavation volumes and total volumes (transport and dump) and net volume (the difference between the calculated data versus on site data) are summarized in the closure document. The total volume is important because it indicates the amount of work which needs to be done in the contract of being placed as excavate and transport during the closure while the net volume indicates the amount of work that are done in required to the employer's need at site to achieve the required closure reliability. These amounts greatly influence the quantities of earthworks and therefore the final closure failure could cost the contractor a fortune.

Closure planning at most earthwork project is typically left until near the end-of-project life, often leaving little time, financial provision or resources for effective planning and closure. This can present a major hurdle to the operating company because earthwork occurs at the beginning of the project where the cash of employer or owner is still strong. The end of earthwork project is clearly not the optimal time to be planning and undertaking the bulk of rehabilitation and closure activities.

Early planning for closure takes commitment, resources and time, but can give increased financial return through effective planning and enhanced efficient. This project uses progressive closure planning to ensure credibility. The basis of the system is that the current information base for any work at site forms the platform from which a rehabilitation and closure strategy for that area can be established. Through the process of gap analysis, works are identified to fill gaps and ultimately refine the rehabilitation and closure strategy for that area. Works are prioritized using risk-assessment and then scheduled over time in a logical order, rather than undertaken as a

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combined one-off activity at the time of earthwork closure. The concept of progressive closure promotes a shift away from conventional 'static' closure plans towards a systematic approach that makes provision for planning and closure as life-of-project processes. The concept has been developed in accordance with the principles of the 'Strategic Framework for Earthwork':

3.4 Lessons Learnt

Many lessons are learnt after completing this project. The study highlights some of the most valuable lessons through each stages of this project for the application of future earthwork attempt. The lessons are put in order for each stage as follow:

3.4.1 Acquiring Stage

Activity	Key Risk	Risk Management
Marketing	Branding risk	An earthwork contractor needs to be clear and consistent with branding to enhance brand awareness. Avoid confusing the customer with various logos and status
	Advertising risk	Spend at least 5% of the revenue on marketing and branding each year
	Communication risk	Build a good website with effective customer communication system
Network & Relationship	Decision maker relationship risk	Establish a good relationship with the decision maker of the project
Bidding	Bidding System risk	Create an efficient bidding system with experienced staffs. Analyze carefully and come up with strategies before enroll into a bidding

Table 3.8: Lesson learnt for Acquiring Stage

3.4.2 Initiation Stage

Activity	Key Risk	Risk Management
Contract negotiation	Negotiate risk	- Contract negotiation the most important steps in this stage. Make sure the experienced and trusted staffs handle the contract - Have clear objectives and applicable strategies before entering a contract negotiation
Prepare resources	Resource risk	Important resources including human resource, financial resource, and machinery resource; need to be prepared carefully before executing earthwork. The contractor must have back-up plan with spare resource at all time
Right of Access	Access risk	- Establish a 'Right to Access' system where every activity in this step are recorded and signed by employer or owner. An earthwork contractor needs to make sure there is no legal burden at site or the project before start excavating - Make sure the site is clear and the site condition is good before executing earthwork. Record any obstacles that stop the work then send to employer/owner and get confirmed.

Table 3.9: Lesson learnt for Initiation Stage.

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3.4.3 Execution Stage

Activity	Key Risk	Risk Management
Delay management	External factor risk	External factor such as people living around the site and local politic could pose seriously risk to delay the project. Deal with all the potential external risk before start excavation. In case that only the owner can solve the local problems, send them notification of the problem and request for work extension.
	Scope risk	Scope of work need to be clear from the very start of the project. Any extra work will need to be formally recorded with suitable price and work extension.
	Work method risk	The working method is also clear from the beginning. If there are any changes in work method, the contractor must formally record with suitable price and work extension.
	Schedule risk	To manage working schedule and avoid delay, the contractor can use the earthwork equations or frameworks in section 3.3.3.1.3 in this study to work out the minimum workload that needed to be done each day.
	Machinery risk	An earthwork contractor should have a good mechanic that can fix the excavator quickly in order to avoid delay from machinery meltdown.
	Sick leave risk	Always have back up staffs to make sure the site run smoothly even there are sick leaves
	Internal factor risk	Formally record any factor that stop that work and inform the employer/owner for work extension.
	Site condition risk	It is best to receive a site with good working condition before start excavating. Make sure to formally inform employer/owner if there are problems with site condition.
Safety management	System risk	Implement safety management system and make sure everyone in the company follow strictly in order to minimize hazard propensity.
	Balance risk	An earthwork contractor should establish a balance of safety responsibility between employers and owner.
	Tool risk	Invest in quality safety tools and hire experienced safety officers.
Quality management	Standard risk	Establish quality benchmark for all the staffs at site. Hire experienced earthwork engineer and ensure that all work scope are done with quality minded.
	Sloop risk	Make sure the steep slope is done nicely with accountable to safety.
	Experience risk	Invest in reliable tools and experienced staffs to ensure the compaction of the earth in the project met the requirement.
Efficiency management	Efficient risk	Install hardware that can measure working hour and oil consumed of each machine. Review the data daily to ensure efficient of the site.
Cash flow management	Forecast risk	Draw cash flow diagram and forecast the cash flow situation of the whole project.
	Payment system risk	Design a suitable cash flow system where the date of paying the subcontractors is followed by the date the contractor is paid by the owner.
	Cash shortage risk	Have back up cash with the at least 10% equivalent to the value of the project to ensure the cash flow is always positive throughout the project.

Table 3.10: Lesson learnt for Execution Stage.

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3.4.4 Closure Stage

Activity	Key Risk	Risk Management
Closure	System risk	- Create a Closure system where all the work at site are formally recorded and get accepted by owner at the early stage of project. - Never wait until the end of the project to start doing closure. - All extra liability need signed in the contract or sub-contract as early as possible. - Implement effective communication for closure process.
	Hand over risk	- Make sure all the work are accepted with formal record - Extra work need to be signed and confirm early
	Paper work risk	- All the paper work needs to be handled by experienced staffs. - Constantly check the progress of the process

Table 3.11 : Lesson learnt for Closure Stage.

4. Conclusion

This study is aimed at identifying and analysing the risks in a deep excavation, recommendations and lessons learnt developed from the case study of a six basements project.

The study outline the theory related to risk management and earthwork then summarize the application of a real life project. The project is divided into four stages including: Acquiring, Ignition, Execution, and Closure. Various risks in each stage are identified, analysed and given recommendation for the future project to apply.

Marketing risk is at medium level because it is the bridge that connects the contractor with the potential customer. Without a good marketing strategy and constant branding, the customer would be constrained to reach the contractor. This means less chance of getting new project for the company. Therefore, a good marketing system is very important.

Network and relationship risk is also at high level because the decision maker is the one determines if the contractor get the job or not. Establish a good relationship with the decision maker is crucial

Bidding risk also has high level, especially in this competitive market; it is very hard to win a project without a good bidding strategy. The risk of preparing resources is at low level as there are various uncertainties when the contractor prepare for the work. However, the risk can be controlled because the contractor has time to find solution.

Right to access the site risk is at medium level because the contractor could inform the owner if there are any obstacles stopping the work.

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Delay risk is at high level as it has very high chance to happen and the contractor has little control over these uncertainties. An earthwork contractor needs to calculate the work schedule to gain some control over delay.

Safety risk is also at high level because earthwork hazards are extremely dangerous. It is crucial for an earthwork contractor to implement formal safety management system to ensure hazard is minimized.

Quality risk is at high level because it reflects the capability and reputation of an earthwork contractor. The contractor has high control over earthwork quality but it sometime cost more to meet a certain benchmark.

Efficiency risk is also at high level because it determines the profitability of the project. There are many risks that affect efficiency; therefore an earthwork contractor needs to install hardware and analyze the data frequently to ensure the efficient of the site.

Cash flow risk is at high level because it determines if the project could run smoothly. Poor cash flow management could lead to bankrupt of the contractor. It is very important to forecast cash flow situation of a project and prepare counter strategies.

This study covers many aspects of risk in of a deep excavation project, however, there are much room for future research to develop from this study such as environmental risk, risk at waste dumping area, etc.

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