

Risk Ranking for Tunnelling Construction Projects in Malaysia

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Abstract: *Tunnelling has become a preferred method of construction for road and highway projects in countries with a lot of hilly slope geological conditions such as found in Malaysia. However the construction works of a tunnelling project are usually complicated and costly, which consequently impose great risks to the parties involved. This paper identifies the key significant risks and sub-risks for tunnelling construction projects in Malaysia through a case study. Interview has been used as the solitary means to determine the significant risks from contractor's eleven key project personnel who were directly involved in the tunnelling construction such as consultant, construction manager and tunnel engineers. The importance of the risks identified is then prioritised and ranked via the Analytic Hierarchy Process (AHP)'s pairwise comparison approach to determine their criticality towards a successful delivery of project. As a result, three key risks have been identified as significant for the tunnelling case study project, namely health and safety, cost overrun in construction and time overrun in construction. Two sub-risks each of the latter categories, which are cost underestimation and unforeseen events (cost overrun in construction) as well as plant and machinery failure and delay in material delivery (time overrun in construction), have occupied the top five overall risk ranking.*

Keywords: *Analytic Hierarchy Process (AHP), Malaysia, risk identification, risk ranking, tunnelling construction projects*

I. INTRODUCTION

Tunnel is an underground feasible structure, which is normally built through three construction procedures, namely cut and cover method, drill and blast method and mined with Tunnel Boring Machine (TBM). These tunnelling procedures are still considered as new practices to the construction industry in Malaysia. Before 1995, most of the tunnels had been excavated through a conventional drill and blast method where the tunnel supports are installed in accordance to the procedure set under the New Austrian Tunnelling Method (NATM) [1].

Since the technology of tunnelling method is being enhanced consistently over time, the level of complexity and cost of tunnelling have also increased significantly. Huge requirements of the underground space and the complexity of underground infrastructures have induced greater demands for safer and reliable tunnelling design [2]. As the construction procedures become more difficult and complex, the degree of risks and uncertainties for most tunnelling projects become greater. Unless an effective risk management measure is implemented, any tunnelling construction projects would be incurring significant impacts and consequences if any of risks identified occur in the actual project.

Thus, this paper identifies the key significant risks for tunnelling construction projects in Malaysia through a case study. The significant risks identified are then prioritised and ranked via the Analytic Hierarchy Process (AHP)'s pairwise comparison, which analyses the criticality and importance of each risk towards a successful delivery of the tunnelling case study project

involved.

Ranking of risk is important due to very scarce accessible resources which disable effective and efficient risk management in most projects. In managing a project, typically, more attention is focused on risks with greater priorities and importance whereas the less important ones are either neglected or ignored. Therefore the findings from this paper would contribute significantly towards a successful project delivery of the case study project and also effective risk management for future tunnelling construction projects in Malaysia.

II. RISKS IN CONSTRUCTION PROJECTS

The construction industry is a vehicle through which a nation's physical developments are activated by initiating projects from the blue print stage to the implementation [3]. However, the phases of a project have greater tendencies to exhibit risk occurrence as results of unforeseen and uncertain events. [4]. Over the decades, there are a number of delayed or postponed large scale projects around the world due to unexpected risks and uncertainties. One of them is the Bakun Dam in Malaysia.

Risks in construction projects can be divided into four levels; national/regional, construction industry, company and project [5]. There are a few risk categories in construction projects that include commercial risk, operational & maintenance risk, design risk, construction risk as well as financial risk. Most of these risks could be identified, quantified, mitigated and prioritised in order to minimize their consequences and impacts on a particular project [6].

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These processes, which involved the identification of risk, analysis of the implications, response to minimize risk and allocation to appropriate contingencies, are known as risk management [7]. However, most of the local Malaysian contractors involved in large scale constructions are not aware of the importance of risk management [8]. Nonetheless, on a small scale, there are some organizations and/or companies that implement proper risk management in Malaysian construction projects.

Over the past twenty years, most of the large-scale and all encompassing public sector projects in Malaysia have been procured through Design and Build (D&B) contracts [3]. Among the typical risks that have been classified as critical in the D&B procurement include; time overrun and cost overrun in construction, lack of information on needs/wants from the employer, difficulty to comply with specification required, conflict of interest and variation to changes. [9].

There is also the potential of partnering risk for construction projects, which involved organisations/companies that work on joint venture basis. , Among the common partnering-related risks in joint venture construction projects include partner’s financial competencies, disagreement on the profit & loss allocation resources, lack of communication as well as poor relationship between the parties involved [9].

III. RISKS IN TUNNELLING CONSTRUCTION PROJECTS

Tunnelling construction project is described as “a risky type of construction method, the trends are towards design and build contract, the construction schedule is tight and contractor has low financial budget” [10]. Table I portrays the key tunnelling construction projects around the world that dealt with great financial losses since 1994.

Amongst them are the Heathrow Express Link tunnel in the UK (1994) and the Shanghai Metro in China (2003) that incurred losses of USD 141 million and USD 80 million respectively due to tunnel collapsed. The most recent major tunnel collapsed incident, occurred in 2005 at the Kaohsiung Metro project in Taiwan where the total estimated losses were USD 196 million. As the construction of tunnel is becoming more complex and costly, the significant risks are becoming greater in terms of the number of occurrences and the consequences/impact.

Several major risks with high rates of occurrence during any tunnelling construction projects are health and safety, geological condition, design risk and force majeure. The health and safety risk includes minimal application of the Personal Protective Equipment (PPE) and standard safety procedure for scaffolding.

Lack of safe escape routes for workers, which usually execute tunnels within a confined working space during construction is another major issue related to health and safety whereby the disintegration of any parts of the primary tunnel structure would be catastrophic. The geological condition is very much critical for underground structure particularly during the primary reinforcement installation.

Force majeure is another major risk issue that could dictate problems to tunnelling construction projects. Natural disaster events such as seismic activity from neighbouring countries may trigger the collapse of a tunnel. Finally, design risk is observed when it fails to accommodate or deliver the desired service successfully due to some deficiency. [11].

TABLE I
MAJOR TUNNEL LOSSES IN THE WORLD SINCE 1994 [10]

Year	Tunnel Project	Cause	Loss
1994	Great Belt Link, Denmark	Fire	USD 33 Mil
1994	Munich Metro, Germany	Collapse	USD 4 Mil
1994	Heathrow Express Link, GB	Collapse	USD 141 Mil
1994	Metro Taipei, Taiwan	Collapse	USD 12 Mil
1995	Metro Los Angeles, USA	Collapse	USD 9 Mil
1995	Metro Taipei, Taiwan	Collapse	USD 29 Mil
1999	Hull Yorkshire Tunnel, UK	Collapse	USD 55 Mil
1999	TAV Bologna - Florence, Italy	Collapse	USD 9 Mil
1999	Anatolia Motorway, Turkey	Earthquake	USD 115 Mil
2000	Metro Taegu, Korea	Collapse	USD 24 Mil
2000	TAV Bologna - Florence, Italy	Collapse	USD 12 Mil
2002	Taiwan High Speed Railway	Collapse	USD 30 Mil
2002	SOCATOP Paris, France	Fire	USD 8 Mil
2003	Shanghai Metro, PRC	Collapse	USD 80 Mil
2004	Singapore Metro, S'pore	Collapse	USD 56 Mil
2005	Barcelona Metro, Spain	Collapse	USD 125 Mil
2005	Lausanne Metro, Switzerland	Collapse	t.b.a.
2005	Lane Cove Tunnel, Sydney	Collapse	t.b.a.
2005	Kaohsiung Metro, Taiwan	Collapse	USD 196 Mil

In Malaysia, tunnelling is usually required to fit in with construction projects that involved various civil engineering applications such as tunnels for highways and railways as well as diversion and pressure tunnels for water supply and hydro power generation [1]. Table II summarises the key tunnelling construction projects in Malaysia. A few well known local projects are the SMART tunnel, Bakun Dam for hydroelectric, the Kuala Lumpur Light rail Transit and Sg. Selangor Dam for water supply.

The SMART tunnel operates in the following way: the first mode, under normal conditions where there is no storm, no flood water will be diverted into the system. When the second mode is activated, flood water is diverted into the bypass tunnel in the lower channel of the motorway tunnel. The motorway section is still open to traffic at this stage. When the third mode is in operation,

the motorway will be closed to all traffic.

The Sg. Selangor Dam meanwhile comprised of a layer of 0.62 million cubic metres of granular material. The dam, 400m wide at the base, 800m long and 110m high, is composed of 1.2 million cubic metres of clay core and 6.4 million cubic metres of granite. During low flow period, water from the dam's reservoir will be drawn for release into the river to ensure sufficient raw water supply for the water intakes downstream.

The technical report for projects like the SMART tunnel and Sg. Selangor Dam has indicated problems that occurred in the project executions i.e. excessive outbreak and sinkholes. Although these projects were successfully completed in 2007 and 2003 respectively, their initial commissioning dates were distantly beyond the actual ones.

TABLE II
TUNNELLING CONSTRUCTION PROJECTS IN MALAYSIA FROM
1995 – 2005 [1]

Tunnel Project	Applications	Geology	Observations
Sg. Selangor Dam (water supply)	Division Tunnel	Granitic/ faulting	Excessive overbreak, D&B, completed 2003
SMART	Dual Flood Mitigation / Roadway	Limestone/ Alluvium	Sinkholes, TBM, completed 2007
Karak Highway	Highway Twin Tunnels	Granite	D&B, 1997
Kelinci Dam (water supply)	Water Transfer Tunnel	Granite/ fault	TBM, 1996
Pergau Dam (hydro electric)	Division & pressure Tunnels, Powerhouse	Granite mostly, minor meta- sediments	Low ground stresses, hydrothermal alteration, D&B, 1997
Penchala Link	Highway Twin Tunnels	Granite/ fault	Some collapse, additional support, D&B, 2004
Kuala Lumpur Light Rail Transit	Subway Twin Tunnels	Limestone /Kenny Hill fm (meta- sediment and skarn)	Sinkholes/hard skarn of 270 MPA UCS, TBM, 2000
Beris Dam (water supply)	Division Tunnel	Sedimentary	5m Dia x 200m long diversion tunnel, D&B, 2001
Kinta Dam (water supply)	Division Tunnel	Granite	D&B
Bakun Dam (hydro electric)	Division & Pressure Tunnel	Sandstone/sh ale	D&B
Interstate Raw Water Transfer Scheme	Water Transfer Tunnel	Granite	45km, NATM & TBM, on-going
Meru and Menora Tunnel	Highway Tunnel	Porphyritic granite	Seepage, leakage, completed 1996
Larut Tunnel	Railway	Granite	NATM, D&B, on- going
Berapit Twin bored Tunnel	Railway	Granite	NATM & MTBM, D&B, on-going

IV. RESEARCH METHODOLOGY

Two key research methods, namely case study and semi-structured interviews were used to identify significant risks and sub-risks for tunnelling construction projects in Malaysia. Some identified tunnelling projects in Malaysia have been completed and are now operating while some are still undergoing constructions. Amongst the tunnelling projects identified include Genting Sempah Tunnel, Penchala Tunnel, Stormwater Management and Road Tunnel (SMART) Tunnel, Larut Tunnel and Berapit Tunnel. Owing to the confidentiality of data and information of other tunnelling projects, only one project is allowed to be used as the case study, which is the Berapit tunnel.

Generally the case study project is one of the two tunnels proposed for the new Electrified Double Track Project (EDTP) (<http://www.2t.com.my/EN/project/index.html>) that links Ipoh to Padang Besar, whereby the latter is located near Malaysia-Thailand border. The other tunnel within the EDTP project is the Larut Tunnel. The EDTP project was proposed in 2002 by the MMC-Gamuda, a company, who at the time was constructing the SMART tunnel as a continuation of the Rawang-IPoh double-track and electrification project.

However, it was only in December 2007 that the Malaysian Government accepted the MMC-Gamuda's proposal for the Ipoh-Padang Besar EDTP on a D & B contract that is worth RM 12.5 billion. The D & B contract between the Joint Venture (JV) company and Malaysian Government was formally signed in July 2008. Figure I shows the bird view location of the Berapit Tunnel which is the focus of this case study. Once completed, the Berapit Tunnel is expected to become the longest railway tunnel in South East Asia.



FIGURE I
BIRD VIEW LOCATION OF THE BERAPIT TUNNEL

The important contractors involved in the tunnelling construction project include the consultant, construction manager, C & S engineers and tunnel engineers. Eleven of them were interviewed to gather information on the tunnelling projects. The semi-structured questionnaire comprises a list of risks and sub-risks identified from

construction projects and tunnelling construction projects around the world, which have been primarily identified through literature review. Amongst them include health and safety, force majeure and design risk. The questionnaire is developed in a semi-structured form to allow respondents some extent of flexibility in indicating other possible occurring risks based on their project experiences.

All the information generated from the questionnaire interviews are then analysed through the Analytic Hierarchy Process (AHP)'s pairwise comparison whereby data is quantified in a matrix system in order to determine their significance/importance for a successful delivery of the case study project. The pairwise comparison in AHP combines both qualitative judgments and quantitative measures under a single analysis [19]. Thus the AHP is suitable to transform the qualitative judgment from the key personnel involved in the questionnaire interviews into a quantitative risk ranking, which is the key aim of this research study.

In the AHP pairwise comparison, the significance/importance of a risk over another is measured qualitatively. The AHP's pairwise comparison scale varies from 0 that indicates equal priority importance up to the score of 9, which reflect an 'extreme' priority of an element/event over another. However if an element/event is measured to have less priority importance over another during assessment, an inverse score that is usually highlighted in red, would be imposed to that particular element/event. Figure II portrays the pairwise comparison scale used in the AHP approach.

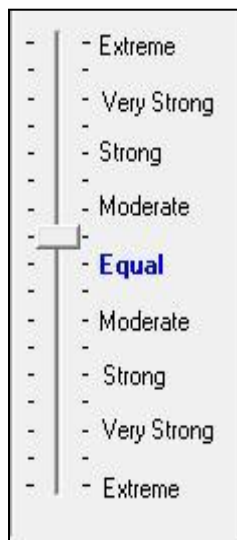


FIGURE II
THE AHP'S PAIRWISE COMPARISON SCALE [19]

V. RESULTS AND DISCUSSIONS

This section presents the results gathered from interviews that have been carried out with several key personnel who are directly involved in the case study project. Seven key risks have been identified, and are

presented as the sub-headings of this section while the significance/importance of their sub-risks are analysed and discussed within each specific heading. The seven key risks identified in the case study project are health and safety, cost overrun in construction, time overrun in construction, design risk, contractual risk, geological risk and force majeure.

However, this section only discusses the pairwise comparison results of three key risks; health and safety, cost overrun in construction and time overrun in construction. This section also discusses the overall risk ranking for all seven key risks as well as their sub-risks, which indicate their level of criticality and importance for proper management in order to ensure a successful delivery of the case study project.

A. Health and Safety

From the interviews conducted with the case study's important project personnel, the following key sub-risks are identified under health and safety, namely; confined working area, dusty and hazardous work environment as well as explosives impact. Typical to a tunnelling construction project, site workers usually work in narrow spaces that restrict their movement as well as their ways in and out of the tunnel. Therefore, any catastrophe that occurs at the tunnelling site, i.e. leakage of hazardous material or tunnel collapse, could leave the workers in fright to find their way out, hence, is highly dangerous. In terms of dusty and hazardous work environment as well as explosives impact, these risks have a great occurrence probability especially in tunnelling projects that are constructed using the drill and blast method or also known as the New Austrian Tunnelling Method (NATM) as in the case study project. The drill and blast method is usually carried out in a loop circle and repetitive way. The process starts with drilling for explosive charging, followed by blasting, ventilation and excavation. These processes will then be repeated. The dust gathered from blasting and potential hazardous gas from the vehicles and equipments used are very risky to human body.

Figure III portrays the scores that have been accumulated by each sub-risk through the questionnaire interviews conducted with several key personnel involved in the case study project. For instance, when confined area is being assessed against explosives, a score of 5.0 is given to the former. This means that confined area has a 'strong priority importance' that ought to be managed properly compared to explosives in order to ensure that potential occurrences of any health and safety issues/problems can be minimised.

	Confined area	Dusty and hazardous	Explosives
Confined area			5.0
Dusty and hazardous			3.0
Explosives	Incon: 0.04		

FIGURE III
PAIRWISE COMPARISON FOR SUB-RISKS UNDER HEALTH & SAFETY

Figure IV shows the results of risk ranking for each of the sub-risks identified under health and safety. Confined working area has been placed at the top of the ranking, hence, becomes the highly prioritised sub-risk risk for health and safety compared to dusty and hazardous work environment and explosive impact. The sequential position of these sub-risks could be influenced by the fact that stringent control and handling procedures has already been practiced in the Malaysian construction industry. To some extent, this is sufficient to minimise the risks of both dusty and hazardous work environment as well as explosive impact, if not totally eliminates their potential occurrences, as being compared to the risk of working in confined areas.

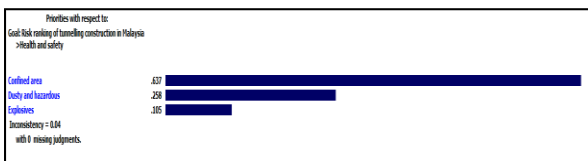


FIGURE IV
RANKING FOR SUB-RISKS OF HEALTH & SAFETY

B. Cost Overrun in Construction

[12] identified that cost overrun is one of the main problems in construction projects. Typically the cost of construction represents approximately 60% - 70% of the total capital cost of a construction project. Thus any cost overrun that occurs during the construction stage would inevitably have a significant impact not only on the cash flow of the project principal but also the project commissioning date. All phases of work in tunnelling construction projects are extremely complicated and sophisticated, thus posing a higher possibility of cost underestimate occurrences. This is similarly observed in the case study project.

The result of the interviews illustrates that the highly likely risks occurrence that could lead to cost overrun in construction in the case study project are as follow: underestimate cost, unforeseen event occurrence, design variation, economic crisis, economic inflation and exchange rate fluctuation.

[13] said that nine out of ten transportation infrastructure projects costs are underestimated and that all project types actually cost 28% higher on average than the estimated costs. Poor site investigation is usually the key reason for cost underestimation to occur and consequently, additional work activities ought to be carried out at a particular cost in order to comply with the actual design specification of the project.

For example, additional volume to cut and cover tunnel has to be executed when there is lack of information about the actual ground condition on site. The volume of concrete may also vary when “over breakage of rocks” often occurs on site due to poor site investigation on rock characteristics and behaviour. However in some countries, the cost underestimation was done deliberately in order to get approval for the procurement of certain projects [14].

Unforeseen risks are defined as unexpected events that have not been considered or looked into during the planning/design stage”. Unforeseen risks in construction projects are usually associated with global-influenced events such as change in the construction legislation as well as force majeure occurrences i.e. flood, earthquake, etc. However in tunnelling construction projects, there are great possibilities for more project-associated unforeseen events to occur than the global-influenced ones.

In the case study project for instance, the existence of wedge-shaped rocks just above the tunnel crown area as well as settlement of steel ribs due to the movement of rocks above require additional repair works, which have not been initially considered either in design specification or cost estimation. As a result of these unforeseen events, minimal design changes have been made in the actual case study project for remedy purposes. Other risks that would have a significant impact on the construction cost of the case study project are economic crisis and economic inflation as well as fluctuation of the exchange rate due to uncertainty in the economy of the world.

	Underestim	Unforeseen	Economic cr	Design var	Inflation	Exchange
Underestimation		3.0	5.0	3.0	5.0	7.0
Unforeseen events			3.0	3.0	4.0	5.0
Economic crisis				3.0	2.0	2.0
Design variations					2.0	3.0
Inflation						1.0
Exchange rate fluctuation	Incon: 0.04					

FIGURE V
PAIRWISE COMPARISON FOR SUB-RISKS UNDER COST OVERRUN IN CONSTRUCTION

Figure V outlines the scores that have been accumulated by each sub-risk through the AHP pairwise comparison. For instance, when economic crisis is being assessed against design variation, the score 3.0 shown in red implies that the latter is classified as ‘moderate priority importance’. This means that, the impact of design variation occurrence will be more significant than the impact of economic crisis risk, particularly with regards to the project cost. This result appears to be influenced by the fact that economic crisis is not a project-oriented risk as it is usually managed by the government/ project clients rather than the contractors or other project parties.

Figure VI specifies the results of risk ranking for each sub-risk identified under cost overrun in construction. Cost underestimation has been identified as the most prioritise risk, followed by unforeseen events and design variation.

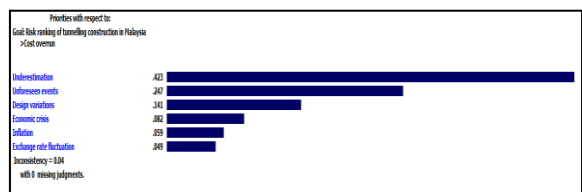


FIGURE VI
RANKING FOR SUB-RISKS OF COST OVERRUN IN CONSTRUCTION

C. Time Overrun in Construction

Time overrun in construction refers to construction work or an activity that is completed later than the anticipated date. This type of delay could result in a serious effect on the delivery of subsequent works or activities, leading towards late completion in the construction and commissioning. Alternatively additional resources may be hired to ensure that all critical activities are completed as scheduled. In the case study project, six sub-risks have been identified for having great attributes to dictate time overrun in construction; accidents, labour remonstration, political change, stop work order, delay in material delivery as well as plant and machinery failure.

Stop work orders usually reflect directives from project clients, which in the case study project, is the Malaysian government, to either hold or cease the currently ongoing project activities. The stop work order in a construction project can be issued due to several reasons. Amongst them include insufficient fund for the project as well as the violation of project regulations and codes/ordinance. Meanwhile, the labour remonstration risk often occurs when there is a disagreement or dispute between the clients-contractors or employer-employees concerning work-related terms such as bias conditions of the contract/employment, fringe benefits and wages demand that may lead to a project delay.

	Plant and m	Delay in mat	Political cha	Accidents	Labor remon	Stop work o
Plant and machinery failure		3.0	8.0	7.0	5.0	3.0
Delay in material delivery			6.0	6.0	4.0	4.0
Political change				2.0	2.0	3.0
Accidents					2.0	2.0
Labor remonstration						3.0
Stop work order	Incon: 0.04					

FIGURE VII
PAIRWISE COMPARISON FOR SUB-RISKS UNDER TIME OVERRUN IN CONSTRUCTION

Figure VII indicates the scores that have been accumulated by each sub-risk through the AHP pairwise comparison. For example, when labour remonstration is being assessed against stop work order, the former is given an inverse score of 3.0 in red, which means that the stop work order has a ‘moderate priority importance’ compared to labour remonstration. In other words, the stop work order has greater tendency to dictate time overrun during construction in the case study project than labour remonstration.

Another example that produces significant results in the pairwise comparison involved the assessment between plant and machinery failure against political change. The former has been given a score of 8.0, which reflects a “very strong-extreme priority importance” compared to political change. This result could be barely influenced by the fact that most of the respondents involved in the case study interviews come from the contractor’s side. Thus a more project-oriented risk would be given higher priorities than other global-influenced ones i.e. political change where project clients usually become the best party to manage the risk in any construction projects.

Figure VIII shows the results of risk ranking for the sub-risks identified under time overrun in construction. Plant and machinery failure has been ranked as the most prioritised risk that could lead to time overrun in construction if it materializes in the case study project. Delay in material delivery has been ranked as the second most prioritised risk under time overrun in construction, despite the fact that most of the major high profile and expensive construction projects like the case study should have an effective supply chain network and efficient delivery mechanism in place prior to project execution. Perhaps the complexity and complication of the project specification, which involved so many parties and equipments, have influenced the prioritisation of this risk in the case study project.

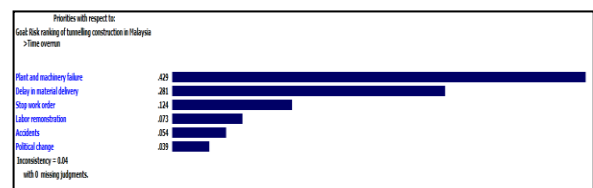


FIGURE VIII
RANKING FOR SUB-RISKS OF TIME OVERRUN IN CONSTRUCTION

D. Overall Risk Ranking

The results of pairwise comparison conducted on the key risks identified in the case study project are shown in Figure IX. For example, when contractual risk is being assessed against cost overrun in construction, the former has achieved an inverse score of 3.0, which means that cost overrun in construction has a ‘moderate priority importance’ in terms of criticality for proper management in the case study project compared to contractual risk. This result appears to be hugely influenced by the fact that most project clients are unwilling to incur additional costs apart from the budgeted amount, which might be due to factors such as inflation and/ or poor cost estimation. Cost overrun in any type of construction projects like the case study would have a significant impact on the project delivery/commissioning date. In other words, the occurrence of cost overrun in any construction activities would certainly lead to a delay from the actual project completion schedule. Therefore the cost overrun in construction risk is handed with the score of 2.0 over the time overrun in construction, which means the former has slightly “moderate priority importance’ than the latter for the case study project.

	Contractual	Cost overrun	Time overru	Design	Health and	Force maje	Geological
Contractual		3.0	2.0	2.0	3.0	7.0	2.0
Cost overrun			2.0	3.0	1.0	8.0	3.0
Time overrun				3.0	2.0	7.0	3.0
Design					4.0	4.0	1.0
Health and safety						8.0	3.0
Force majeure							4.0
Geological	Incon: 0.02						

FIGURE IX
PAIRWISE COMPARISON FOR KEY RISKS IN CASE STUDY PROJECT

Most of the studies made in the past by other researchers have identified cost overrun and time overrun in construction as the two most common risk problems for construction projects around the world. [15] identified that 70% of public projects in Saudi Arabia have experienced time overruns. According to [16], a research by the World Bank discovered that a total of 1627 projects, which have been completed between 1974 and 1988, had experienced time overrun between 50% and 80% in each project. Meanwhile, [17] specified that 70% of the construction projects in Botswana that were involved in his cost performance research had experienced cost overrun. Out of these two common risk problems, [18] found out that cost overrun occurred more frequently compared to time overrun in high-rise construction projects in Indonesia.

As for the case study project, cost overrun in construction has greater risk prioritisation compared to time overrun in construction. In other words, most of the key personnel involved in the interviews are expecting more cost overruns in construction to occur in the case study project rather than time overrun. The results of the overall risk ranking for the case study project are shown in Figure X.

The results however indicated that health and safety risk has been ranked higher than the cost overrun and time overrun in the case study project. One of the possible reasons behind the higher health and safety ranking than both cost overrun and time overrun in construction is the complexity of the tunnelling construction, which may impose huge risks to the people involved especially workers on site. The occurrence of any particular health and safety problem would consequently dictate the case study project to incur an additional cost (cost overrun) and/or project delay (time overrun) as a result.

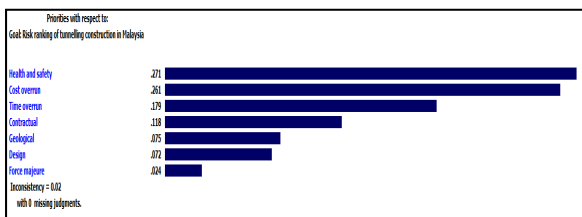


FIGURE X
OVERALL RANKING FOR KEY RISKS IN CASE STUDY PROJECT

Figure XI shows the overall ranking of all twenty-four sub-risks within the seven risk categories identified in the case study project. Confined working area (under health and safety) and cost underestimation (under cost overrun in construction) are the top two most prioritised risks in the case study project. Although the former is ahead of the latter in the risk ranking, their priorities difference is not significant. Thus, both confined working area and cost underestimation can be classified as ‘risks with equal priority importance’ for the case study project. Other top five risks for the case study projects are plant and machinery failure (time overrun in construction) and

unforeseen events (cost overrun in construction) as well as contract not properly written (contractual risk) and delay in material delivery (time overrun in construction) where two of the latter risks have equal priority importance.

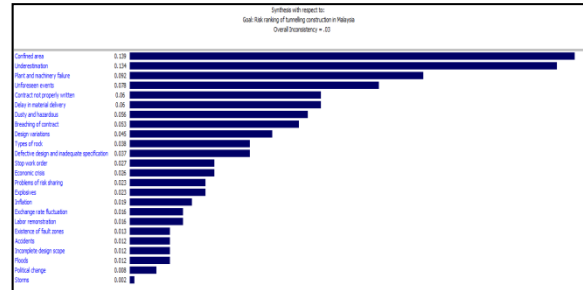


FIGURE XI
OVERALL RANKING FOR ALL SUB-RISKS IN CASE STUDY PROJECT

VI. CONCLUSIONS

In recent years, the advancement of construction technology has made feasible and enabled complex and complicated construction projects like tunnelling construction for highways and railways. From the conventional drill and blast method to a more advanced Tunnel Boring Machine (TBM), various numbers of tunnels have been constructed and currently operating for various purposes around the world. The construction industry in Malaysia has also benefitted from the advancement of tunnelling technology. A number of multi-functional tunnels have been developed by the Malaysian government in order to serve the public needs. Amongst them is the SMART Tunnel, which acts not only as a road tunnel but also as flood mitigation strategy in central Kuala Lumpur. The Larut Tunnel and the Berapit Tunnel are the current on-going tunnelling for the new Electrified Double Track Project (EDTP) railways that links a state in the west coast up to the north border of Malaysia and Thailand. However there has never been a tunnelling construction project that is risk free. Failure to manage relevant project risks has resulted in the collapsed of metro tunnels in Switzerland, Spain and Taiwan in 2005. It is therefore important to identify and rank significant risks at the project outset in order to ensure a proper risk management implementation.

Owing to data confidentiality, only key significant risks and sub-risks from a tunnelling construction project, the Berapit Tunnel, could be identified and analysed as a case study. Seven key risk categories and twenty-four sub-risks have been identified via a series of interviews with eleven key project personnel from the contractor’s company. The priority importance of all risk categories and sub-risk within each risk category has been evaluated through AHP pairwise comparison method, which produces risk ranking.

As a result of risk ranking, the top three risk categories for the case study project, arrange sequentially from most significant to less significant, are as follows; health and safety, cost overrun in construction and time overrun in construction. In terms of the sub-risks ranking, the top

five sequential ranking is filled by risks from these risk categories; confined working area (health and safety), cost underestimation (cost overrun), plant and machinery failure (time overrun), unforeseen events (cost overrun) and delay in material delivery (time overrun).

Although they have been identified as major risks in most construction projects around the world for a long time, there is still no specific or standardised solution offered to minimise, if not entirely eliminating both cost overrun and time overrun and their key sub-risks in practice. Nevertheless, the effectiveness and efficiency in managing these risks by project parties would rely very much on the complexity or size of the project that reflects technical needs of the clients.

Unless appropriate risk management measures and contingency plans that relate to the risks are addressed prior to project execution, there is a great possibility that at least one of the top five sub-risks identified, if not all, would occur in tunnelling construction projects in Malaysia. This is highly due to the fact that most of the project planning details including cost estimation and time scheduling are developed purely based on assumptions rather than actual project facts. Despite being identified through a single case study, the three top risks and five sub-risks are critical and must be considered for future tunnelling construction projects in Malaysian case studies.

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