RISK ASSESSMENT OF PUBLIC ROAD CONSTRUCTION PROJECTS USING ANALYTICAL HIERARCHY PROCESS (AHP)

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ABSTRAK

Projek pembinaan lebuh raya atau jalan raya merupakan salah satu projek prasarana awam yang penting untuk pembangunan ekonomi sosial. Oleh sebab itu, kerajaan Malaysia memberi lebih banyak perhatian kepada projek-projek ini. Walaupun pengukuran yang sesuai telah diambil, namun masih terdapat kebarangkalian risiko yang besar yang menyebabkan projek pembinaan jalan berisiko menimbulkan peningkatan kos, kelewatan dalam pembinaan projek dan kualiti pembinaan yang tidak bersesuaian dengan piawaian. Kajian ini dijalankan bertujuan untuk menganalisis penilaian risiko projek pembinaan bagi jalan raya awam. Faktor-faktor dan sub-faktor risiko dalam projek pembinaan jalan diperolehi dari kajian literatur. Tinjauan soal selidik telah diedarkan kepada bahagian kejuruteraan jalan jabatan kerja raya, kontraktor jalan dan pemegang konsesi jalan mengikut Proses Hierarki Analitik (AHP). Kajian ini mengenal pasti faktor-faktor risiko utama seperti berikut: ekonomi dan kewangan (0.267), teknikal (0.165), organisasi (0.148), kontrak (0.130), bencana alam (0.125), sosio dan politik (0.086). Sub-faktor risiko juga disenaraikan dan lima sub-faktor utama ditentukan seperti berikut: banjir (0.633), risiko inflasi (0.561), perubahan dalam undang-undang dan peraturan kerajaan (0.543), kekurangan koordinasi antara pihak-pihak (0.467) risiko dana (0.439). Dapatan kajian yang diperolehi dalam kajian ini diharapkan dapat digunakan dalam pemilihan elemen strategik untuk pemantauan risiko terhadap risiko yang dominan.

ABSTRACT

Highways or road construction project are one of the public infrastructure project that are important for social economic development. Due to this reason Malaysia government paying much more attention to these projects. Even though appropriate measurement taken, there is still great probability of risk to occur which places the road construction project at risk of cost, time overruns and poor quality delivery. The aim of this study was to analyze the risk assessment of public road construction projects. The factors and sub-factors of risk in public road construction project were scrutinized from the literature review. The designate pair-wise questionnaire survey was distributed to the road engineering section of public work department, road contractors and road concessionaires in accordance with the Analytic Hierarchy Process (AHP). This study identified the most prioritized risk factors as follows: economic and financial (0.267), technical (0.165), organizational (0.148), contractual (0.130), natural hazard (0.125), socio and politic (0.086) and resources (0.079). The risk sub-factors were also ranked and the top five sub-factors were determined as follows: flood (0.633), inflation risk (0.561), changes in government law and regulation (0.543), lack coordination between parties (0.467), fund risk (0.439). It is expected that the data presented in this study can be used to strategically select elements for risk monitoring on the prioritization risk.

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LIST OF SYMBOLS

%	Percent
λ	Lambda

LIST OF ABBREVIATIONS

GDP	Gross Domestic Product
FATA	Federally Administrated Tribal Area
AHP	Analytical Hierarchy Process
PWD	Public Work Department
MCDM	Multi Criteria Decision Making
ANP	Analytic Network Process
CI	Consistency Index
CR	Consistency Ratio
RI	Random Consistency Index

CHAPTER 1

INTRODUCTION

1.1 Introduction

Construction industry is known as one of the major contribution to the socioeconomic development. It helps in increasing the economic growth and has contributed to the Gross Domestic Product (GDP) (Mohd Yusuwan, 2001). This industry is important to the developing countries including Malaysia, Indonesia and Thailand. Construction projects can be divided into several types including residential housing construction, institutional and commercial building, infrastructure and heavy construction and specialized industrial construction. Infrastructure and heavy construction project includes highways, mass transit systems, tunnels, bridges, pipelines, drainage systems and sewerage treatment plants. (Giang & Sui Pheng, 2011) asserted that transportation has an important role in economic growth. This due to the reason that most of these projects are owned by the government for public use and financed mostly came from the taxes paid by the citizens.

Highways or road construction project are one of the public infrastructure project that are important for social benefits. (Naidu, 2008) Affirm that public infrastructure is important to the development of economic country based to that premise, Malaysia government paying much more attention to the infrastructure development. Even though appropriate measurement taken for the road construction project, there is still great probability of risk to occur which places the road construction project at risk of cost, time overruns and poor quality delivery. However, every risk that occurred in the construction project may be reduced with the implementation of risk management. Risk management consist of four process which is risk identification, risk assessment, risk response and risk mitigation (Akinrinade, 2018).

Risk management can be defined as a process where potential risks in a project is identified and to reduce any such threats. ISO 31000 the international organization that provides a guideline and framework in managing risks defined risks as the effect of uncertainty on objectives. Construction industry is likely more prone to risk due to its complex features. However, the implementation of risk management in a project is still not widely use. Furthermore, construction industry in Malaysia is lacking in awareness of that the importance of providing risk management plan in a project where resulting in delays, cost overruns and reduction of quality of projects (Ehsan, Mirza, Alam, & Ishaque, 2010). Consequently, this will effect in damaging the reputation of organizational and financial loss of a construction project.

Risk mitigation or known as the risk control are the method to evaluate any risk that will affect the project performance. Once the risk has been identified and evaluates the risk mitigation plan is developed. Risk mitigation plan is developed in order to control and minimize the risks (Wang, Dulaimi, & Aguria, 2004). It is an important process for controlling the cost, schedule, and quality of the project. This study is conducted in three folds, one is to identify associated risks that were revolving in the public road construction, secondly to analyse prioritization of each risk and further suggest the incorporation of risk mitigation in public infrastructure projects.

1.2 Problem Statement

Construction of road plays an important role in linking one area to another, and also acts as a substance for the local economy. It is anticipated that 25 million km of newly surfaced roads will be globally developed by 2050. This symbolises the adequacy of encompassing the planet for more than 600 times (Alamgir et al., 2017). Several types of roads are being constructed in Malaysia which are dependent on the suitability of the location such as gravel road, bitumen paved road, concrete road (rigid pavement), and locking block paving road.

It is universally known that road construction projects entail a higher risk compared to building projects as they require higher expenditure other than a complicated site condition. Major risks are constantly acquainted with road construction projects. Thus, it requires distinct responsiveness from contractors to evaluate and cope with their risks. Although risk in any construction cannot be disregarded, it can be reduced or conveyed from one project stakeholder to another (Zayed, Amer, & Pan, 2008). For developing countries, road construction is contributed as an imperative element in the construction industry. This shows that the national financial plan on infrastructure improvement is mostly channelled to road construction projects (Kaliba, Muya, & Mumba, 2009).

In Malaysia, the implementation of risk management in construction projects is still on a small scale and has a long way to go (Yusuwan, Adnan, & Omar, 2008). The awareness in realizing the importance of providing risk management reports for construction projects in Malaysia is still minimal by most parties, especially for public projects. For example, construction projects of more than fifty million ringgit under the supervision of Malaysia Public Work Department are mandated to submit risk management reports. Nevertheless, the construction players, especially from the client's perspective have beginning to slowly acknowledge risk management as an aiding instrument in handling a construction project successfully and productively (Yusuwan et al., 2008). While many studies have been conducted, particularly on the risk of road injury, accidents, and safety, only several authors including (Aziz & Abdel-Hakam, 2016; Kaliba et al., 2009; Mahamid, 2011) reported risk in the delay of road construction project. Therefore, a case study is a valuable method to discover an appropriate risk provision for road construction projects. For example, (Zafar, Yousaf, & Ahmed, 2016) carried out a case study on instruments to classify the crucial threat criteria causal due to failure in attaining financial aid for road projects in Federally Administrated Tribal Area (FATA) and suggests measures to overcome them. Similarly, (Perera, Dhanasinghe, & Rameezdeen, 2009) identified the risk accountabilities of contractual parties in order to develop risk control approaches with regards to Sri Lankan road projects. As delays in any civil engineering project in Egypt are a normal phenomenon, it is essential to study and analyse the causes of road construction (Aziz & Abdel-Hakam, 2016).

Public infrastructure project mainly focuses in transport infrastructure is a project in providing by the government for public use. Public infrastructure project is beneficial value of money to the country. Transport infrastructures are including the roads, bridges, rail services and airport. Public infrastructures are essential to the country as it promoting economic growth, and further improving the country development. However, there are multiple challenges during construction of the road project. The challenges can led to risk emerged which causes cost overruns, delays, failed procurement and lack of private funds (Beckers, 2013). According to (Wang et al., 2004) it is important to manage the multifaceted risks associated to construction project. Risk management is the process of identifying, analyzing and monitoring project to prevent any threats occur (Ft. Wainwright, 2015). The threats mean here referring to the challenges occurs in the project.

1.3 Objectives of Study

The main objective of this study was to analyze the risk assessment of public road construction projects. In order to achieve the main objective, there were two (2) specific objectives as follows:

1. To explore the risk associated to public infrastructure road construction projects, and

2. To analyse the associated risk by using Analytical Hierarchy Process (AHP).

1.4 Scope of Study

This research was limited and focussed on determining the risks associated to the public work department (PWD) road construction project. Purposive sampling was used as the method for sampling the PWD Professional Road Engineers in Pahang state. The research will assess the degree of risk severity by using Analytical Hierarchy Process (AHP). The term "risk" in this research is referred to the negative consequences of the unforeseen event which is usually called threat. Further explanation of the methods chosen will be discussed in Chapter 3.

1.5 Significance of Study

This study will provide a good guidance for public road construction sector specifically in managerial position in managing risk associated to the public road construction project. It is anticipates that the findings will provide the public sector with information that may help mitigate the frequency of risks in among road construction projects, especially in Malaysia.

Besides, from this study we can conclude the ranking of the risk in public road construction projects. The results obtained from this study can be use as references to produces a risk management framework. Therefore, the risk will be managed systematically and reducing the risk to occur during project life-cycle.

1.6 Structure of Thesis

This thesis comprises of five chapters. The first chapter consists of introduction of the study which includes the background, problem statement, objectives, scope of study and significance of study. For chapter two, the key terms in-purpose for this study are described and also the literature review that related and suitable for this study. Chapter three explains the research methodology for data collected and the method of data analysis to be employed. For chapter four, the results of the study obtained from the data collection were analyzed and discussed. Finally, chapter five comprises the conclusion from the overall chapter and relates some recommendations for future work on research field.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter presents a review on existing research that is relevant to the current study, with the objective of providing sufficient background information to facilitate the understanding and evaluation of this research. The chapter begins with terminology and definition of risk, risk management, risk management in construction and risk assessment. Simultaneously, previous researches particularly in public infrastructure construction risk were reviewed.

2.2 Definition of Risks

A construction risk can be defined as any exposure to possible loss. Similarly, stated by (Schieg, 2010) in terms of general risks is a loss, meanwhile, in terms of theory risks is defined as an inconsistent consequences from predicted results. Risk is inevitable when it comes to construction industry. Construction industry is subject to various risks that could have effect on project achievement (Taillandier et al., 2015). In addition to that, construction industry is more vulnerable to risk compared to other industries (Perera et al., 2009). In terms of project management, risk is defined as a measure of the possibility and effect of not acquire project objectives (Toth & Sebestyen, 2015). Meanwhile in construction prospect, it is contemplated as occurrences that effect the principal objectives (Bahamid & Doh, 2017). Fundamentally, risk is equivalent to something that cannot be calculated, measured or exactly known the value from a project (Zolkafli et al., 2012).

Furthermore, risks in construction projects can be classified into external risk and internal risk as illustrated in the figure 2.1 below which in particular categories as political risk, financial risk, market risk, intellectual property risk, social risk, safety risk, etc (Wang et al., 2004). According to (Z. Ali, Zhu, & Hussain, 2018) internal risk is controllable meanwhile external risk is uncontrollable. In addition, categorizing the risk will help to identify the risk; hence, the risks can be avoided in the early stages. Correspondingly, internal risks are relevant to local or international projects meanwhile external risks are relevant to international projects. Besides, risk also can be categorized into two categories which are known and unknown (Bahamid & Doh, 2017). Known risk can be identified and being analysed meanwhile unknown risk is harder to identify and resolve it. Overall, having a good understanding of risk can help reducing it in construction projects.

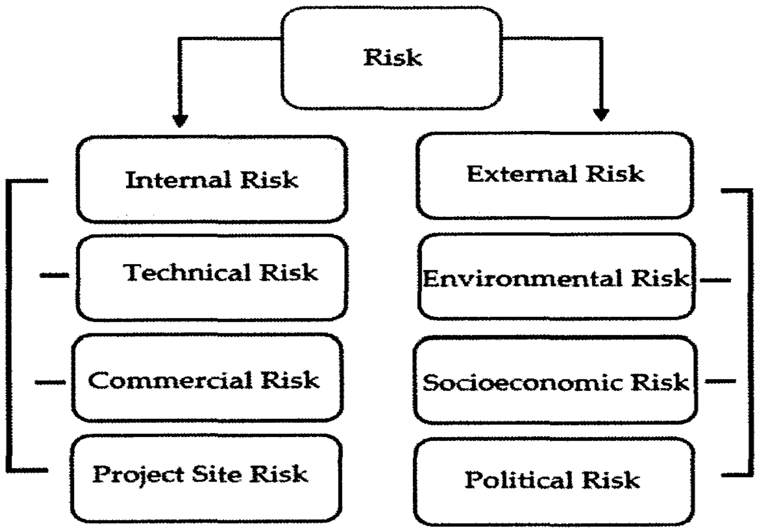

Figure 2.1 Classification of Risk

2.3 Risk Management

The study of risk management was first started after the world war II, it began to surface during 1970's and continued expanded until 1980's (Dionne, 2013). When it is first started to developed it is used to associate with the market insurances but now it is widely used in many industries. Risk management is a decision-making process used to reduce and handled the risks in the most systematic and appropriate manner (Abdul-rahman, Wang, & Mohamad, 2015). In addition, it is a system which aims to identify and quantify all risks, to which a business or project is exposed, so that a conscious decision can be taken on how to manage the risks (Browman, 2015). Besides, risk management can be used as a tool to manage the construction risk and to control the issue (Perera et al., 2009). Hence, ineffective use of risk management tools and techniques to identify the risk can result to cost overrun in operation and maintenance, non-availability of services due to asset failure and poor quality of service delivery (Ezanee & Ghazali, 2010).

An effective implementation of risk management system can result to a better understanding of the outcomes of the risks but also focuses on a more organize approach (Goh & Abdul-rahman, 2013). However, this system does not totally remove all the risks instead it helps to manage the risks systematically in effective manner. Understanding risks allows contractors to take steps to reduce their negative impacts. To ensure a successful construction projects there is three components that is important which is time, cost and quality. As shown in figure 2.2, in project management terms, these three components are known as the triple constraint. Time, cost and quality are always in interaction with each other therefore if any risk happen involving one of these components it will definitely affect the project performance (Kazaz, Ulubeyli, Er, & Acikara, 2016).

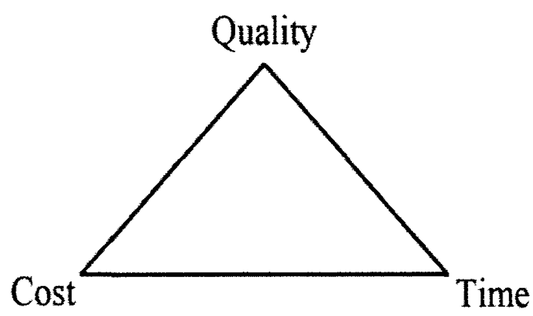

Figure 2.2 The Triple Constraint

2.4 Risk Management Process

Risk management is implementing in order to reduce risk. It is important to understand the process in order to make sure the implementation of risk management is successful. It is known that risk management defined as the organized process of analyzing, identifying, and responding to projects risk (Bahamid & Doh, 2017).

Moreover, managing risk has been recognized as the vital method in order to achieve project objectives in terms of cost, time and quality (Ft. Wainwright, 2015). Risk management process include risk identification, risk assessment, risk response and as main process. As shown in figure 2.3 below, a systematic method must be taken to handle the risks throughout the development of a project (Goh & Abdul-rahman, 2013).

Figure 2.3 Risk Management Cycle

2.4.1 Risk Identification

Risk identification is the process where the potential risk is identified and the outcome that might happen. This process is the most vital among risk management process (Bahamid & Doh, 2017). Similarly stated by (Maytorena, Winch, & Kiely, 2011) the identification and analysis process are the most important as both process have big impact on the next process which is risk assessment. Risk identification is a process where potential risks are identified by recognising, filtering and ranking the risks in a risk profile (Goh & Abdul-rahman, 2013). However, the major difficulties existing in this process are the lacking of historical data of the risk. In addition, poorly understood and less developed technique also one of the constraint in this process (Maytorena et al., 2011). To conduct risk identification, project team, risk management team, subject matter experts from other parts of the company, customers, end users, other project managers, stakeholders, and outside experts were targeted to engage in this process.

2.4.2 Risk Assessment

According to (Dedasht et al., 2017) risk assessment is defined as the "procedure of prioritizing risks for further analysis by assessing and combining, generally, their probability of occurrence and impact". Equally, stated by (Zolkafli et al., 2012) risk assessment is the evaluation of an estimated risk with respect to others risk. There is a link between effective risk assessment and successful risk management. The success of risk management requires a wide assessment of risk management processes. This process should be addressed during design stage to consider any possible risk before the projects begin. The overall process of risk assessment includes risk analysis and risk evaluation (Zolkafli et al., 2012). For instance, the risk should be investigated in order from the likely to occur to the least likely.

Besides, The risk assessment includes the qualitative assessment and quantitative measurement of the risks including the interrelationship of their consequences (Schieg, 2010). Qualitative assessment provides a method to classified possible risks in terms of their preference which let the project managers to determine whether to continue with quantitative assessment or immediately to risk response planning (El-sayegh, Ph, & Mansour, 2015). The model of risk portfolio of the project can be illustrated with the result of risk assessment. For example, there are several studies that use Multi-Criteria Decision Making (MCDM) for risk assessment such as TOPSIS, AHP and ANP (Dedasht et al., 2017). However, risk assessment is the most difficult process in risk management since it involving the analysis in potential risk and its effects to the project goals (El-sayegh et al., 2015). Therefore, the proposed risk framework augments the process of risk assessment and enhances the effectiveness.

2.4.3 Risk Response

Risk response is the process of evolving strategic options and determining actions to increase the chances and reduce threats to the projects objectives. Proper risk identification and assessment enable project managers to decide on appropriate risk response strategies. The appropriate risk response strategies should be construct in order to cope with the risk that have been identified and analysed in the project (Zou & Wang, 2007). Systematic risk responses strategies are required to minimized and avert the risk (Choi, Cho, & Seo, 2004). Risk response are classified as risk avoidance, risk transference, risk mitigation and risk acceptance (Ward & Chapman, 2003). The table 2.1 below shows example of risk response planning.

Table 2.1 Risk Response Planning (Hosny, Ibrahim, & Fraig, 2018)

Risk/Trigger	Preventive Response	Corrective Response
Major forces	- Avoid: scope change (design and/or piling method)	-Apply cost and time reserves
Weather conditions	-Mitigate: scheduling the work out of flood season	-Use an instant dewatering system, special personal tools and equipment
Inadequate soil assessment	-Avoid: use multiple trusted consultations sources (Delphi technique) -Mitigate: monitoring the soil intake process	-Stop construction and use a new trusted consultation source
Scope creep, shrinkage or vagueness	-Avoid: clearly define the scope and get final approval from all impacted stakeholders	-Communicate the problem to stakeholders through an integrated change request and get their approval
Innovative construction technology	-Exploit: perform a feasibility study, quick decision making to optimize the use of the new approach	-Accept: no action
Design changes Incomplete design	-Avoid: clearly define the product and get final approval from all impacted stakeholders	-Communicate the problem to stakeholders through an integrated change request and get their approval
Delay in designer's response	-Avoid: clearly show the project communication requirements in the designer agreement associated with a penalty for non conformance -Mitigate: create a planned approach to allow effective communication between designers and executers	-Follow up with the designer until you got the desired reply
Poor stakeholders	-Mitigate: develop a	-Maintain status meetings

Risk/Trigger	Preventive Response	Corrective Response
communication	communication management plan based on stakeholders' communication requirements.	with impacted stakeholders to clarify any communication problems and perform the suitable solution.
Improper organizational structure	-Avoid: create a responsibility assignment matrix RAM) to define roles, responsibilities and reporting relationships	-Create a new RAM for the rest of the project and introduce it to your team
Ineffective decision making	-Mitigate: create decision making procedures.	
Delay in the approval of contractor's submittals	-Mitigate: tailor a contract clause that organizes processing of submittals with a due date of disposition	-Track the processing of your submittal to claim any delay as early as possible
Labour mistakes, rework and idle times	-Avoid: create affirmative selection criteria for labour selection based on experience, skills, competency and capacity to perform -Mitigate: create ground rules regarding labour performance with a suitable rewarding system to motivate them.	-Monitor and control labour performance on a regular basis to detect any variation and take suitable corrective actions based on analysis of weaknesses (e.g.: training, development or replacement)
Safety issues	-Avoid: assign an experienced HSE officer to secure suitable safety precautions to keep all stakeholders safe	-Determine the nearest hospital/clinic to your site to transfer cases. -Be prepared with first aid medications
Labour cost fluctuation	Avoid: use long term contracts with labour with fixed wages/salaries.	-Negotiate with
Surveying and site handling mistakes.	-Mitigate: select skilful and experienced surveyors -Transfer: ask your client to provide you with his fixed points	-Apply contingency reserves to adjust (redesign) any surveying mistakes

2.4.4 Risk mitigation

Risk mitigation is one of the technique lies under risk response. Risk mitigation reduces the any possible risk. Similarly, stated by (Keshk, Maarouf, & Annany, 2018) risk mitigation is to reduce the probability or consequences of a risk to an adequate level. During these stages, it is important to ensure that the implementation of risk response is accomplished throughout the project life cycle. It is not required to eliminate all the risks of the project due to resource and time constraints but there are certain risks that cannot be eliminated. However, their impact to the projects performance can be reduced. It is said by (Wang et al., 2004) that priority of risk mitigation strategies should be given to the dominant risk. The dominant risk should be mitigated before any occurrence that will affect project performances. Project performances are determine by the risk mitigation strategies in project planning (Z. Ali et al., 2018). In project risks, mitigation requires risk classification and an understanding of the magnitude of all risks from different sources (Z. Ali et al., 2018). In essence, effectiveness of risk mitigation relies on the concordance of all stakeholders risk perceptions (Zhao, McCoy, Kleiner, Mills, & Lingard, 2016).

2.5 Risk Management in Construction

Over the past decade, implementation of risk management has become significant in a construction projects. It is fundamental as construction projects are facing with risk which mostly has negative result on project. Risk management is a decision making process use to reduce and control the risk in systematic and proper manner (Singh, 2016). According to this definition, based on previous studies in Chile have shown that unsystematically implementation of risk management in a construction project resulting in negative aftermath in project performance (Federico, Ferrada, Howard, & Rubio, 2014). It is also stated by (A. S. Ali, 2014) that there is a proof that the implementation of risk management in a projects shows the improvement of project performance. The reasons why the implementation of risk management in construction projects mostly unsuccessful because there is still lack of expertise in this field (Federico et al., 2014). It is important to have knowledge and experiences in orders to make sure the risk management is effective in a construction projects.

Furthermore, it is essential to implement risk management from the early stages of construction project (Ft. Wainwright, 2015). This is because it is easier to prevent the risk from occurring if the root of risk is found earlier. According to (Maytorena et al., 2011) interest in managing risk has increased among the construction projects and this led to the evolution of best practice standards, tools and techniques. However, construction industry still has poor reputation in managing risk management as many projects delays and over budget (Browman, 2015). To ensure the risk management in construction industry is effective, the proper systematic methodology should be implementing. Therefore, the implementation of the risk management is one of the significant frameworks that should be applied in construction projects in order to manage risk.

2.6 Public Road Construction Projects

Public infrastructure is infrastructures that are owned by government for public use. Public infrastructure can be broken down to three main categories which is transport infrastructure, utilities and social and service infrastructure. The infrastructure sector has acquire massive amount of share from the government in every Malaysia Plans (Naidu, 2008). This is because the government foresee infrastructure sector as a base for long-term economic growth and quality of life improvements of citizen. Malaysia government has encouraged and facilitated private sector participation in infrastructure development to help finance the projects. Over two decades, road networks in Malaysia have shown a rapid economic growth in fact the government introduced road tolls to increase cost effectiveness (Olszewski & Tay, 2014).

According to Eleventh Malaysia Plan, public infrastructure especially in road network has developed to 68% between 2010 and 2015. In addition, a report published by Global Construction Perspective, highlighted that the global construction industry will rise over 70 percent by 2025. Moreover, the average economic return on World Bank between the years 1983-1992 in infrastructure projects was estimated at 16%, with highways contribute about 29% (Olszewski & Tay, 2014). Economic development depends primarily on location too, whether it is between cities, states, or countries. For instance, west coast of Peninsular Malaysia has biggest advantage in infrastructure development (Naidu, 2008). Thus, the government tried to achieve socio-economic development by focusing to developed infrastructure in rural area.

2.7 Risk Management in Public Infrastructure Projects

All construction projects are economically risky, especially projects in developing countries (Z. Ali et al., 2018). Although, all are aware with the possible risk and its outcome, not all organizations applied well establish risk management in their construction project (Kural, 2014). Moreover, numerous studies have shown that highway construction projects have higher risks compared to other construction projects due to the geographic area and threat from underground conditions (El-sayegh et al., 2015). In addition, (Awotunde & Babajide, 2014) asserted that risk that related with highway and road construction projects have a major impact on issues related to cost, time and quality of project delivery. It is known that road construction projects required a very large investment and to prevent costly project failures and other risk to occur, a systematic risk management need to be established.

According to (Hosny et al., 2018) implementation of risk management in construction industry has a potential effect on project success. The proper risk management should be well-established and agreed by all parties before implementing it. Eventually, different understanding during the early stage of risk management process between the stakeholders of road projects in Sri Lanka has affect the implementation of risk management (Perera et al., 2009). Three elements that are important in risk management process are time, cost and quality. Furthermore, cost overrun, delays and reduction of quality can be prevented by applying the risk management to the construction projects. In addition, previous studies also have shown that there are several highway projects that exceeded their budget and time due to what have been called unforeseen events (El-sayegh et al., 2015). Therefore, this study provides evidence that involving public infrastructure project particularly in road networks towards the implementation of risk management.

2.8 Conclusion

This chapter explored the concept of risk management and the various techniques employed in the risk management process. Various means for risk identification were also explored. The importance of risk management in road construction projects was also highlighted.

Different models propose by other researchers were presented and concise explanations regarding the workings of these models were given. This chapter helped to elucidate this research by helping to illuminate some of the research objective.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes the research methodology used to identify the risk assessment of public road construction projects. It addresses the methodology which is utilised to achieve the research objectives. In this chapter, it will discuss in detail about the methodology and procedures that will be applied in order to achieve all the data needed in this research. Figure 3.1 below shows the research methodology flowchart.

This research is designed in two distinct phase; phase 1 is the risk identification stages whereas all identified risk pertaining to road construction project were identified from the literature review. Second phase is the risk assessment stages whereas all the identified risks that were associated to the public road construction research used for this thesis. The project will be analyse adopting the multi criteria decision making method (mcdm), the analytical hierarchy process (AHP).

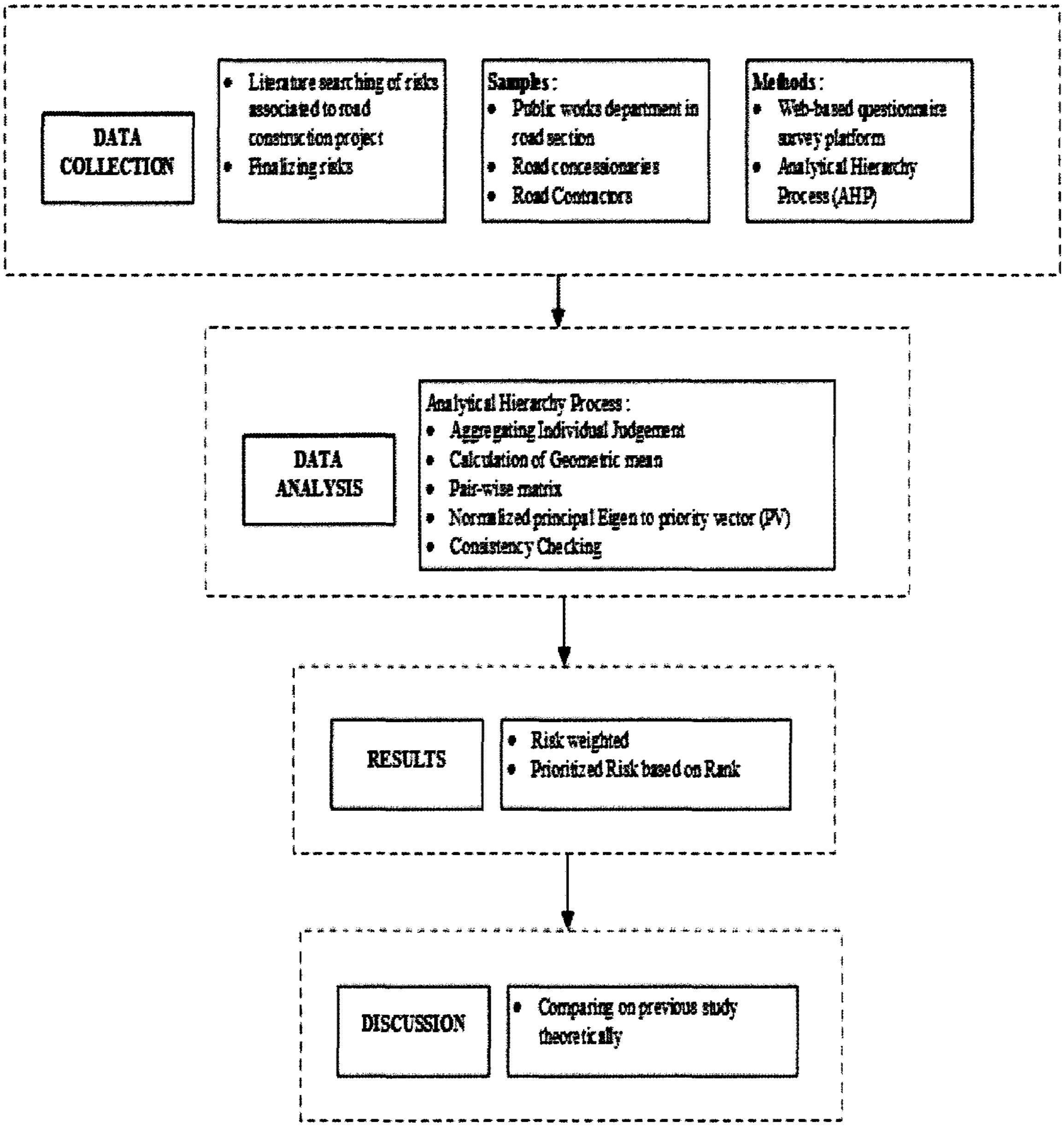

Figure 3.1 Research Methodology Flowchart

3.2 Data Collection

3.2.1 Research Approaches: Quantitative

This section briefly explains the quantitative research methodology which has been adopted for this research. It discusses the background and nature of quantitative approaches used in this study.

According to Creswell (2012), a quantitative approach is typically used when the research needs to describe a research problem through a description of trends or seeks an explanation of the relationship among known variables. In quantitative research, the investigator identifies a research problem based on trends in the field or on the need to explain why something occurs. Describing a trend means that the research problem can be answered best by a study in which the researcher seeks to establish the overall tendency of responses from individuals and to note how this tendency varies among people.

Analyses in the quantitative method are based on tabulated and numerical data. In quantitative research, data are collected in numerical form, often with pre-coded categories. This data collection enables the researcher to generalize the findings from a sample of responses to a population.

3.2.2 Sampling Procedure

The sampling procedures that will employ in this study were predetermined for the respondent with inclusion criteria of:

- Public work department road section (technical position)
  Road contractors and concessionaries
- Possess knowledge of risk management.
- Since AHP requires expert judgement, particular attentions have been made for selection of the respondent that extensively involved in the road construction.

3.2.3 The Analytical Hierarchy Process (AHP)

Analytical Hierarchy Process which was first introduced by Prof. Saaty (Saaty, 1988) offer a flexible and simply implicit approach of analysing complex dispute. It is a multi-criteria decision method that permits subjective as well as objective factors to be deliberated in the decision-making process. The AHP permits the vigorous involvement of decision-makers in getting reconciliation, and helps to decide on a rational basis. For this reason, AHP was considered one of the great tools since introduced in 1988, still practical until this millennium era. The main strength of AHP is its ability to consider the subjective opinions of decision-makers. This feature has made it especially attractive for combining with other methodologies that are usually developed to deal with objective data (Subramanian & Ramanathan, 2012).

In recent years, it reported that the decision makers in most construction project commonly the project managers, the client or stakeholders has accepted AHP more extensively as a tool for their decision making process. As a result, a systematic risk management program adopts AHP widely applied in the construction project life-cycle. Many previous studies including (Al-Tabtabai & Thomas, 2004; Aragonés-Beltrán, Chaparro-González, Pastor-Ferrando, & Pla-Rubio, 2014), (Hossen, Kang, & Kim, 2015) adopting AHP as decision methods in their construction case study. The next following section will elaborate on the steps of AHP method.

3.3 Data Analysis

3.3.1 Steps in AHP Method

The steps of calculation that are considered in AHP include; Hierarchy Construction; Comparative Judgment Matrices; Normalization Procedure; and Weight Synthesis and Consistency Test. It utilizes the judgments of decision makers to structure decision problems into hierarchies. An opinion scaling from point one- nine scaling (1–9) is employed for measuring logical preferences of decision makers (Saaty, 1988). AHP constructs ranking of decision items utilizing comparisons or correlations between every pair of items constituted as a matrix. The matched comparisons generate weighting scores that measure the amount of significance items and criteria have with one. Matrix algebra is then used to sort out variables to arrive at the best. The steps of the AHP methodology involve the following;

Step 1: Develop the matrix of factors. The problem is decomposed into a hierarchy of goal, factor, sub-factor and alternatives as shown in Figure 3.1.

Step 2: Make a pair wise comparison of alternatives on a qualitative scale. The weightings of the risk delay factors were assessed by using nine (9) scales of importance, as shown in Table 3.1.

Table 3.1 Scale of Relative Importance for Pair-Wise Comparison (Saaty, 1988)

Intensity	**Definition**	**Explanation**
1	Equal Importance	Two activities contribute equally to the objective
3	Moderate Importance	Experience and judgement slightly favors one activity over another
5	Essential or Strong importance	Experience and judgement strongly favor one activity over another
7	Very Strongly Importance	An activity is strongly favored and its dominance demonstrated in practice
9	Extremely Importance	Evidence favoring one over another of highest possible order of affirmation
2,4,6,8	Intermediate values	When compromise is needed

Step 3: The pairwise comparisons of various factors generated are organized into a square matrix.

Let C = {Cj | j = 1, 2, ... n} be the set of criteria. Equation (2) is the pairwise comparison shown by a square and reciprocal matrix.

$$A = aij = \begin{Bmatrix} a11 & \dots & a1n \\ \vdots & \ddots & \vdots \\ an1 & \cdots & ann \end{Bmatrix} \qquad 1$$

Step 4: The principal eigenvalue and the corresponding normalized right eigenvector of the comparing matrix give the relative importance of the various factors being compared. The elements of the normalized eigenvector are termed weights with respect to the factors or sub-factors and ratings with respect to the alternatives. Equation (3) showed formula of each matrix that needs to be normalized.

$$Aw = \lambda max.W \qquad 2$$

(Saaty, 1988) demonstrated that $\lambda_{max} = n$ is a necessary and sufficient condition for consistency. Inconsistency may arise when λ_{max} deviates from *n* due to varying responses in the pairwise comparisons. Therefore, (Saaty, 1988) proposed a method to measure the inconsistency by first estimating the consistency index (CI). The CI is defined in Eq. (3). Then, to obtain the consistency ratio (CR), the CI is divided by the random consistency index (RI) in Eq. (4), value of RI as tabulated in Table 3.2. The CR value should not greater than 0.1 otherwise the pairwise comparison result should be rejected.

$$CI = \frac{(\lambda max - n)}{(n-1)} \qquad 3$$

$$CR = \frac{CI}{RI} \qquad 4$$

Table 3.2 Random Consistency Index (RI)

Number of factors	1	2	3	4	5	6	7	8	9
Random Index (RI)	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

3.3.2 Design of AHP model in using 'Superdecision Software'

The AHP Hierarchy structure which was developed and shown in figure 3.2 were then employed in the 'Superdecision Software' .The 'Superdecision Software' implements the Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP) for decision making with dependence and feedback, a mathematical theory for decision making developed by Thomas L. Saaty. The software for the decision making with dependence and feedback was developed by William Adams in 1999-2003. He and his team have developed software which can undergo AHP and ANP and is known as 'Superdecision Software' from Creative Decisions Foundation.

Generally, the procedure for operating the 'Superdecision Software' is indicated as follows:

The desired model according to the developed hierarchy created using the function of cluster and nodes. Each cluster represent the main criteria that to be define, while nodes represents the factors on each of the groups that they are belongs to. Model developed for this study depicted in figure 3.2 below. The connection between goal, factors and sub-factors were created to facilitate the next procedure i.e. pairwise ratings.

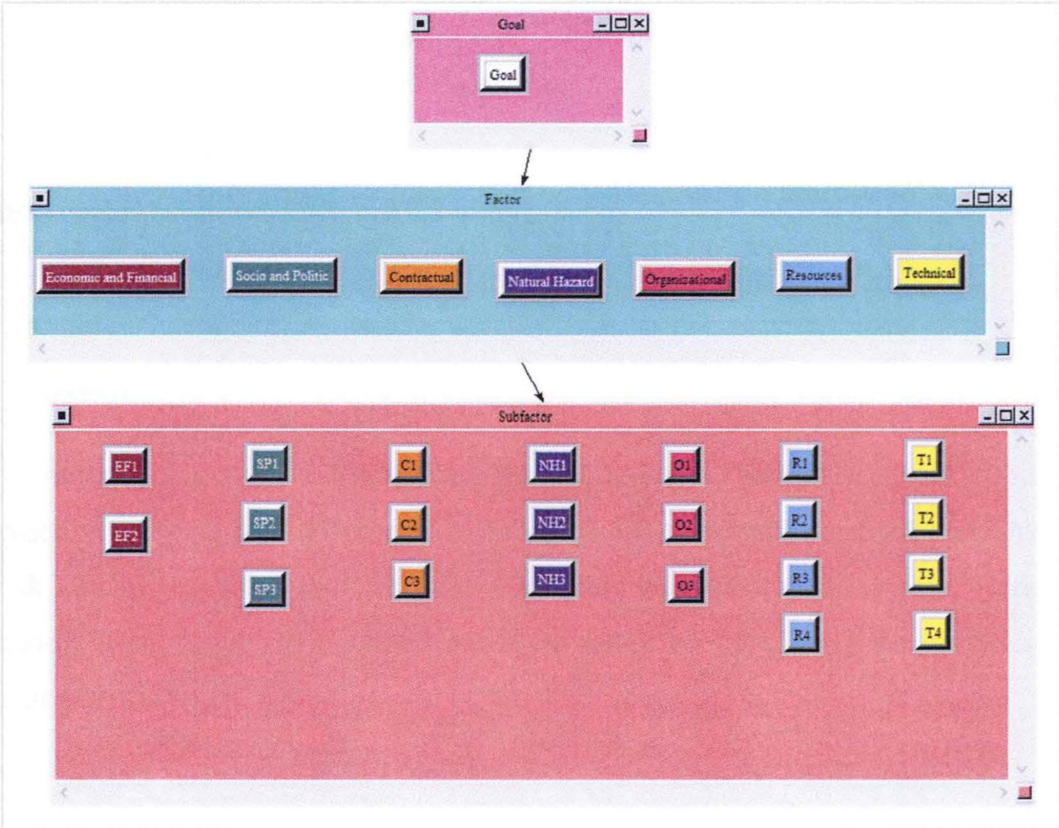

Figure 3.2 AHP model in develop in 'Superdecision Software'

Next, the operation of pairwise rating procedure conducted using the matrix command and the 'geomean value' as shown in figure 3.3 below.

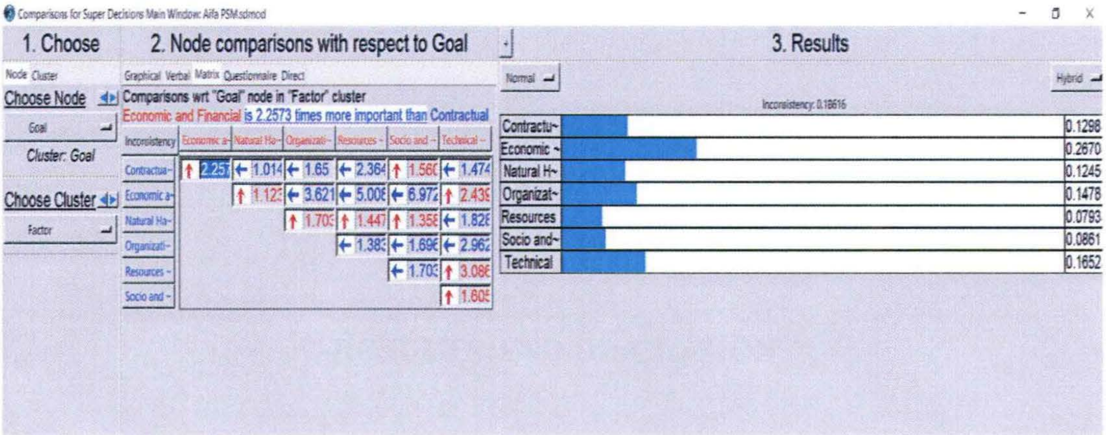

Figure 3.3 The pair-wise comparison

Similarly, the prioritized values were given and results were checked for any inconsistencies as shown in figure 3.3 above.

3.4 Result

After data analysis is completed, the risk weighted of risk occurs in public road construction projects will be obtained. Based on the weighted obtained the ranking of the risk can be achieved therefore the prioritized risk will be determine. Hence, the discussion from the result obtained could be made by comparing on previous study theoretically.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the quantitative findings of all the data collected through the questionnaire. This questionnaire focused in finding the relative importance score of the risk for road construction project. The purpose of this study is to analyse the associated risk by using Analytical Hierarchy Process (AHP) among the public work department road section in Pahang state. The implementation of AHP method in this study will determine the weighted risk. All the data will be analysed and the result will be presented by using bar chart.

This discussion for chapter is divided into two sections which consist of:

Section 1: Demographic data

Section 2: Risk Prioritization based to Analytical Hierarchy Process

4.2 Questionnaire Design

The questionnaire has been distributed through web based survey platform to public work department road section in all Pahang state, road contractors and road concessionaries. Out of fifty (50) online questionnaires sent only thirty (30) responded and filled accordingly, this represent 60% of response rate. However, this figure is sufficient due to the targeted samples is for the public work department in road section. In AHP analysis, there are no pre-set rules to determine the acceptable sample size of experts. One expert judge may be sufficient unless political practicality requires that several judges from different constituencies are necessary.

This questionnaire is design based on the AHP hierarchy that was analysis based on factors that may cause delay in public road construction project. The AHP hierarchical model as depicts in Figure 4.1 below was adapted and modified following (Razi, Ali and Ramli 2019) AHP hierarchical diagram. Once the questionnaire is done, the questionnaire is then distributed through web-based survey. The respondents were required to compare the importance of two pairwise factors and to rate the scale of importance of the factor. The reason this questionnaire is distributed through web-based surveys is because the quick result returns from the respondent. Besides, it is also cost effective as it is free for user to use. According to (Heiervang & Goodman, 2011) the benefit of web-based survey may connected to the speed and cost of data collection as well as data quality.

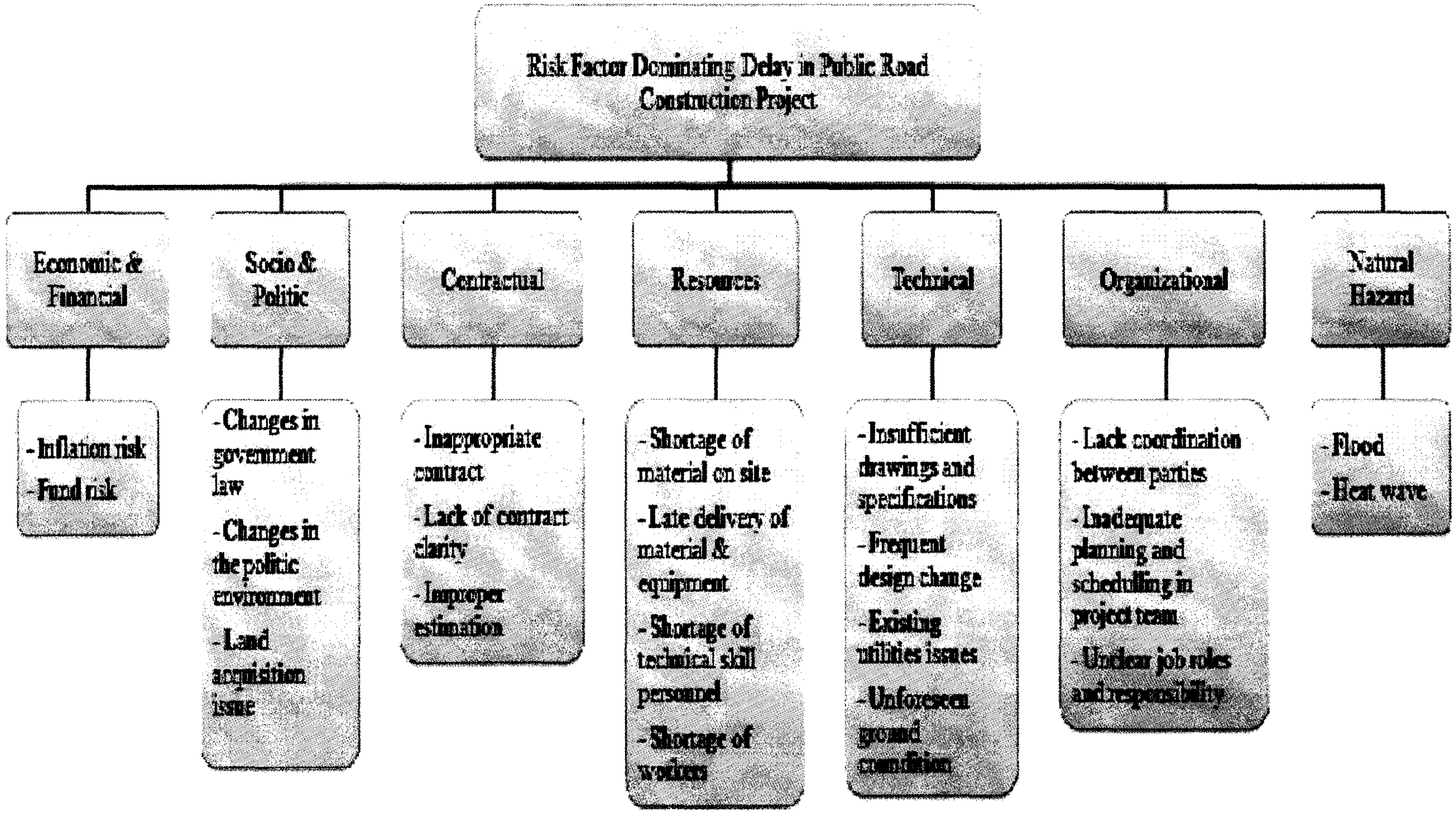

Figure 4.1 Analytical Hierarchy Process (AHP) Risk Framework AHP Models were adapted and modified from (Razi, Ali, & Ramli, 2019)

4.3 Demographic Data

Figure 4.2 shows that most of the respondent that participates in this survey is male with the highest percentage which is 54%. Meanwhile, the female respondent that participates in this survey is 46%.

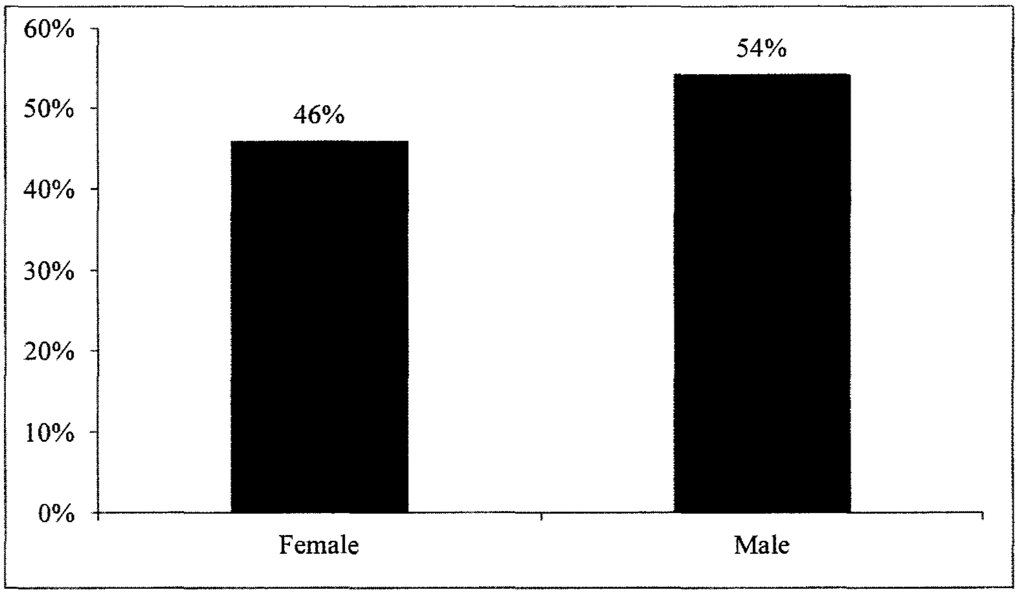

Figure 4.2 Gender of Respondent

As in figure 4.3 it shows that the highest percentage position of the respondent that participates in this survey is civil engineer with 50%. Next, followed by quantity surveyor with 25%, project manager with 13%, main contractor with 8%, sub-contractor with 4% and lastly mechanical engineer with 0%.

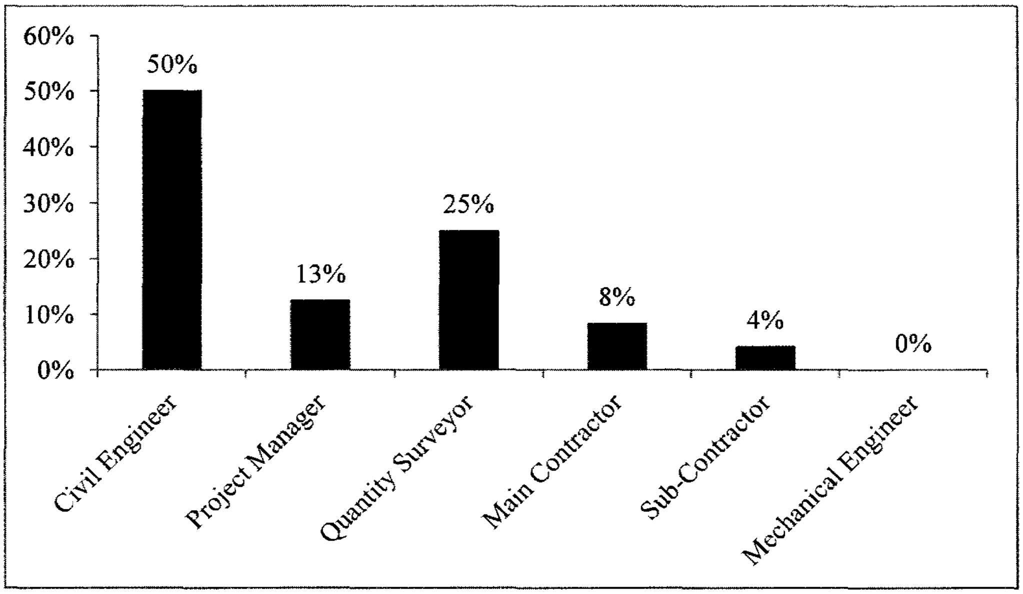

Figure 4.3 Position of Respondent

Among the participants of this survey, figure 4.4 shows that 54% of the respondent is from the public sector and 46% of the respondent is from the private sector.

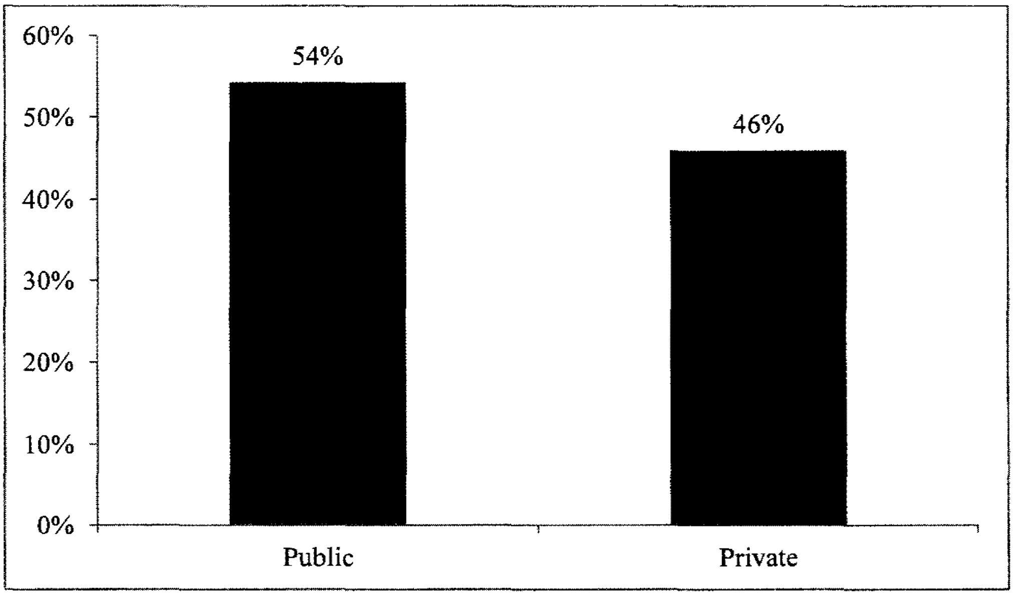

Figure 4.4 Working Sector

54% of the respondent has 10 – 14 years of experience in the industry and 38% of the respondent has 5 – 9 years of experience in the industry. Furthermore, 8% of the respondent has 1 – 5 years of experience in the industry. Meanwhile, there is 0% of the respondent that have over 15 years of experience in the industry. The results are shown in the figure 4.5.

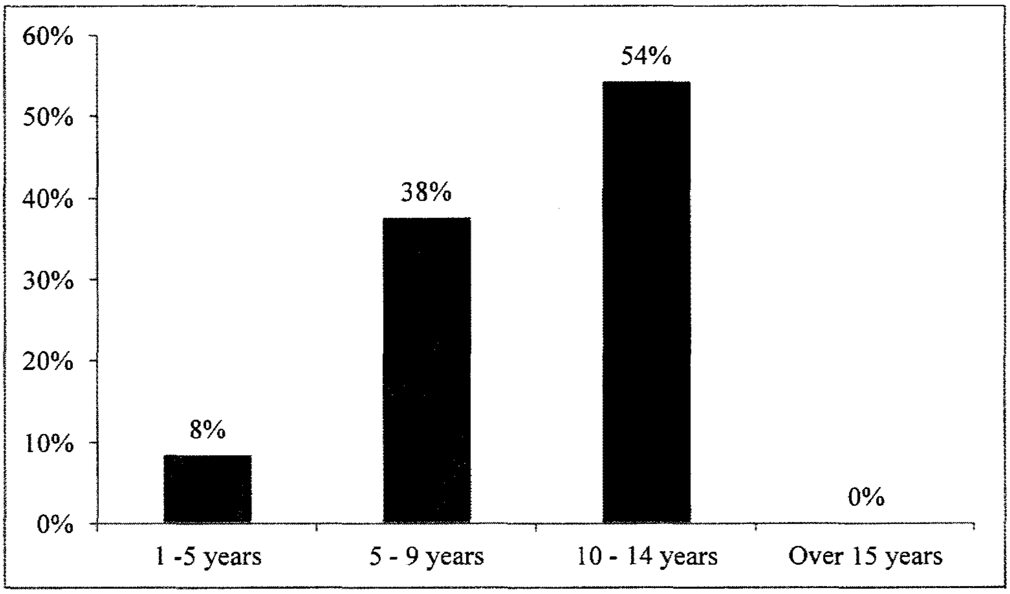

Figure 4.5 Years of Experience in the Industry

Figure 4.6 show that degree is mostly the education level of the respondent with the highest percentage 75%. Next, 17% of the respondent has master degree as their education level and the respondent with diploma is 8%. Meanwhile, none of the respondents holds PhD.

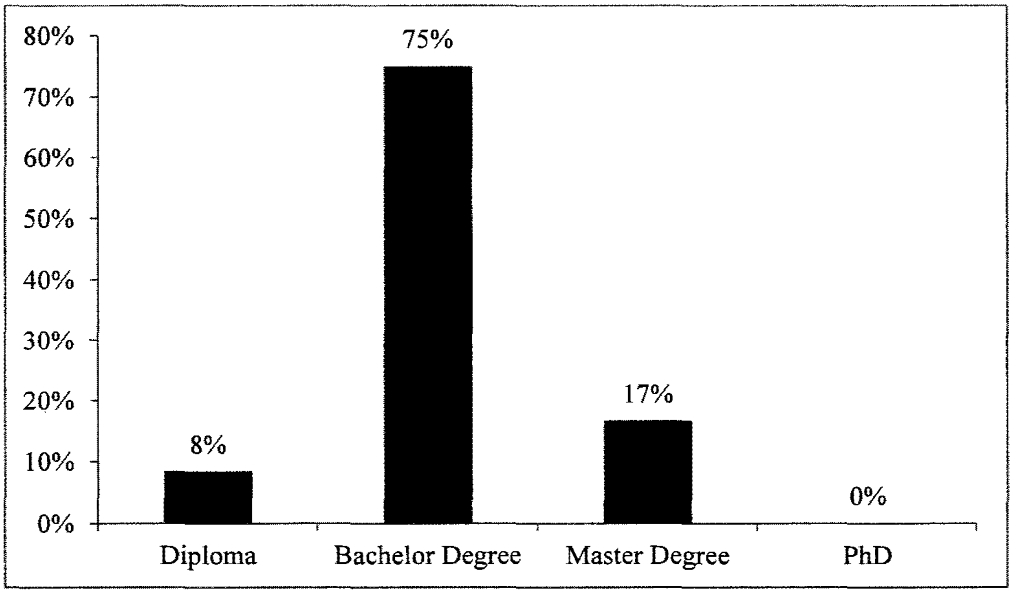

Figure 4.6 Education Level

Based on figure 4.7 most of the respondent level of knowledge in risk management is intermediate with 54%. Meanwhile, only 21% of the respondent has advanced knowledge in risk management. Followed with 13% and 8% are respondent with basic and novice in knowledge in risk management. Lastly, only 4% of the respondent is experts in risk management. Taken together, more than half of the respondents (54%) have at least a knowledge of risk management aspects, evidenced by their intermediate knowledge, thus turns this study practical in the context of the sample taken.

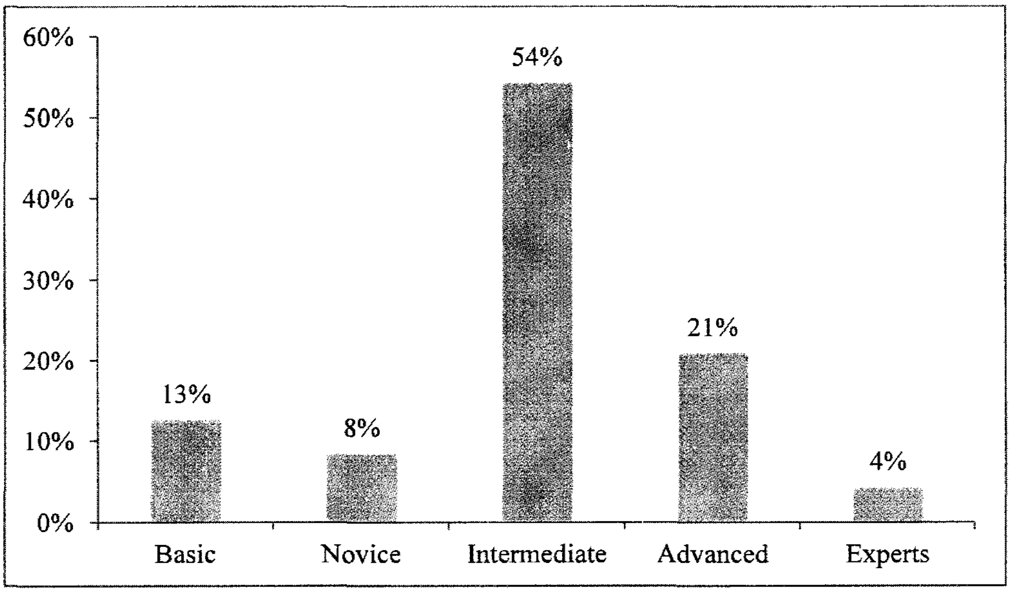

Figure 4.7 Level of Knowledge in Risk Management

Based on figure 4.8 it shows that 58% of the respondent agrees that risk management should be implemented during planning, design, and construction and completion stages. Followed by 17%, the stages that respondent think should be implemented are during design and construction. Next, 8% of respondent think that during planning, design and construction stages risk management should be implemented. Meanwhile another 8% of respondent think that risk management should be implemented during planning stages only. Lastly, planning and design stages and construction stages only is in the last place with 4% of the respondent. The evidence from this suggests that most of the respondents agree upon the implementation of risk management in the life-cycle of public road construction projects.

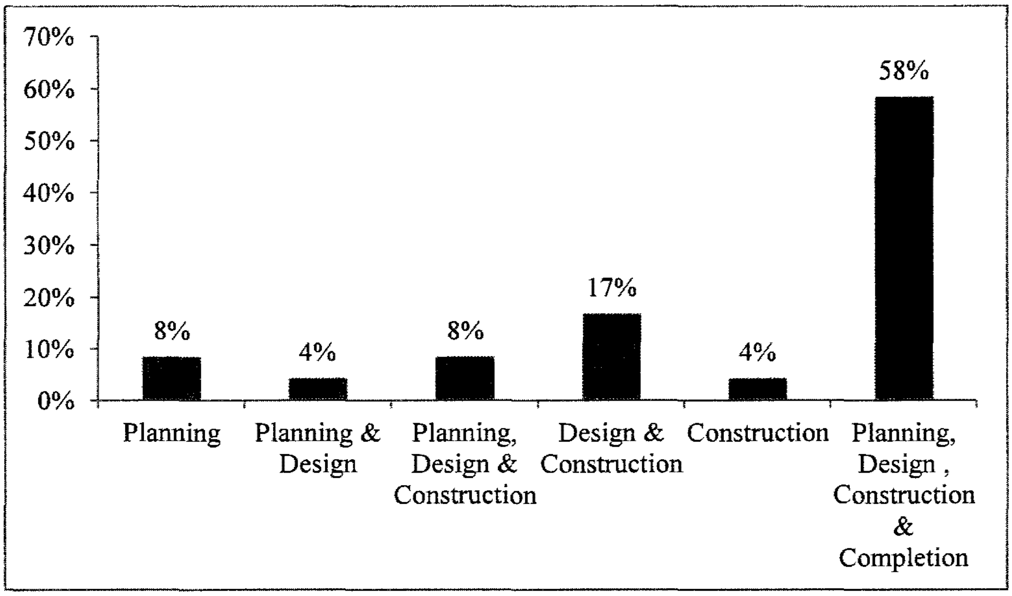

Figure 4.8 Stages Risk Management Should be Implemented

4.4 Risk Weighted Using AHP Superdecision Analysis

The aim of this study is to analyze the associated risk by using AHP method. In AHP method, geometric mean is used rather than arithmetic mean because it involves reciprocal value during matrices. Furthermore, the ratios of the global priorities change with different normalizations of local priorities when arithmetic mean aggregation is used but remain the same when geometric mean aggregation is applied (Stoklasa & Krej, 2018). The risk factors and sub-factors are rank based on its prioritization weighted that obtains through 'Superdecision Software' as shown in table 4.1 below.

Table 4.1 List of prioritized risk factors and sub-factors

Risk Factors	Rank	Risk Sub-factors	Rank
Economic and Financial (0.267)	1	Inflation risk (0.561)	2
		Fund Risk (0.439)	5
Contractual (0.130)	4	Inappropriate contract (0.386)	6
		Lack of contract clarity (0.370)	7

		Improper estimation (0.243)	16
Natural Hazard (0.125)	5	Heavy Rain (0.273)	12
		Flood (0.633)	1
		Heat wave (0.094)	22
Organizational (0.148)	3	Lack coordination between parties (0.467)	4
		Inadequate in planning and scheduling in project team (0.317)	10
		Unclear job roles and responsibility (0.216)	18
Resources (0.079)	7	Shortage of material on site (0.286)	11
		Late delivery of material and equipment (0.323)	9
		Shortage technical skill personnel (0.252)	15
		Shortage of workers (0.138)	21
Socio and Politic (0.086)	6	Changes in government law and regulation (0.543)	3
		Changes in politic environment (0.192)	19
		Land acquisition issue (0.265)	13
Technical (0.165)	2	Insufficient drawings and specification (0.230)	17

	Frequent design change (0.167)	20
	Existing utilities issue (0.350)	8
	Unforeseen ground condition (0.253)	14

Table above shows that the most prioritized risk factors are economic and financial (0.267), followed by technical (0.165), organizational (0.148), contractual (0.130), natural hazard (0.125), socio and politic (0.086) and resources (0.079). Economic and financial dominated the ranks largely due to most road construction project are depended on the project expenditure and lack of funding will causes project delay. Prior studies have also reported that technical issue is exposed to escalating cost in projects which enhances the probability of additional claims from opportunistic contractors (Z. Ali et al., 2018).

Organizational risk in road construction project occurs when there is lack of understanding between the project team and client. Project managers should ensure that contractual obligations are dealt diligently to avoid any delay payment and consequently cause project delay (Kaliba et al., 2009). Natural hazard is deemed as a natural disasters that occurs and have the potential to cause serious damage to roadway infrastructure. Socio and politic have bigger impact in road construction project as the funds to highway project mostly came from the government. Resources took last place in the risk factors however when it is occur in the construction project it will affect the project schedule.

Furthermore, the risk sub-factors were also ranked and the top five sub-factors will be further discussed. The table shows that flood (0.63306) as the prioritized risk which cause delay in the project, followed by inflation risk (0.56063), changes in government law and regulation (0.54314), lack coordination between parties (0.46672), fund risk (0.43937). Flood is chosen as the highest risk even though it is a natural risk however it is seen as events with negative consequences that occur beyond the control of human being (Ezanee & Ghazali, 2010). Moreover, (Kaliba et al., 2009) also stated that floods is the number one cause for cost escalation.

Next, inflation risk is also a major risk that fall under economic and financial. According to (Antón, Rodríguez, & López, 2015), inflation and sudden price changes represent the most important economic risks in countries such as, for example, the UAE. In addition, inflationary increase in the price of construction materials has been one of the major banes to development and a contributing factor to frequent cost overruns and subsequently project abandonment (Oghenekevwe, Olusola, & Chukwudi, 2014). Changes in government law and regulations result in lots of uncertainty about construction regulation shifts and might impact small construction firms. This will result to project delay.

Besides, coordination between the parties involved is one of the key criteria leading to a construction project success. (El-razek, Bassioni, & Mobarak, 2009) highlighted lack of coordination between parties in Egyptian construction projects is the main causes of delays in the project. Therefore, poor coordination between the client and design team only affecting the project performance. Fund risk is ranked as the fifth prioritised risk factor, which cause time overrun in road construction project. According to (Razi et al., 2019) the issue of fund risk in the project team was rank as one of the prioritised factor which often led to time overrun.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Introduction

This final chapter will be discussed all the data that had been tabulated and analyzed in the previous chapters. The objectives that mentioned in chapter 1 will be concluded and briefly discussed. Moreover, the objectives of this study have achieved based on the analysis and observation of the result in chapter 4. Furthermore, some recommendation was listed in order to improve further study of this research.

5.2 Conclusion

The conclusions of each objectives of the research had been discovered and explained accordingly. Basically, the objective highlighted in the chapter 1 had been achieved from this research. This study proposed to explore the risk associated to public infrastructure road construction project adopting AHP method. Based on the findings and analysis several conclusions may be drawn as follows. Through AHP method we can develop a model for decision making to derive the prioritized weighted risk factors and sub-factors. Moreover, from the risk weighted obtained the road engineers can focus on which stages to implement the risk management. This can prevent the risk to occur from early construction phases. Furthermore, this research opens the door for future studies specifically in risk response planning and control. Mitigation measures can be studied and response plans can be developed.

The findings of this study may be focusing to the road construction project only. However, this finding may also be applicable to a similar scale road construction project. Further work is called upon to adapt the risks associated with larger infrastructure projects not limited to the road construction, including mixed-development of cities, power plant construction project, railway construction and others mega development construction projects.

5.3 Recommendation

This study is mainly focus on the risk assessment of public road construction project. Further study is needed to account for the varying:

i) Bigger sample size and longer time frame for an inferential analysis.

ii) A mixed up qualitative study (interview) within the road engineers in Malaysia.

iii) All the engineers in Malaysia need more exposure in risk management so that the risk can be identified in the early stages.

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APPENDIX A
EXAMPLE OF QUESTIONNAIRE FORM

Road Construction Survey

Dear kind and cooperative respondents,

Y.Bhg Tan Sri/Dato/Datin/Mr/Mrs,

My name is Putri Aifa Syuhaida Bt Shabuddin,
currently pursuing my final year in Bachelor Degree in Civil Engineering.
This survey is conducted for my final year project.

The purpose of this questionnaire survey is :

To determine the relative importance score of the risk for road construction project by using the Analytical Hierarchy Process (AHP) scale.

I hope that you could spend some time in answering the survey.

If you have any query, Please contact:
Putri Aifa Syuhaida Shabuddin,
Bachelor Degree candidate,
Faculty of Civil Engineering and Earth Resources,
Universiti Malaysia Pahang.
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*Please select your gender ?

- ( ) Male
- ( ) Female

*Please select your profession ?

- ( ) Civil Engineer
- ( ) Mechanical Engineer
- ( ) Project Manager
- ( ) Quantity Surveyor
- ( ) Main Contractor
- ( ) Sub-Contractor
- ( ) Other

*Working sector ?

- Public
- Private

*Years of experience in construction (including previous experience) :

- 1 to 5 years
- 5 to 9 years
- 10 to 14 years
- over 15 years

*Education level ?

- PhD
- Master Degree
- Bachelor Degree
- Diploma
- Certificate
- SPM / SPM (V)

*What best describe your experience and knowledge in risk management ?

- Basic
- Novice
- Intermediate
- Advanced
- Expert

*What best describe your experience and knowledge in risk management ?

- ○ Basic
- ○ Novice
- ○ Intermediate
- ○ Advanced
- ○ Expert

*In what stages/phases of construction do you think risk management should be implemented ? (You may tick all if you think it is appropriate)

Multiple answers are possible

- ☐ Planning
- ☐ Design
- ☐ Construction
- ☐ Completion

*Please choose the relative important weight of the listed risk factors

	9	7	5	3	1	3	5	7	9	
Economic and Financial	○	○	○	○	○	○	○	○	○	Socio and Politic
Economic and Financial	○	○	○	○	○	○	○	○	○	Contractual
Economic and Financial	○	○	○	○	○	○	○	○	○	Resources
Economic and Financial	○	○	○	○	○	○	○	○	○	Technical
Economic and Financial	○	○	○	○	○	○	○	○	○	Organizational
Economic and Financial	○	○	○	○	○	○	○	○	○	Natural Hazard
Socio and Politic	○	○	○	○	○	○	○	○	○	Contractual
Socio and Politic	○	○	○	○	○	○	○	○	○	Resources
Socio and Politic	○	○	○	○	○	○	○	○	○	Technical
Socio and Politic	○	○	○	○	○	○	○	○	○	Organizational
Socio and politic	○	○	○	○	○	○	○	○	○	Natural Hazard
Contractual	○	○	○	○	○	○	○	○	○	Resources
Contractual	○	○	○	○	○	○	○	○	○	Technical

***Please choose the relative important weight of the "socio and politic" risk listed risk factors**

	9	7	5	3	1	3	5	7	9	
Changes in government law and regulation	O	O	O	O	O	O	O	O	O	Changes in the politic environment
Changes in government law and regulation	O	O	O	O	O	O	O	O	O	Land acquisition issue
Changes in the politic environment	O	O	O	O	O	O	O	O	O	Land acquisition issue

***Please choose the relative important weight of the "contractual" risk listed risk factors**

	9	7	5	3	1	3	5	7	9	
Inappropriate contract	O	O	O	O	O	O	O	O	O	Lack of contract clarity
Inappropriate contract	O	O	O	O	O	O	O	O	O	Improper estimation
Lack of contract clarity	O	O	O	O	O	O	O	O	O	Improper estimation

***Please choose the relative important weight of the "resources" risk listed risk factors**

	9	7	5	3	1	3	5	7	9	
Shortage of material on site	O	O	O	O	O	O	O	O	O	Late delivery of material and equipment
Shortage of material on site	O	O	O	O	O	O	O	O	O	Shortage of technical skill personnel
Shortage of material on site	O	O	O	O	O	O	O	O	O	Shortage of workers
Late delivery of material and equipment	O	O	O	O	O	O	O	O	O	Shortage of technical skill personnel
Late delivery of material and equipment	O	O	O	O	O	O	O	O	O	Shortage of workers
Shortage of technical skill personnel	O	O	O	O	O	O	O	O	O	Shortage of workers

***Please choose the relative important weight of the "technical" risk listed risk factors**

	9	7	5	3	1	3	5	7	9	
Insufficient drawings and specification	O	O	O	O	O	O	O	O	O	Frequent design change
Insufficient drawings and specification	O	O	O	O	O	O	O	O	O	Existing utilities issue
Insufficient drawings and specification	O	O	O	O	O	O	O	O	O	Unforeseen ground condition

***Please choose the relative important weight of the "organizational" risk listed risk factors**

	9	7	5	3	1	3	5	7	9	
Lack coordination between parties	○	○	○	○	○	○	○	○	○	Inadequate planning and scheduling in project team
Lack coordination between parties	○	○	○	○	○	○	○	○	○	Unclear job roles and responsibility
Inadequate planning and scheduling in project team	○	○	○	○	○	○	○	○	○	Unclear job roles and responsibility

***Please choose the relative important weight of the "natural hazard" risk listed risk factors**

	9	7	5	3	1	3	5	7	9	
Heavy rain	○	○	○	○	○	○	○	○	○	Flood
Heavy rain	○	○	○	○	○	○	○	○	○	Heat wave
Flood	○	○	○	○	○	○	○	○	○	Heat wave

***Please choose the relative important weight of the "organizational" risk listed risk factors**

	9	7	5	3	1	3	5	7	9	
Lack coordination between parties	○	○	○	○	○	○	○	○	○	Inadequate planning and scheduling in project team
Lack coordination between parties	○	○	○	○	○	○	○	○	○	Unclear job roles and responsibility
Inadequate planning and scheduling in project team	○	○	○	○	○	○	○	○	○	Unclear job roles and responsibility

***Please choose the relative important weight of the "natural hazard" risk listed risk factors**

	9	7	5	3	1	3	5	7	9	
Heavy rain	○	○	○	○	○	○	○	○	○	Flood
Heavy rain	○	○	○	○	○	○	○	○	○	Heat wave
Flood	○	○	○	○	○	○	○	○	○	Heat wave