Kamboçya’da Yapılan İnşaat Projelerinin Zaman, Maliyet Ve Kalite Üzerine Risk Yönetimi

Sochetra Chrin

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Sochetra Chrin

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by
Sochetra Chrin

Supervisor: Dr. Öğr. Üyesi Osman AYTEKİN

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ETHICAL STATEMENT

I hereby declare that this thesis titled "Risk management on Time, Cost, and Quality in Construction Projects in Cambodia" has been prepared in accordance with the thesis writing rules of Eskişehir Osmangazi University Graduate School of Science under the academic consultancy of my supervisor Dr. Öğr. Üyesi Osman AYTEKİN. I hereby declare that this MASTER OF SCIENCE THESIS is an original work prepared by me; that I have respected scientific ethical principles and rules in all stages of my thesis, data collection, analysis and presentation of my work; that I have cited the sources of all the data and information that could be obtained within the scope of the study, and included these sources in the section of references.

I also declare that I have obtained permission to implement data collection tools of Eskişehir Osmangazi University Science and Engineering Sciences Scientific Research and Publication Ethics Board Decision on 2021-04 with the decision number of **E-53893652-050.01.01-167585**.

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Sochetra CHRIN

Signature

ÖZET

İnşaat projelerinde yapım öncesinde, sırasında ve sonrasında her zaman riskler vardır. Bu calışmada, inşaat projelerinde risk yönetiminin zaman, maliyet ve kalite üzerindeki etkisini incelemiştir. Projeyi etkileyen en kritik engelin hangisi olduğunu analiz etmek amacıyla üç alternatifi incelenmiştir.

Araştırmanın amacı, zaman, maliyet ve kalitenin Kamboçya yapılan inşaat projelerinin risk yönetimi üzerindeki etkilerini araştırmektedir. Araştırma kapsamında Kamboçya'da bölgesindeki hem devlet hem de özel sektör bina tipi inşaat projeleri üzerinder araştırmalar yapılmıştır. Pilot çalışma olarak anket uygulamaları gerçekleştirilmiştir. Ankette katılan katılımcılar inşaat mühendisi ve mimar olarak görev yapan kişilerden seçilmiştir. Yapılan anketlerden elde edilen verileri değerlendirmek için SPSS yazılmı, Excel yazılımı ve Analitik Hiyerarşi Süreç Yöntemi (AHP) kullanılmıştır. İstatistiksel, Delphi tekniği, T-test analizi ve Cronbach Alpha kullanılarak analizler yapılmıştır. İstatistik analizlerinden elde edilen veriler kullanılarak AHP yönetimi üzerindeki etki değeri elde edilmiştir.

Sonuç olarak, istatistik verilerden elde edilen değelere göre inşaat proje yönetiminde en önemli risk faktörlerinin sırasıyla niteliksiz proje yöneticisi, mali sorunlar, yüklenicilerin deneyim ve iş organizasyonu eksikliği, şantiye içi iletişim ve koordinasyonu eksikliği, yüklenicilerin çalışmalarında yaptıkları hatalar, düşük teklif veren yüklenicinin seçilmesi olarak belirlenmiştir. Ancak risk değerlendirme analizinde ise en kritik faktörlerin sırasıyla proje yöneticisi deneyimi, şantiye içi iletişim ve koordinasyon eksikliği, yüklenici deneyimi, sözleşmede sonradan yapılan değişiklikler, finans imkanlarındaki eksiklikler, Covıd-19 pandemisinin ekilleri, iş gücü kalitesi emek ve kalite olarak belirlenmiştir.

Anahtar kelimeler: İnşaat projesi, Risk yönetimi, AHP yöntemi, Risk tanımlaması, Risk analizi, Risk tepkisi, Risk kontrolü, Risk değerlendirmesi,

SUMMARY

Construction projects always accompany risks at the beginning, during, and after the construction. This study includes the risk management impact on time, cost, and quality in construction projects. Among taking these alternatives to analyze which one is the most critical obstacle in the project.

The research aims are to evaluate the risk management impacts on time, cost, and quality in construction projects as evidence from Cambodia. The research scope is considered the building construction projects in both public and private sectors in the Cambodia region. The pilot study and survey questionnaires are applied in the research. The selected respondents are civil engineers and architects. To evaluate the study, descriptive statistical analysis and analytic hierarchy process methods are used by the SPSS program and Excel software. Delphi technique, T-test analysis, and Cronbach Alpha also work for the research investigation. The analysis is concentrated on the impact (only threat) on risk management in construction projects.

Consequently, the most critical risk factors happening in CPs are the unqualified project manager, financial issue, lack of skills and work organization by the contractor sectors, poor communication and coordination of participants, mistakes during processing work by contractors, selecting low bid of the contractor by clients or owners. However, the most critical problems of RC assessment analysis are the project manager, communication and coordination of participants, contractor parties, change in scope of work, finance, the pandemic of Covid-19, labor, and quality respectively.

Keywords: Construction project, Risk management, AHP method, Risk identification, Risk analysis, Risk response, Risk control, Risk assessment,

LIST OF CONTENTS

Page

LIST OF CONTENTS (continued)

Page

LIST OF CONTENTS (continued)

LIST OF FIGURES

Figure **Page**

LIST OF TABLES

Table **Page**

LIST OF TABLES (continued)

Table **Page**

LIST OF TABLES (continued)

Table **Page**

LIST OF ABBREVIATIONS AND SYMBOLS

Abbreviations	**Descriptions**
CCI	Cambodian Construction Industry
CCP	Cambodian Construction Project
CI	Construction Industry
CP	Construction Project
CRM	Construction Risk Management
Diff.	Difference
FDI	Foreign Direct Investment
MLMUPC	Ministry of Land Management, Urban Planning and Construction
PM	Project Management
PRM	Project Risk Management
RA	Risk Analysis
RC	Risk Category
RS	Risk assessment
RF	Risk Factor
RI	Risk Identification
RM	Risk Management
RMS	Risk Model Structure
Std.	Standard Deviation

1. INTRODUCTION AND PURPOSE

Researchers are around the world always think about the economic and flexible prior factors; especially considering cost, time, and quality. Similarly, the construction field is an important part of the economic role in infrastructure in every country. Each procedure of the Construction Project (CP) would have many ways and factors in order to manage to gain the smooth project without any struggle. Project management is to organize the project needs to be undertaken to use the knowledge practice, skills, tools, and techniques (PMBOK, 2013). All project management approaches have always appeared to the uncertain and contingency events. That is called risk.

Studying in risk management of construction projects plays an important role to make success stronger and more power of project management under better quality, cost and time control, and safety works. Project risk management is inevitable, but it must be addressed to solve in an effective way. Risk management would be as much as different uncertain events and contingency happened in construction projects. It depends on locations, conditions, management systems, natural environments, resources for projects, techniques, people's knowledge or performances.

A lot of previous researchers focus on the cost overrun, delay schedule, low quality, safety accident or environmental issues in Cambodian construction projects (CCPs) such as (Durdyev et al., 2018; Durdyev et al., 2020; Durdyev et al., 2017; Kang et al., 2018; Peansupap and Cheang, 2015; Sepasgozar et al., 2019). Additionally, based on (Kang et al., 2018), claim that those problems happened due to the lack of construction management, capacity management, lack of risk factor control, poor time management, low standards, lack of laws and regulations in CPs. These problems point out that risk factors conduct on the cost, schedule, quality of the CP being project objectives.

Actually, all participants in a construction project want the project to runs as well. Unfortunately, most of them claim that the projects were struggling with cost, schedule, and quality. To help and understand clearly how the critical risk factors impact these three elements, this study will be beneficial for critical analysis of the project risk before deciding on whether to invest this and implement it.

Thus, the risk management impacts on time, cost, and quality in construction projects in Cambodia will be studied in this research. Through Google Scholar, there would believe that it is the first study of risk management in CPs in Cambodia. In this research, we focus on critical schedule, cost, and quality that cause by risk happening in the project experiences. Then, project stakeholders would establish and solve more confident comprehension in the right solution at the right time in construction project management.

This research surveys the civil engineer who works involved with the client, owner, designer, architect, contractor, sub-contractor, and supplier in the construction project in Cambodia. The result will show how much risk management plays a necessary character in a successful construction project. Especially, the percentage of project experiences has met the time delay, cost overrun, any quality problem. The risk identification will be noticed and evaluated in Cambodian construction projects (CCPs). Additionally, it will be pointed out the among the cost, time, and quality which will be the most critical risk impact in the CPs.

The research purpose is to evaluate the risk management impacts on time, cost, and quality in construction projects as evidence from Cambodia. So, it will identify whether how much level likelihood and impact of each risk factor affecting these three elements in the previous project. Therefore, the objectives in the research are:

- To find out the most critical significant risk events being harmful in construction projects
- To find out the risk assessment analysis and set the priority rank of each risk affecting cost overrun, schedule delay, and quality issue
- To represent the weight of critical risks and risk alternatives by the AHP method; the interaction between main criteria and risk alternatives, and the interaction between sub-main criteria and risk alternatives (based on surveys)

The research scope is focused on the building construction project in Cambodia. The research context collects data in both public and private construction project sectors from respondents. Respondents are civil engineers and architect engineers who have been involved in the firm of clients, consultants, architects, contractors, sub-contractors, and suppliers. So, the research measurements will respond to the viewpoints of critical project risks in the region of Cambodia. Further, this study will evaluate the degree of likelihood and impact of risk factors (RFs), risk categories (RCs), and main risks (MRs). Additionally, descriptive statistical analysis and analytic hierarchy process technique are used by SPSS program version 26 and Excel software 2016 to evaluate the risk occurrence and consequence. However, the analysis is concentrated only on project risks being harmful to the construction project.

This research has seven chapters. The first chapter (this chapter) represents the introduction and purpose of the study. The second chapter is about the construction industry in Cambodia. It conducts the Cambodia economy related to the contractor sectors, and risk in Cambodian construction industry (CCI). The third chapter represents the literature review associated with risk management in construction projects. The fourth chapter represents the materials and methods. It provides the research procedure, risk model, survey questionnaires, risk analysis, and assessment matrix method, AHP technique, and limitation of the study. The fifth chapter represents the results and discussions of the research. It is about the result of data analysis and risk responses conducted on risk evaluations. The sixth chapter is the application of the Analytic Hierarchy Process method applying in the risk model of the study. And, the final chapter represents the conclusion and suggestions.

2. CONSTRUCTION INDUSTRY IN CAMBODIA

Cambodia country is called ‘The Kingdom of Cambodia’ or ‘Kampuchea’ which is the one of developing country in South-east Asia or called Indochina. Thailand, Laos, and Vietnam are the border countries of Cambodia. There have 24 provinces, plus Phnom Penh is the capital city in Cambodia, see Figure 2.1.

Figure 2.1. Map of Cambodia’s location (Chandler and Overton, 2019)

In summary, the area of Cambodia is 181 035km^2. Khmer is the official language, and the Buddhism religion is official. Number population is around 15 288 489 people and 86 per km^2 at the 2019 census. Moreover, the Gross Domestic Product (GDP) of Purchasing Power Parity (PPP) is \$76.635 billion, and nominal GDP is \$26.628 billion in 2019. The currency unit is used as ‘Riel’ that 4 000 Riel is around 1 dollar (Anonymous, 2021).

2.1. Cambodia economy related to the construction sector

The economy is the heart of every country. According to World Bank (2020), the economic growth of Cambodia was 7% in 2017, 7.5 % in 2018, 7.1% in 2019, and -1% in 2020; see Figure 2.2. There has a 7.14% increase between 2017 and 2018, and it has a 5.33% decrease between 2018 and 2019. The year 2020 seemed hard for the country's economy.

Since the pandemic of Covid-19 has started, the economy has struggled not only in Cambodia but also in the world. Consequently, it has made people lost their jobs and health. The education is not very enough qualified, some projects have been delayed, some construction projects are struggling in finance. It makes sense that if the economy is in crisis, everything will take the risk immediately.

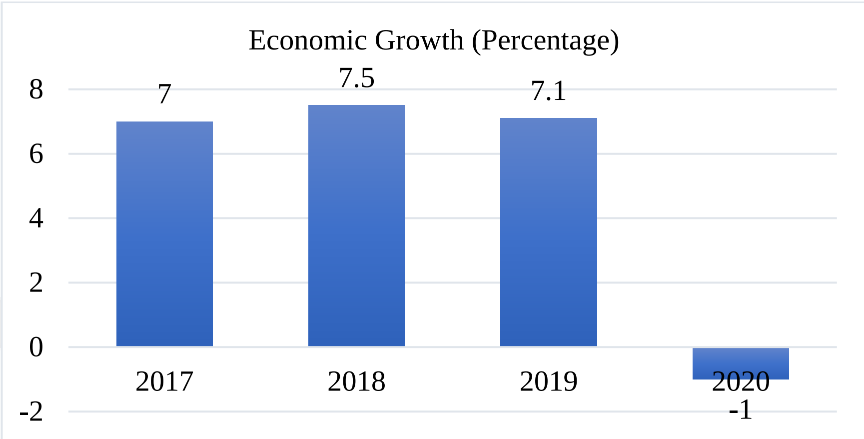

Figure 2.2. Economic Growth of Cambodia from 2017 to 2020

Based on World Bank (2020), the construction sector and real estate are necessary for Cambodia's economic growth, it was the third-rank of GDP growth in 2019. After pandemic Covid-19 has been increasing in the world, tourist and construction sector have been affected so much, economic growth decreased minus 1 in 2020. As we know that import is more than export for construction field in Cambodia (Bodach, 2019; World Bank, 2020). So, when the pandemic is spreading, the supply chain is seemly late more than regular time. Thus, the procedure of construction would take more time than previously.

Nevertheless, World Bank (2020) indicates that the Chinese companies (43.9%) are a huge foreign investment in the infrastructure and construction sector in Cambodia like Diamond Island or Koh Pich, Preah Sihanoukville, and Koh Kong. As the Figure 2.3, we can claim that Chinese construction companies in Cambodia have a much impact on the economy of CPs. The second foreign construction investment is the United Kingdom (23.6%). And next is Hong Kong, Japan, Taiwan, South Korea, Singapore, etc., respectively playing the main role in infrastructure and CCPs. That’s why the government has been opened and taken care of FDI (foreign direct investment) to take more attractive for construction investment and real estate, and business investment in Cambodia.

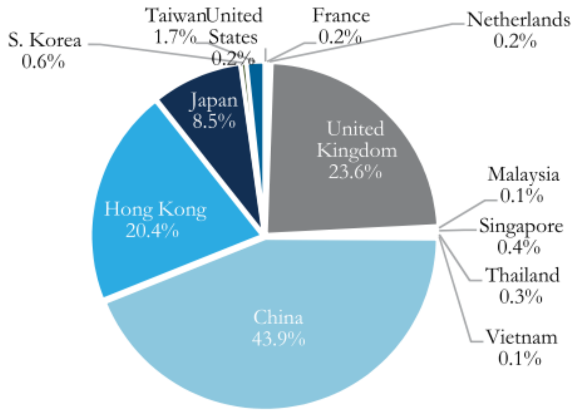

Figure 2.3. FDI in construction and real estate field in 2019 (World Bank, 2020)

The construction sector in 2017 had a total of 3 052 projects, their areas were 10 746 219 m^2, and the investment was around $6.4 billion (MLMUPC, 2018). It increased 22.31% comparing to 2016. Moreover, we can recognize that the construction sector in 2018 had a total of 3 290 projects, their areas were 12 378 119 m^2, and the investment was around $5.7 billion (MLMUPC, 2019a). It decreased 15.35% compared to 2017. Further, the construction sector in 2019 had total 4 888 projects, their areas were 23 257 414 m^2, and the investment was around $11.4 billion (MLMUPC, 2020b). It reached increasingly 98.73% comparing to 2018. And the final data of the construction sector from MLMUPC for 2020 recently is not fully available. However, it has only for nine months in 2020. There had 3 739 projects whose areas were 12 918 579 m^2, and the investment was around $5.8 billion (MLMUPC, 2020a). It decreased 9.64% compared to nine months in 2019. It shows that the Cambodian construction projects (CCPs) are a key to the economy with the high rates due to openly of foreigners directly investing (FDI) in Cambodia.

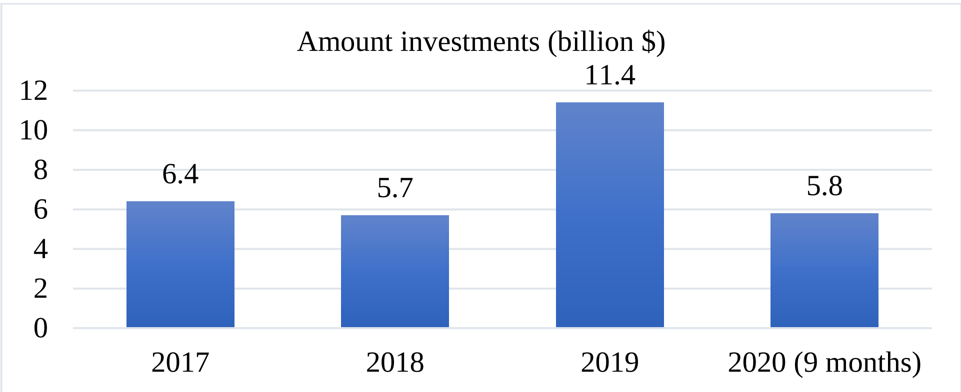

Figure 2.4. Amount investments of construction sectors in Cambodia from 2017 to 2020

2.2. Risks in construction industry in Cambodia

In developing countries like Cambodia, there seems lack of information about CPs; unfortunately, there is no available database related to Cambodian construction standards or national code design yet. Construction designation depends on the firm's rule or owner's need such as Japan code, Vietnam code, ACI code, or Europe code. The procedure of the construction industry is based on the approval between owner requirements, participants, or principal projects. However, after a building collapse in Sihanoukville in June 2019, the law and regulation of CCIs have strictly been reviewed in August 2019 (Bodach, 2019).

Ministry of Land Management, Urban Planning and Construction (MLMUPC) was recently declared in 2019 about taking action against construction firms and construction owners who do not comply with the obligations and conditions (MLMUPC, 2019b). In this promulgation, they want to ensure the construction work using proper constructions such as the legal and technical standard of the building, the quality of construction safety, the protection of property with the welfare of construction owners, the safety of construction users, and efficiency in the procedure of CPs. Evidently, the provincial governor, Kuoch Chamroeun of Sihanoukville controlled 40 building construction projects that were failed due to the quality inspections (Dara, 2019). This indicates that the construction industry has experienced a high-risk situation in construction fields in Cambodia.

Moreover, depending on the New York Times, the ceiling collapse at a small shoe factory in the urban area of the capital city that was dead two people and injured nine people on May 16, 2013, because of falling concrete pieces (Bradsher, 2013). In June 2019, a 7-story building collapsed in Sihanoukville that took 28 people dead and 26 people injured in Sihanoukville province (Bunthoeun, 2020; Dara, 2019). After six months this event happened, a 6-story building collapsed which took 36 people dead and 23 people injured in Kep province on January 3, 2020 (Dara and Chheng, 2020). Nevertheless, after the building collapse in Sihanoukville, the rule and regulations of CCIs were strictly efforts to make in August 2019 (Bodach, 2019). Minister Chea Sophara of MLMUPC reminded during the awareness session of construction law all professionals that the construction companies have to verify their work strictly in both design and implementation at Sokha Hotel after building collapse in Kep (Bunthoeun, 2020). He claimed that to accomplish construction, there must do the construction quality, security, and safety effectively.

And right now, the ministry has been considering, creating, and upgrading a national code standard related to safety and security first of construction and people, building quality, or conducting infrastructure project, technical and training skills. By the way, laws and regulations seem no effective well and seem no adoption well in nearly future (Bodach, 2019). As the evidence has shown the authorities had tried to stop the building construction, but the owner didn’t listen to them and ignored the requests (Dara, 2019). It indicates that the law and regulation can’t work effectively as soon as possible, but it will work effectively step by step.

There has been tried to increase the financial resource, technical and skills of human resources, infrastructure management, construction, private investing infrastructure due to the lack of resources in Cambodia (Sum, 2008). Additionally, Bodach (2019) claimed that insufficient skills of workers are also training during the construction at the site. The public, private, and NGO (non-government organizations) make the vocational training courses, educational training, technical work, or workshops to help them. It has been shown that the skills, knowledge, and technicians need to enhance at the bottom of the hearts.

So as to enhance in the construction field, MLMUPC is strictly so much on the construction permit and procedure as well. It clearly shows that risk management needs to focus on the construction project in Cambodia as well. Risk management always associates with a lack of skills, lack of knowledge, unfollowing laws and regulations, lack of experience and technicians, payment problems, and unsafe buildings, etc. That’s why there really needs to help researchers more and more fields associated with CPs to get better and successful construction business projects.

3. LITERATURE REVIEW

Generally, the aim of the literature review is to understand associated a topic with debate and to improve the knowledge level with a flexible update. In this chapter, we will describe the risk management of the previous studies, what the previous researches found, evaluation, risk identification, and definitions associated with risk management with construction projects. The advantages and disadvantages of risk management will be added in this chapter too.

3.1. Previous studies

In this part, the review of previous studies is important so much in order to gain more knowledge and gap studies of the literature. In this literature, we will focus on the key risk factors happening in construction projects. The barrier factors impact cost, time, and quality that make the project risk.

One of the studies is focused on six major risk factors affecting risk management in CPs in India (Srinivasan and Rangaraj, 2020). It conducts with questionnaires and the analysis that undertake the SPSS program. The outcome indicates that market risk and managing risk are the highest affecting risk management in CPs.

El-Karim and his friends study identifying and assessing the risk factor impact on CPs in Egypt. The study conducts on determining, analysing, and evaluating risk factors that affect to cost and time contingency of the projects. Through questionnaires and interviews, the mean value of data collection is done by Crystal ball and generated into the AHP method. As a result, it expresses that the cost and time should be increased at a high-risk level in order to reduce risk factors in the construction project (El-Karim et al., 2019).

One study associate with the determination how the application of risk management working in CPs in Ethiopia. After the questionnaires are done for the data collection, the analysis uses the SPSS program to get the outcome of the research. Consequently, it indicates that practices of risk management in CPs are not enough due to the insufficient knowledge of project risk management in the construction sector, lack of experienced technical personnel, budget, and design errors (UDAN, 2019).

Musta investigates risks related to time, quality, and cost in CPs of two specific projects in Germany. The analysis was focused on the theoretical risk analysis and assessment of the project's firms through project teams' evaluation and interviews. As a result, the solution of risks at the high level needs to decide on by the director or CEO (chief executive officer) of firms. And if the risk at the medium or low level, the project manager can decide an evaluation to solve it by given the specific solution of each risk (Musta, 2018).

According to Onengiyeofori (2016), he focuses on a risk management model to guide building construction projects in Nigeria of the managing field. The data undertakes the SPSS program and the Bayesian Belief Network model by Netica software. The result of this research could be used the risk management model to guide building construction projects exactly.

Regarding Mustafa and Al-Bahar (1991), they report about the project risk assessment in a CP in Bangladesh by using the AHP method. They claim that this method can get results easily, fast, and flexibly; especially giving a rational performance of risks. As a result, among the evaluation of alternatives, low risk is 40.10%, medium risk is 36.40%, and high risk is 23.50%. Thus, the project risk level is in a low situation.

Dey (2002) studies the project risk management involving the AHP and DTA (decision tree approach) in India. Delphi technique uses for identifying risks and the Monte Carlo technique applies in risk analysis. Every risk in this study is to estimate the cost of the financial risk in order responses to the cost and time impact in a project practice of a petroleum pipeline. A result of the total cost of risk responses is around $65.65 million that is lower than previously.

Depending on (Karim et al., 2012), there focus on risk factors in CPs from contractors' understanding in Malaysia. The data is under survey questionnaires with 5-point Likert scales are applied. The statistical analysis of SPSS and RII (Relative Importance

Index) helps for risk analysis. The outcome of the research shows that construction and finance are critical factors.

Zou and Zhang (2014) consider identifying and analysing the 20 critical risk factors in CPs from a life cycle and stakeholders' understanding. The objective is to give the best options for managing risks in CPs. Main risks conduct to the cost, time, quality, construction safety, and environmental impact. In order to manage risks, a framework is proposed in this empirical study. And solution strategies of the framework are done by stakeholders with the project life cycle. It also shows that the tight project schedule impacts all phases of projects.

Another research report about analysing and managing risks in construction in the United Kingdom. The aspect related to risks in survey questionnaires come from contractors and project management applications. Finally, the risk factor level of contractors is higher than the risk factor level of project management practices. It also claims that the official analysing and managing risk techniques are not really applied in the construction industry due to the lack of knowledge and hesitation in using proper technique tools (Akintoye and Macleod, 1997).

According to (Pialles, 2017), he focused on the relationship between quality and risk management in the construction industry. And the result is shown that the main risk factors which impact the quality are lack of safety, poor working conditions, poor environmental issues, budget overrun, and time delays.

The table below indicates the risk categories in CPs and CIs from the previous studies with different countries. We also include factors that affected cost overrun, time delay, quality problem, labour productivity, construction safe of previous studies in Cambodia and Indonesia as Southeast Asia countries due to related risk management in the construction. Here represent 22 types of research with available countries from 1991 to 2020. Risk categories and their references are available to control the flexibility of generating ideas for the pilot study and filling the study gap.

Table 3.1. Summarily risk identifications of literature review

No	Types of projects (Country)	Risk categories (RCs)	References
1	Construction project (Bangladesh)	• Acts of God • Physiques • Finance and environment • Design • Job site	(Mustafa and Al-Bahar, 1991)
2	Construction industry (United Kingdom)	• Environment • Politics • Construction • Society & Economy • Contractual agreement (responsibilities) • Finance • Market/ industry • Company (cooperate) • Development in IT project	(Akintoye and Macleod, 1997)
3	Construction of high-rise project (Indonesia)	• Lack of experience • Design change • Labor productivity • Weather • Resource shortages	(Kaming et al., 1997)
4	Construction project (India)	• Technique • Acts of God • Finance, economy and politics • Organization • Statutory clearance	(Dey, 2002)

Table 3.1. Summarily risk identifications of literature review (continued)

5	Construction Projects (Palestine)	• Physique • Environment • Design • Logistics • Finance • Legality • Construction • Politics • Management	(Mousa, 2005)
6	Construction projects (China)	• Risks related to client • Risks related to designer • Risks related to contractor • Risks related to subcontractor/ supplier • Risks related to government agency • External issue	(Zou et al., 2007)
7	Construction industry (Pakistan)	• Technique • Logistics • Management • Environment • Finance • Socio-politics • Variance	(Ehsan et al., 2011)
8	Construction projects (Ghana)	• Finance • Resource • Technique • Economy • Environment • Operation • Government and politics • Relationships • Security • Legal	(Chileshe, 2012)

Table 3.1. Summarily risk identifications of literature review (continued)

9	Construction projects (Malaysia)	• Construction • Politic and contract provision • Design • Finance • Environment	(Karim et al., 2012)
10	Construction project (Tanzania)	• Finance • Construction • Physique • Design • Politics • Legal • Environment	(Ally, 2013)
11	Construction projects in the Gulf region (Kuwait and Bahrain)	• Management • Design • Finance • Material • Labour and equipment • External	(Altoryman, 2014)
12	Construction project (Australia)	• Cost related risk • Time related risk • Quality related risk • Environment • Construction safety	(Zou and Zhang, 2014)
13	Construction project (Nigeria)	• Physique • Environment • Design • Logistics • Finance • Legal • Construction • Politics • Management	(Onengiyeofori, 2016)

Table 3.1. Summarily risk identifications of literature review (continued)

14	Construction safety performance (Cambodia)	• Management and organization • Resource • Site management • Cosmetic (External factors) • Workforce (labour)	(Durdyev et al., 2017a)
15	Time delay in the construction industry (Cambodia)	• Material and equipment • Management • Workforce (labour) • Project • External	(Durdyev et al., 2017b)
16	Cost overruns in the construction industry (Cambodia)	• Project risk • Project and cost management • Project finance	(Durdyev et al., 2017c)
17	Construction industry (Europe countries)	• Lack of safety • Poor working condition • Environmental issue • Budget overrun • Time delays	(Pialles, 2017)
18	Construction projects (Poland)	• Preliminary design • Tender • Detailed design • Construction work • Financing the investment	(Szymański, 2017)
19	Construction projects (Nigeria)	• Technical risk in construction industry • Organization • Environment • Coordination • Factor affecting risk management	(Akinbile et al., 2018)

Table 3.1. Summarily risk identifications of literature review (continued)

20	Construction projects (Egypt)	• Site condition: – Environment – Sub-surface – Site location • Resource – Labour – Equipment – Material • Project party – Owner – Engineering and Design – Contractor – Project Management • Project feature – Finance – Politic – Schedule	(El-Karim et al., 2019)
21	Construction projects (Somali)	• Management • Contract • Finance/ Economy • Technicality • Material • Environment • Society/ Culture • Politic • Safe • Legality	(UDAN, 2019)
22	Construction projects (India)	• Management • Market • Technicality • Society • Legality • Environment	(Srinivasan and Rangaraj, 2020)

3.2. Risks in construction projects

According to Jaafari (2001), risk refers to the potential problems making struggling activities of a project. When a project is uncertain circumstances, the project is exactly high risk. Oppositely, if the project has the specific information within a clear detailed plan in the right way, it's clear that the project is possible in the low level of risk. Then, construction projects will be able to have a chance to succeed.

Regarding Szymański (2017), types of risks are focused on financial risk (total cost or project budget), time-related risk, technical risk, market risk, nature risk, external risk, risk related to the human factor, and safety. Risks have five main groups in construction projects. They are preliminary design, tender, detailed design, construction, and investing finance. Whatever the risk contributes into two parts is direct risk and indirect risk (Saporita & P.E., 2006). For instead, the direct risk of schedule delay or quality issues would be transferred to cost overrun (indirect risk).

Risk has reviewed the problems associated with a project with cost, time, safe, or overall project's goal (Saporita and P.E., 2006). It would say there have 3 principal types of risk such as cost risk, schedule risk, and performance, scope, quality, or technological risks in the project. In summary, we are going to set definitions of risk related to cost, time, and quality as below:

- Cost overrun: project cost is not accurate in budget estimation or extended during construction. One or more parts of a project changed without any plan are also harmful to the budget. Durdyev et al. (2017c) survey on cost overrun in CPs in Cambodia. The result illustrates three components that make the budget over; project risk factors, project finance, project and cost management. They concentrate on 26 factors of cost overruns in the construction industry. Risk factors are a part of affecting cost overrun as well. It is simple to hear this word but whether those problems are acceptable or avoidable for a project.

- Time delay: procedure of project schedule is extended or increased due to inaccurate schedule estimation or affected other factors during construction. It is often complained about and not satisfied by project participants, especially, clients. Time duration is vital for completing the success of a project. The project schedule would increase due to uncertain factors. And if risk factors happen because of contingency, it could impact the schedule. Durdyev et al. (2017b) also report the cause of delay in CPs of Cambodia. It conducts by contractors and consultants. Under 31 causes of delay provide into five categories. These causes are the issues of the project, management, workforce, external, material and equipment. Actually, the behind of these issues includes the contingent risks.

- Quality problem: project quality refers to the satisfying owner's requirement or acceptable standard of a project. It would depend on the schedule and budget performance as well. So, quality problems focus on three important elements such as participant quality, product quality, and performance quality (communication, work activities). When the quality has a problem or poor level, it means one or all of those elements are dissatisfied in the construction project. If risks happen, the quality level would be counted enter and reviewed.

3.3. Risk management in construction projects

Construction project (CP) refers to the work process of a project such as construction, building assessment, structure, or infrastructure. CP is come from different kinds of projects, various sources with various uncertainties, and across different participants (Rumane, 2013). That's why it's not strange when the risk is multi-faced in the CP. And risk challenges are the cost, time, and quality so as to achieve one goal in a project. In Rumane's book, there have three main points considering the risk management in CPs as below:

- What is logically acceptable to quality
- What is acceptable to schedule without any delay
- What is approved to cost without any overrun budgets?

Project risk management (PRM) performs a vital part of project construction management. PRM is the operation associated with risk management planning, identification, analysis, assessment, response, and control of a project (PMBOK, 2013). PRM begins from the initial plan until the end of the project. Everything needs to start with process management. But if all the work doesn't know how to manage the risk management, then everything will be empty. And it would be blacklisted for the next project or next tender. The purpose of PRM is to gain positive opportunity activities and to mitigate the threat activities. And to accomplish the processing project would be on time, controllable cost, acceptable quality, and safety in CPs.

Risk management (RM) is "the process of identifying, assessing, and prioritizing different kinds of risk, planning risk mitigation, implementing a mitigation plan, and controlling the risks" (Rumane, 2013:p101). Risk management working in a CP is to guarantee the controlling budget, a well multi-disciplinary project with on-time, better quality, project safe approval from stakeholders. The risk management aim in design and construction is to ensure timely achieving all project goals in reducing quarrel during and after construction (Saporita and P.E., 2006). By the way, a low or high level of risk factors in previous projects can learn and keep updating on the risk management and then preparing the next project.

3.3.1. Advantages of risk management

Everything always has both advantages and disadvantages even though RM can't be avoidable. However, we have to deeply understand which one is more beneficial than or which one is better safe with comfort. According to (Saporita and P.E., 2006; Smith et al., 2006), the advantages of risk management are:

- To consider, comprehend, and verify the project problems before the project starts
- To help and deals with clear decisions
- To clarify the project structure is regularly controlled and monitored
- To identify specific risks with a project
- To prepare the lessons learned risk management for the next project
- To reduce the power of participants' argument during and after construction
- To improve the chance of successful project and successful investment project
- To satisfy the project safe for the sponsor
- To be avoidable claims in the project

- To enhance their companies as the top-listed engineering of design professionals and contractors
- To be on time associated budget under control with good quality if risks happen positively.

3.3.2. Disadvantages of risk management

Based on (Saporita and P.E., 2006), there have some disadvantages of RM as a note below:

- Spend the budget and schedule allowance of contingent uncertain events in every project phase
- Add the part of the budget and time on the evaluating risks involved in the contract with various delivered methods (design-build or design-bid-build)
- The project owner has a difficult decision on hire design professionals or contractors for the exact budget.

3.4. Procedures of risk management

Lester et al. (2017), risk management plans are to notify of risk significances, performances of risk owners and establishment of the probability-impact factors as qualitative or quantitative items. It easily examines and assesses every risk during the processing project. Here, the procedure of RM has three main stages. They are the identification, analysis and assessment, risk response and control (Cooper et al., 2005; Saporita and P.E., 2006).

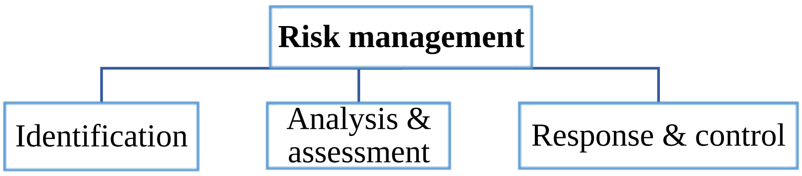

Figure 3.1. Risk management procedure

3.4.1. Identifications

An uncertain event or unpredictable action often happens. It can't be avoidable in the projects. Actually, risk produces contingency and can be harmful to other parts of construction projects. It is called risk identification (RI). RI obtains from anywhere we noted historical project information, previous research, survey, etc.

Risk identification is how we record and collect risk events associated with projects. We admit areas of risks such as hesitated decisions, unclear knowledge, events possibly dangerous in the project, etc. Thus, we have to make a risk list so that we can analyze and assess the risks in projects. In the procedure of risk identifications, we can define risks from previous studies, actual projects, and then accompany them with methods to develop and do the evaluation. Then, methods often used to identify risk are document reviews, checklists, brainstorming techniques, Delphi techniques, diagraming techniques, professional judgment, etc. (PMBOK, 2013).

3.4.2. Analysis and assessments

According to (Cooper et al., 2005), risk analysis (RA) is the process of determining risk occurrence and the magnitude of their impact. Risk evaluation assigns to the risk estimation procedure to protect the risky project. And the process of risk analysis with risk evaluation is called risk assessment. Risk analysis determines under two methods; qualitative and quantitative methods. Risk analysis addresses project control tools such as responsibility, material cost, or time delay, quality control which arrange a means associated analysis undertaken quantitative cost and time-related risks (Saporita and P.E., 2006).

Risk assessment (RS) is to multiply the value of the probability of occurrence with the amount associated risk impact (Saporita and P.E., 2006). That is RS= P*I (P=probability of risk occurrence or likelihood, and I= risk impact). For example, the total budget has 5 000$, the risk impact (negative impact) is 5%, and the probability of experience happened is 10%. So, RS is (10%) *(5%) = 0.5%. Therefore, the cost of RS is 5 000$*(0.5%) = 25$.

Basically, the main analysis of the research comes from theoretical books Cooper et al. (2005), Kendrick and PMP (2015), Özbek (2017), and PMBOK (2013). The research has followed these books by applying the set risk technique, descriptive scale rating of the probability of likelihood and consequence (scale of quality, time, and cost), scales of risk assessment matrix, qualitative and quantitative technique, AHP technique, and solution technique. In order to detailed these methods associated with the study, it will describe in the next chapter.

3.4.3. Responses and controls

Risk response is the project procedure of decision-making on options and performance. It minimizes uncertain areas by improving the chance of project goals (PMBOK, 2013). In this step, it needs to be strong involvement from project stakeholders. It is how much we respond to the risk significance of a project. It is a mechanism that we can remove and decrease the harmful project to be acceptable. Cooper et al., (2005), risk responses could reduce and determine the response risks for projects to bring the accurate estimation associated with project purposes. Risk response should select the best alternatives and recommendations for the project to take action plans with appropriate project budgets.

Risk control is the way of checking and verifying the risk events in a project under control. It aims to enhance the efficiency of associated risk from project goals in constantly optimized risk response (PMBOK, 2013). Control risk management involves training team members, project managers, respective project managers, and project participants with communication to stakeholders (Burke, 2003).

Based on (PMBOK, 2013), risk response provides into two parts, negative risk or threats, and positive risk or opportunities as the description below:

- Negative risk (threat): refers to the risk factors that be harmful to the project. It has three types excluding, risk acceptance. Risk avoidance is to remove threats and to protect goals so that they can't impact to appear anymore in the project. Risk transference is to transfer or reduce risk impact only to other parties. For example, risk transfers through insurance, contract with the participant, etc. Risk mitigation (control) is to reduce threats of risk occurrence and risk impact so that the threats are acceptable. It needs to investigate the high developed options between risk with its cost or schedule.

- Positive risk (opportunity): refers to the risk that gives a chance to win a project. It has three types excluding, risk acceptance. Exploit is to ensure risks that visualize positive impacts. It can reduce the duration and cost of project goals. Enhance is to upgrade risk occurrence or risk impact instead of an opportunity. For example, the construction time finishes early. Share is to generate or transfer an opportunity with third parties such as risk-sharing participants, teams, or special partners through their activities and contracts.

- Risk acceptance is the risk gap between threat and opportunity. Risk acceptance is at the low level among risk factors that should occur or approve from negative risk or positive risk. However, it has to make sure it doesn't affect bad things in the project goals.

Preparing the insurance of contingency plans is necessary for every project. It needs decision-making by the director or CEO's firms. Regarding Table 4.3 concentrating on the negative risks (threats), we would provide the risk assessment with risk responses and controls into three parts below:

$$\text{Risk } a\text{cceptance} \Leftarrow \begin{cases} \text{very low risk} \\ \text{low risk} \end{cases} ; \ \text{Medium risk} \Leftarrow \text{Moderate risk} \ , (\text{consideration})$$

$$\text{Risk unacceptance} \Leftarrow \begin{cases} \text{high risk} \\ \text{very high risk} \end{cases}$$

- Acceptable risk: refers to the risk factor is at the level of uncritical issues. There is no high problem for making the risk project management getting overtime and cost.

- Medium risk: refers to the risk factor is in the middle of low risk and high risk. It's maybe an opportunity or threat in the project. We need to consider and review those risks as well. Onengiyeofori (2016), takes a medium risk as the baseline between uncritical risk and critical risk.

- Unacceptable risk: refers to the risk factor is at a high-level or extreme level. It is a deep critical factor analysis to avoid, transfer, or high control the risk before happening. This situation needs to discuss and make the right decision by professional and owner.

3.5. Technique tools of risk management

The best smart needs to know how and which techniques can use for risk identification and analysis. A few most popular technique tools below would describe the risk management can process the significant risk events and risk analysis in practically qualitative and quantitative methods:

- Brainstorming refers to identify risk factors defining as the list structure of brainstorming by project teams or group workshops. What the risk list review seems likely to happen and get project evaluations. It could be generated critically for considered analysis (Cooper et al., 2005; PMBOK, 2013).

- Interview technique refers to the way to collect risk factors by interviewing participants of a project (PMBOK, 2013). Because interviews can collect risk factors both inside and outside of our project; it is a potential method for identifying and organizing risk that probably happens in future projects (Kendrick and PMP, 2015).

- The checklist technique is an examination of risk recording in the historical information from previous. Then, work teams can generate and analyze those risk factors to improve for future projects (PMBOK, 2013). A review checklist can minimize and reserve risks for organizing in a project (Cooper et al., 2005).

- Scenario analysis refers to possible and logical risk factors that probably happen in construction projects. Scenario analysis can help to analyze risk factors in a project to select and update the best options for project risk solutions (Kendrick and PMP, 2015).

- Delphi technique: refers to the way to collect the critical risk factor through questionnaires from anonymous to generate and analyze the risk levels (PMBOK, 2013). Risk factors are assigned scores to the position in a risk factor list. And, the score of risks will be measured to examine in order to bring an outcome (Kendrick and PMP, 2015).

3.6. Analytic hierarchy process (AHP) method

The Analytic Hierarchy Process (AHP) is coming from 3 words; there are analytic, hierarchy, process. Depending on Cambridge English Dictionary 3rd edition, analytic is assessing very critically. Hierarchy means a structure or model in which people manage the necessary sequences. Last, process means a series of activities that are done to accomplish the best result. Therefore, the analytic hierarchy process means a series of actions to evaluate carefully in which to take a logical one and get the best option. However, according to the previous studies in Table 3.1 of Mustafa and Al-Bahar (1991), Dey (2002), and El-Karim et al. (2019), they also apply the AHP method to investigate risk management for their researches.

AHP was proposed by Saaty in 1980 being the basic purpose in decision-making among complicated criteria to get the best options (Saaty and Vargas, 2012). The beneficial hierarchy is solved the structural problem of criteria to get both qualitative and quantitative aspects through the decision on clear and well judgments for destinations (Mu and Rojas, 2017). The AHP method purpose is to select the alternative that is in ordering priority among the cost, time, and quality of the risk model. It will define that one is the most critical risk in the project experiences. Further, we are going to explain the procedure of this method in the next chapter (section 4.5).

3.7. Critical risk factors in the study

In the literature review in Table 3.1, risk categories are investigated for risk factors here. The risk factor list is the sub-risk category which depends on discussions, reviews, risk evaluations, and different risk situations in CPs. The research has been done in the pilot study for verifying, and making sure whether the most critical risk occurrence and risk impact in CCP experiences.

Firstly, we focus on 48 critical RFs through the literature. Then, those factors are discussed with five civil engineering managers as a pilot study Online. Then, they could take a look at the RFs quickly and easily notations whether which factors happened in CCPs. In the way of semi-structured interviews, we take time less than one hour for discussing risk problems with them. Consequently, 23 critical RFs are rejected, and 25 risk factors happened in CCP experiences. Additionally, 9 RFs were involved in the pilot study. Totally, this study contains 34 risk factors in the critical analysis showing in Appendix-A.

3.8. Risk classifications of the study

Therefore, we divide five main risks in this risk structure breakdown for the best structure to control risk factors. The main risk is the project stakeholder, project resource, construction site, project feature, and project management. Moreover, the risk category (RC) is designed as the sub-criteria of main risks (MR). Furthermore, risk factors (RFs) are applied to the sub-criteria of RCs. So, the risk classification of this research is described below:

- Project stakeholder: refers to all the participants who work on a construction project. According to (Saporita and P.E., 2006), three principal participants are divided as client/owner, design/architect, and contractor parties (contractor, sub-contractor, and supplier). The objective of the client/ owner is to win the project scope complete safely, on time under budget control, and to satisfy the quality. The design is assigned by the client/owner to complete the demands of a project owner. Contractor parties are hired by the client/owner to construct the project.

- Project resource: refers to all elements that would be used and it can assist in construction projects so as to supply the project successfully. The project resource provides into three items. They are labor, equipment/ materials, and finance. The labor focused in this study is inadequate labor and unskilled labor. The problems of equipment/ materials contain such as inadequate equipment, material shortages, late delivery of materials. And, finance issues take attention on financial failures or lack of finances, late payments by the client, cash flow problem by contractor, and inaccuracy of cost estimations.

- Construction site: refers to all performances related to actions and causes that make the obstacle in project sites. It provides three risk categories; the environment, site condition, and Pandemic of Covid-19. In the environmental issue, we focus on weather problems: such as flood and rainy seasons, and issues of construction programs: such as pollution, noise, or ecological damage. The site condition conducts on issues of safety and health, issues of site's topography and geotechnical investigation. The pandemic of Covid-19 refers to the impact of economic projects and worker's health.

- Project feature: refers to the most vital characteristics to point out in risky construction projects. We consider three parts such as politics, schedule, and quality. And politics refers to bribery and corruption for involving finances. Schedule focuses on the delay schedule due to project sizes/ complexity project, missing update schedule based actual work at the site, and not enough schedule to see all major at the site. For quality problems, we conduct on the misunderstanding/ unclear of a quality control plan, and unclear specification with a standard.

- Project management (PM): is a technical process for preparing activities as a team to complete the project requirements at a specific time (PMBOK, 2013). Each project needs to lead the plan, implementation, and control as well as possible. PM could be associated with stakeholders, resources, procedures of a construction site, and other features. Project management needs the project manager in order to organize the project procedure.

4. MATERIALS AND METHODS

We will describe the processing research materials and methods in this chapter. In the literature review chapter, we have investigated the key risk factors in CPs. The consequences of the risky project are late, over budget, contingent risk, frequently changing scope of work, poor quality performance, argument during and after construction, etc. However, this methodology is the processing research of finding a specific topic in order to make the satisfaction, verification, assessment, exploration, or unexpected result.

4.1. Research procedures

Figure 4.1 indicates the research procedure. There are six main parts to do in this research. It contains the significance of key risk factors, survey questionnaires, data collections, methodology conducting the risk analysis, assessment, risk strategies, conclusions, and suggestions.

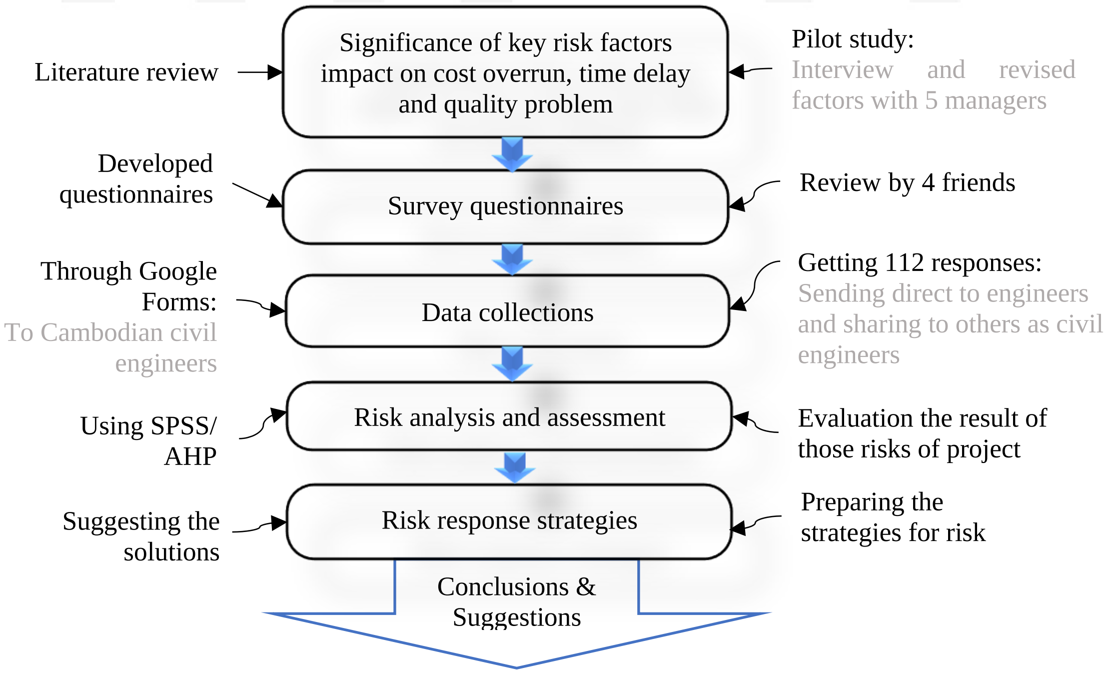

Figure 4.1. Research procedures

4.2. Risk model of research

The risk model of the research indicates in Figure 4.2 below. It contributes two parts that are main risks (MRs) as main criteria, and risk categories (RCs) as sub-criteria or sub-MRs. MRs provide into five components explaining in the previous chapter (section 3.8). Sub-main risks provide into 17 elements that are the head of risk factors.

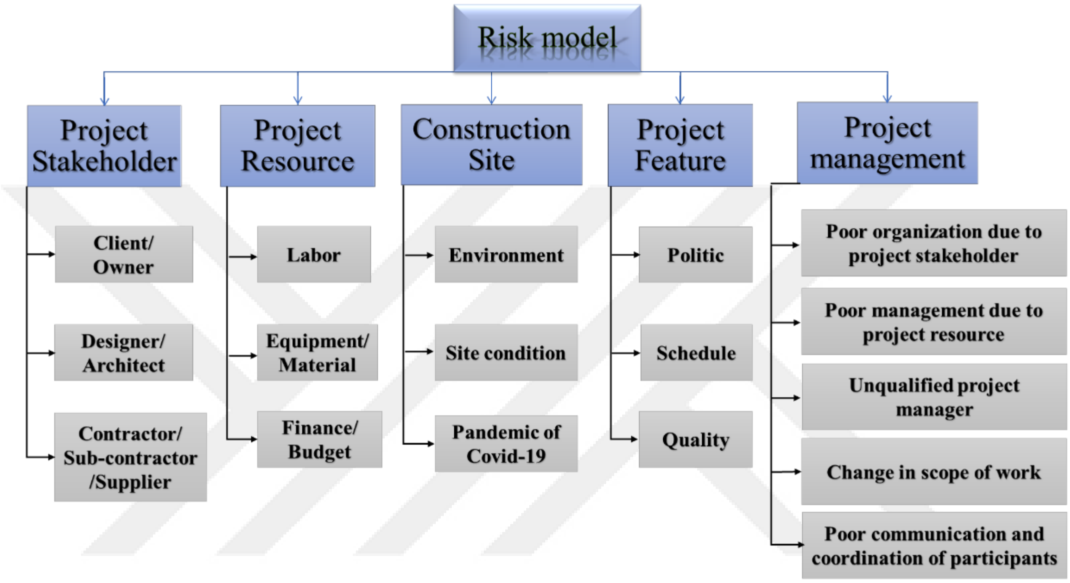

Figure 4.2. Risk model of the research

4.3. Survey questionnaires

The survey questionnaires will be used for collecting data to assess the most critical RFs in CCPs. According to among technique tools described (Chapter 3), the Delphi technique is the survey technique for collecting risk identifications. We can generate viewpoints for risk evaluations from civil engineers individually who involve in the CPs. And we can analyze how the risk occurrence impacts cost, time, and quality as majors.

It is not quite easy to design or develop survey questionnaires for a specific study. Consequently, this research has developed the concept of survey questionnaires from the literature of (El-Karim et al., 2019; Onengiyeofori, 2016; UDAN, 2019). Questionnaires can survey the recent information clearly to collect the data. It can assist in evaluating and completing the research objectives. It also helps to fill the gap in the literature.

Questionnaires need to make clear and easy for survey responses to obtain both exact data and situation.

4.3.1. Questionnaire design

Questionnaire design is the way to prepare the questions to get the data collection from respondents to complete the research purposes. In the research, several questions developed from the previous studies. And others are reviewed by four engineering friends of the author for sake of the convenience of respondents. So, questions can be suitable and logical conditions in the research region. The questionnaires are organized into Google Form due to the easy way for sharing and controlling for research. Few questions recommend changing and managing the questionnaire system so the respondents wouldn’t get bored on questionnaires.

Most structured questionnaires have types of closed-ended questions, and a few of them are open-ended questions. Survey questionnaires are distributed in three main sections. The first section is about general information, it contains three questions. The second section is about the knowledge level of risk management in construction projects. It provides five questions. And the third section contributes two parts. Section 3a surveys the risk category impact on cost, time, and quality issues, this part has 15 factors. And section 3b is the significant risk occurrence and its impact on CPs. It contains 34 factors. For more detailed survey questionnaires, let’s see Appendix-F.

4.3.2. Data collection

Data collection here means the way we collect a group of people’s ideas obtaining the data through the questions or interview by the researcher. Survey questionnaires are distributed via Google Form due to the Pandemic of Covid-19. These questionnaires provide to civil engineers involving the client, owner, designer, architect, contractor, sub-contractor, and supplier.

Survey questionnaires share with friends, seniors, and lecturers of field civil engineering. Fortunately, a few close friends and seniors are kind to forward this survey to their colleagues and friends. They have experience working with CPs as a part of project stakeholders. The data survey started on 30 October 2020 and finished on 30 November 2020. Finally, questionnaires have 112 responses including four improper responses. So, 108 survey responses will be used for the analysis to complete the research objectives. The data is 96% at a high confidence level for using analysis.

4.4. Risk analysis and risk assessment

The technique application of risk analysis and risk assessment is the most important performance in every research. Detailing technique means how to find and to do the analysis study of the risk degree and their impact issues in the project. Basically, it’s simple to say that risk analysis provides two methods. One is a qualitative method, and the other is a quantitative method. The mean value (average), Alpha Cronbach, and T-test analysis will be calculated by Statistical Product and Service Solutions (SPSS) version-26. Analytic Hierarchy Process (AHP) will base on the mean value instead of decision making for risk structure breakdowns. AHP can make the research more satisfying, strengthen, and fulfill the research objectives.

4.4.1. Qualitative method

The qualitative method is to set the priority of risk occurrence and risk impact to reduce and control the risk in the project (Cooper et al., 2005; Kendrick and PMP, 2015). This method can give us to know significant risks, degree of risks, assessing options, comparison methods, and descriptive analysis. However, a semi-quantitative method is extended the qualitative method by using numerical value to descriptive scale and derive as quantitative risk (Cooper et al., 2005).

Using the qualitative method determines the risk probability or risk likelihood, and its impact to obtain the risk assessment matrix. Risk probability is the uncertain events and contingency that probably happened in CPs. Risk impacts suffer from risk occurrences making any struggle problems especially, over budget, schedule delay, insecurity, etc. Risk assessment is combined by risk likelihood with its impact. The analysis is only focusing on the negative impact of the project risk. It’s the most critical factor for avoiding unsuccessful projects and disputes before and after construction.

Moreover, risk probability and its impact are measured between 0 and 100 percent (Cooper et al., 2005; Kendrick and PMP, 2015). Mathematical models, statistical analysis, and guesses are the methods for establishing them (Kendrick and PMP, 2015). In this research, we will determine risks being a statistical analysis assisting with Excel, multiply criteria decision analysis of AHP method in order to fulfill research objectives. There will explain in the following section.

Based on (Cooper et al., 2005; Kendrick and PMP, 2015; PMBOK, 2013), it has some categories of rank scales. And depending on these books, the scale rating is set 5 rank scales for risk probability and impact; they are in Table 4.1 and Table 4.2 below:

Table 4.1. Rank scales of risk likelihoods (Cooper et al., 2005; PMBOK, 2013)

Risk likelihoods	Scales	Descriptions
Very low	0.10	Likely to occur less than 0.02
Low	0.30	Likely to occur from 0.02 to 0.10
Moderate	0.50	Likely to occur from 0.1 to 0.50
High	0.70	Likely to occur from 0.50 to 0.80
Very high	0.90	Likely to occur over 0.80

Table 4.2. Rank scale of risk impact (PMBOK, 2013)

Risk impacts	Scales	Descriptions		
		Cost	Time	Quality
Very low	0.05	Insignificant cost increase	Insignificant time increase	Tiny degraded quality
Low	0.10	<10% cost increase	<5%-time increase	Only very demanding applications are affected
Moderate	0.20	(10-20)%-cost increase	(5-10)%-time increase	Quality reduction requires sponsor approval
High	0.40	(20-40)%-cost increase	(10-20)%-time increase	Quality reduction unacceptable to sponsor
Very high	0.80	>40% cost increase	>20% time increase	Project end item is effectively useless

After we define the scale for risk likelihood (Table 4.1) and their impact (Table 4.2), we can obtain the risk assessment as in Table 4.3 below:

Table 4.3. Scale rates of risk assessments (PMBOK, 2013)

0.90	0.05	0.09	0.18	0.36	0.72
0.70	0.04	0.07	0.14	0.28	0.56
0.50	0.03	0.05	0.10	0.20	0.40
0.30	0.02	0.03	0.06	0.12	0.24
0.10	0.01	0.01	0.02	0.04	0.08
Likelihoods	0.05	0.10	0.20	0.40	0.80
Threats	Impacts				

4.4.2. Quantitative method

The quantitative method is a numerical ratio scale of probability and impacts more than descriptive scales to complete the project objectives (Cooper et al., 2005; PMBOK, 2013). Similarly (Kendrick and PMP, 2015), there mentions using the absolute numerical estimation of risk probability and consequence on project resources. It’s applied for a model such as decision trees, influence diagram, probabilistic analysis, sensitivity analysis, Monte Carlo technique, simple assessment, or critical analysis (Onengiyeofori, 2016).

The quantitative method can extend or replace the numerical estimation analysis of project purposes after the qualitative method is organized the risk priority and selection (Kendrick and PMP, 2015). Regarding this reference, there contain six kinds of important techniques to conduct the quantitative method as below:

- Risk graph: is made by two graphs between risk likelihood (vertical axis) and risk impact (horizontal axis) from risk assessment (Table 4.3). And then risk boundary needs to point to the plots between the vertical and horizontal axis to estimate the project cost from each aim variances of the projects for example Figure 4.3.

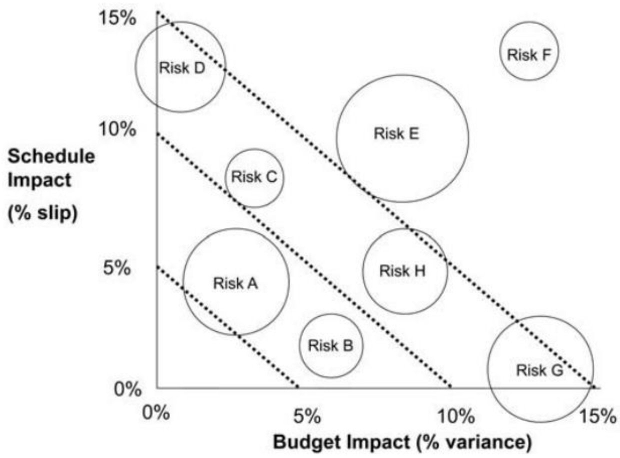

Figure 4.3. Risk assessment graph (Kendrick and PMP, 2015)

- Sensitivity analysis: refers to the significant risk probably impact on project delay or over budget through putting those risks into project schedule or cost; and then, we can see the outcome of quantitative sensitivity of the project schedule or cost.

- Decision trees: are applied for evaluating alternatives prior or options to selecting one of among risk solutions to execute (Kendrick and PMP, 2015). So, the weight of risks from the qualitative method can convert into the quantitative method to discuss as options. The decision trees analysis can assist from the PERT technique, and help to select the optional expected monetary (EMV).

- Simulation and Modeling: are used the Monte Carlo technique or computer-based technique. So, the distribution of risk measurement from schedule or cost activities would be simulated or run those techniques as a model of project goals.

- PERT method: the full name is Program Evaluation and Review Technique. PERT conducts the graphical network of project activities such as project duration or project cost through a chart or graph. Data estimation of PERT has 3 parts; they are an optimistic value at the low level, a most likely value at the peak in the middle level, and a pessimistic value at the high level. PERT is applied for risk data due to the estimation of the project outcome from risk activities.

- Statistical concepts and probability distributions: are the way of using any associated distributions and statistics for analyzing risk. In a simple way, PERT can define the continued possibility data of risk factors as the Beta distribution (normal distribution). Triangular distribution and uniform distribution are commonly used for this technique too.

4.5. Procedures of AHP (analytic hierarchy process) method

In this research, AHP will be used instead of quantitative method and to fulfil the objective. AHP has five important processes, detail in Figure 4.4. First sets the problems as a model structure (hierarchy risk model) that is available in Figure 4.2. And it's plus the risk alternative is cost, time, and quality. The second is to make pairwise comparisons based on basic scale numbers. The measurement of pairwise comparisons comes from the mean value of SPSS. The third is the calculations of criteria weight of MR (main risk), RC (risk category), and alternatives. Simultaneously, the consistency ratio needs to consider verifying the pairwise comparisons. As a result, the rank of risk priority will be arranged respectively by the weight of criteria in the study objectives. Expressly, the AHP technique will be assisted by Microsoft Excel 2016.

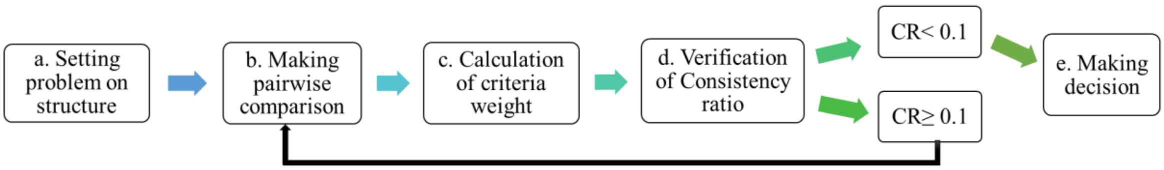

Figure 4.4. The procedure of analytic hierarchy process application

4.5.1. Risk model structures of the AHP method

Risk model structure designs for the risks criteria to help and fulfill the research objectives. The risk model structure above is going to generate the setting problems structure for the AHP method in this study. In Figure 4.5, the matrix structure contains main risks (MRs) instead of main criteria and sub-main risks (risk categories) instead of sub-main criteria. The aim of alternatives is to focus on the among cost, time, and quality which are the most critical issues in the project experiences in Cambodia.

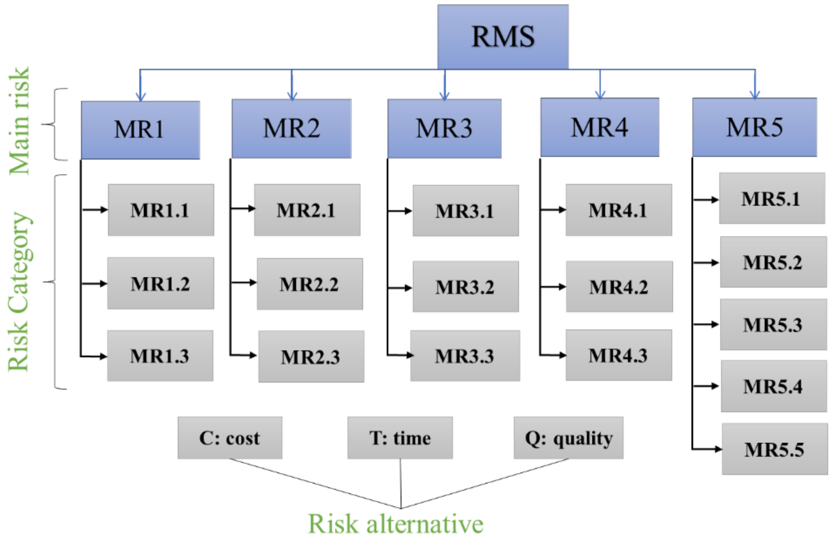

Figure 4.5. The organization of risk model structure works for AHP method

4.5.2. Determination of pairwise comparison matrix

Basic scale number: is the number of pairwise comparison judgments using in the AHP method (Saaty and Vargas, 2012). The scale number effectively evaluates being the number in comparison value in both theories and practices. Saaty and Vargas (2012) distribute nine numbers to make a pairwise comparison to evaluate. They are the 1, 2, …, until 9 in the ordering level of the importance table as represented below.

Table 4.4. Basic scale number (Saaty and Vargas, 2012)

Scale	Definition	Descriptions
1	Equal importance	Two factors are equal
3	Slightly strong importance	One is slightly importance than another
5	Strong importance	One is strong importance than another
7	Very strong importance	One is very strong importance than another
9	Absolutely importance	One is the highest importance than another
2,4,6,8	Intermediate value	Middle values between two adjoining judgments

Pairwise comparison matrix: is conducting all pairwise comparison using basic scale number with applying for a generally formal matrix (n x n) in the equation below (Özbek, 2017).

$$C = \begin{bmatrix} c_{11} & c_{12} & c_{13} & \dots & c_{1n} \\ c_{21} & c_{22} & c_{23} & \dots & c_{2n} \\ c_{31} & c_{32} & c_{33} & \dots & c_{3n} \\ \dots & \dots & \dots & \dots & \dots \\ c_{n1} & c_{n2} & c_{n3} & \dots & c_{nn} \end{bmatrix} = \begin{bmatrix} 1 & c_{12} & c_{13} & \dots & c_{1n} \\ 1/c_{12} & 1 & c_{23} & \dots & c_{2n} \\ 1/c_{13} & 1/c_{23} & 1 & \dots & c_{3n} \\ \dots & \dots & \dots & 1 & \dots \\ 1/c_{1n} & 1/c_{2n} & 1/c_{3n} & \dots & 1 \end{bmatrix} \tag{4.1}$$

Note: when $i = j \Rightarrow c_{ii} = c_{jj} = 1$ (self-comparison) with i=1,2,...,n ; j=1,2,...,m

4.5.3. Calculation of criteria weight

- Normalize matrix (c'_{ij}) is coming from each criterion of pairwise comparison matrix divided by the summation of each column criterion. Normalize matrix is calculated by the equation (Özbek, 2017; Saaty and Vargas, 2012):

$$c'_{ij} = \frac{c_{ij}}{\sum_{i,j=1}^{n} c_{ij}} \tag{4.2}$$

Table 4.5. Normalize matrix of each criterion (c'_{ij})

$C'_{ij} \therefore [n \times n]$	Criterion 1	Criterion 2	…	Criterion n
Criterion 1	c'_{11}	c'_{12}	…	c'_{1n}
Criterion 2	c'_{21}	c'_{22}	…	c'_{2n}
…	…	…	…	…
Criterion n	c'_{n1}	c'_{n2}	…	c'_{nn}

- According to (Özbek, 2017; Saaty and Vargas, 2012), the calculation of the criteria weight or eigenvector (**Wi**) is an average value of summation of each row criterion in the normalize matrix; which i, j=1,2,3,...,n

$$w_i = (\frac{1}{n}) \times \sum_{i,j=1}^{n} c'_{ij} \tag{4.3}$$

- Consistency Ratio (CR): is the Consistency Index (CI) divided by Ratio Index (RI), (Özbek, 2017; Saaty and Vargas, 2012). When the CR is less than 0.1 or 10% (<0.1), it means that generated reciprocal matrix by using the scale for pairwise comparison is acceptable or judgment is well. However, if the value of CR is greater than or equal to 0.1 (≥0.1), we need to reorganize the pairwise comparison (Özbek, 2017; Saaty and Vargas, 2012).

$$\text{CR}=\frac{\text{CI}}{\text{RI}} \tag{4.4}$$

- Consistency Index (CI) is following the equation: $\text{CI}=\frac{\lambda_{\max}\text{-n}}{\text{n-1}}$ which, $\lambda_{\max}$ is the maximum eigenvalue and n is number of criteria or alternatives. Based on (Özbek, 2017; Saaty and Vargas, 2012), we can find the maximum eigenvalue as equation below:

$$\lambda_{\max} = \frac{1}{n} \times \sum_{i=1}^{n} \left(\frac{\sum_{j=1}^{n} c_{ij} \times w_j}{w_i} \right) \tag{4.5}$$

$$\text{, where } \sum_{i,j=1}^{n} c_{ij} \times w_i = C \times W = \begin{bmatrix} c_{11} & c_{12} & c_{13} & \cdots & c_{1n} \\ c_{21} & c_{22} & c_{23} & \cdots & c_{2n} \\ c_{31} & c_{32} & c_{33} & \cdots & c_{3n} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ c_{n1} & c_{n2} & c_{n3} & \cdots & c_{nn} \end{bmatrix} \times \begin{bmatrix} w_1 \\ w_2 \\ w_3 \\ \cdots \\ w_n \end{bmatrix} = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ \cdots \\ x_n \end{bmatrix} \tag{4.6}$$

Right now, we can write that $d_i = \frac{x_i}{w_i}$ and then, $\lambda_{\max} = \frac{\sum_{i=1}^{n} d_i}{n}$

- Ratio Index (RI): refers to random index of values. Table 4.6 of RI below is shown the average consistencies (CI) of 500 randomly to complete matrix as different order random matrices (Golden and Wasil, 1989). Which, N is the number of criteria and n is the random index values.

Table 4.6. Average random matrix of Consistency Index (Golden and Wasil, 1989)

N	1	2	3	4	5	6	7	8
n=	0	0	0.58	0.90	1.12	1.24	1.32	1.41
N	9	10	11	12	13	14	15	
n=	1.45	1.49	1.51	1.53	1.56	1.57	1.59	

4.5.4. Decision making bases on results

The evaluation of decision-making is the aim of getting results from the structure goal. Here is applying synthesis. Basic Synthesis of the AHP method is the process of multiplying weight criteria from main criteria until alternatives respectively (Özbek, 2017; Saaty and Vargas, 2012). Take an example of criteria weight, a criterion MR1 is 0.2, one of sub-criterion MR1.1 is 0.35, and the C as an alternative of criterion MR1.1 is 0.5. As a result, this synthesis is 0.2x0.35x0.5=0.035 (it is the C's weight of one alternative of one MR1.1 of one MR1).

4.6. Research limitations

In this research, the data collection is from the client, owner, designer, architect, contractor, sub-contractor, and supplier in Cambodia. Risk factors are verified by the civil engineering managers coming from the clients, consultants, and contractors. This study investigates risk management in the different phases of building construction projects in both private and the public sectors. And, this study is also focused on the only negative impact (threats) of risk management in CPs.

5. RESULTS AND DISCUSSIONS

We explained how to do the questionnaires, how to collect data, and which scale is applied in the previous chapter. For this chapter, the important work here is to conduct the data collection into the analysis to complete the research objectives. It will be investigated how are the characteristic risk management in CCPs.

Data analysis refers to the process of determination for research goals in ordering to investigate, verify, satisfy, or new explore. The data analysis is applied to the SPSS program Version-26 and assisting the Microsoft Excel 2016. The data analysis will appear the descriptive statistical analysis, t-test analysis, Alpha Cronbach, and analytic hierarchy process.

5.1. Description and analysis of participants in construction projects

Table 5.1. Numbers of project stakeholders participate in the CPs

Items	Number	Frequency	Cumulative
Contractor	41	38%	38%
Client/owner	25	23%	61%
Consultant/architect	36	33%	94%
Sub-contractor	3	3%	97%
Other (supplier)	3	3%	100%
Total	108	100%	

The survey questionnaires were done and obtained 108 responses that are utilizable for analyzing the data. Table 5.1 above describes that 38% of respondents work for contractors, 23% of respondents work for clients and owners, 33% of respondents work for consultants and architects, 3% of respondents work for sub-contractor, and 3% of respondents work for suppliers. Consequently, the result has indicated that the highest respondents come from contractors. Next after, they come from consultants and architects. Then, they're from clients and owners.

This study is concentrated on three mains of project stakeholders. One is client/ owner, two is consultant/ architect, and final is contractor sectors. So, Figure 5.1 is summarized in 3 main parts; Client/ Owner contain 23%, Consultant/ Architect contain 33%, and Contractor/ Sub-contractor/ Supplier contain total 44% of respondents in survey questionnaires. As a result, the most influential respondents' percentage is the contractor sectors.

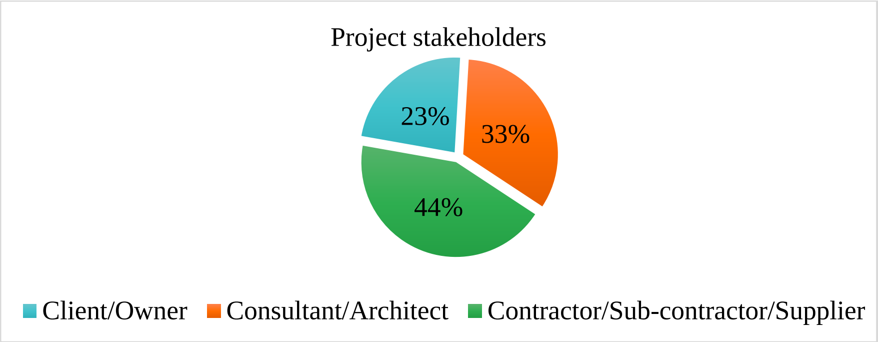

Figure 5.1. Percentage of project stakeholders in CPs

Table 5.2. Respondents' experiences (years) have been worked in CPs

Items	Number	Frequency	Cumulative
Less than 1 year	16	15%	15%
From 1 to 5 years	62	57%	72%
From 6 to 10 years	23	21%	94%
From 11 to 15 years	4	4%	97%
More than 15 years	3	3%	100%
Total	108	100%	

Table 5.2 is about the respondents who have experienced working in CPs. It indicates that 15% of respondents have experienced less than one year, 57% of respondents have experienced from 1 to 5 years, 21% of respondents have experienced from 6 to 10 years, 4% of respondents have experienced from 11 to 15 years, and only 3% of respondents have experienced more than 15 years. As a result, the experiences from 1 to 5 years are the biggest response. And the second bigger response is the experience from 6 to10 years in this study.

Table 5.3. The percentage of respondents' position currently works

Items	Number	Frequency	Cumulative
General/Site manager	14	13%	13%
Project manager/Director	9	8%	21%
Designer/ Architect	34	31%	53%
Site engineer	25	23%	76%
Quantity surveyor	10	9%	85%
Inspector/Organizer	6	6%	91%
Supervisor	5	5%	95%
Asst. manager/Director	3	3%	98%
Research engineer (PhD)	2	2%	100%
Total	108	100%	

The respondents' position is one of the survey questionnaires in the study too. It can make to get more flexible reasons associated with characteristically performance. Table 5.3 indicates that 13% of respondents are general managers and site managers. 8% of respondents are project managers and directors. 31% of respondents are designers and architects; 23% of respondents are site engineers. 9% of respondents are quantity surveyors; 6% of respondents are inspectors and organizers, 5% of respondents are supervisors, 3% of respondents are assistant managers and assistant directors, and 2% of respondents are doctor researchers. As a result, the bigger response is designers, site engineers, general and site managers, quantity surveyors, and project managers/ directors respectively.

5.2. Description and analysis of risk management in CPs

The center of this research is the risk management approach in CCPs. This section illustrates the knowledge level of risk management of respondents. It expresses that how the importance of risk management in CCPs needs to review and alert. Figure 5.2 indicates that only 44% of responses have joined the workshop, seminar, or training on risk management in CPs, and 56% of responses haven’t participated. This means the risk management in CPs is not fully thinking in the project as well.

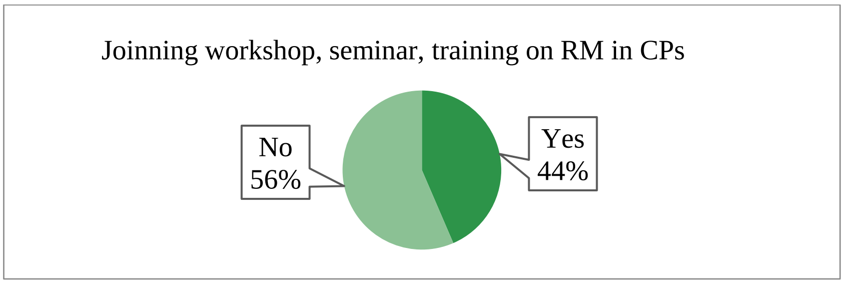

Figure 5.2. Percentage of respondents have jointed workshop, seminar, or training on risk management in CPs

Table 5.4. Respondents' knowledge level of risk management in CPs

Items	Number	Frequency	Cumulative
Low	25	23%	23%
Moderate	74	69%	92%
High	9	8%	100%
Total	108	100%	

The evaluation of risk management knowledge in construction projects can't remove in this research. So, Table 5.4 illustrates the knowledge level of risk management in CPs. Shortly, 23% of responses are at the low level, 69% of responses are at the middle level, and only 8% of responses are at the high level. In conclusion, the knowledge degree of risk management in Cambodia still has limitations. They are probably uncertain how to manage and solve the risks well in their projects.

Table 5.5. The organizer manages risk strategy to avoid risks in CPs

Items	Number	Frequency	Cumulative
Construction manager	22	20%	20%
Project manager	53	49%	69%
Supervisor	9	8%	78%
Designer	2	2%	80%
Specialized risk management team	17	16%	95%
Other (contractor and giving advise)	5	5%	100%
Total	108	100%	

Table 5.5 describes the managing risk strategy to avoid uncertain events and contingency in CPs. It illustrates that 49% of responses are project managers, 20% of responses are construction managers, 16% of responses are specialized risk management teams, 8% of responses are supervisors, 5% of responses are others, and 2% of responses are

designers. So, the percentage of project manager and construction manager is performed importance to manage risks in CPs. According to (Cooper et al., 2005), project managers have to have a high responsibility than others to solve and treat risky projects.

Table 5.6. Perceptions of managing risks play an important role in the successful completion of CPs

Items	Number	Frequency	Cumulative
Disagree	4	4%	4%
Neither agree nor disagree	2	2%	6%
Agree	102	94%	100%
Total	108	100%	

Table 5.6 represents the responses' perceptions of managing risks play an important role in the successful completion in construction projects. It illustrates that 94% of responses are ‘Agree’, only 4% of responses are ‘Disagree’, and 2% of responses are not sure about this perception. This evidence is manifested that risk management is necessary for focusing on construction projects.

Figure 5.3 represents the percentage of responses that meet the time delay, or cost overrun, or quality problem in their project experiences. The result illustrates that 92% of the project experiences have the problem conducting on cost, or time, or quality, or two of them, or all of them. Only 8% of responses are not getting any obstacle of these three components. As a result, any risk factors that must happen in the project experiences need to review and find the solution. A respondent complains that stuck projects due to pandemic of Covid-19. Nevertheless, a few respondents express that a few projects can run smoothly. They have two reasons; one is the good plans and rules to control work well. And the second reason is the international and standard company.

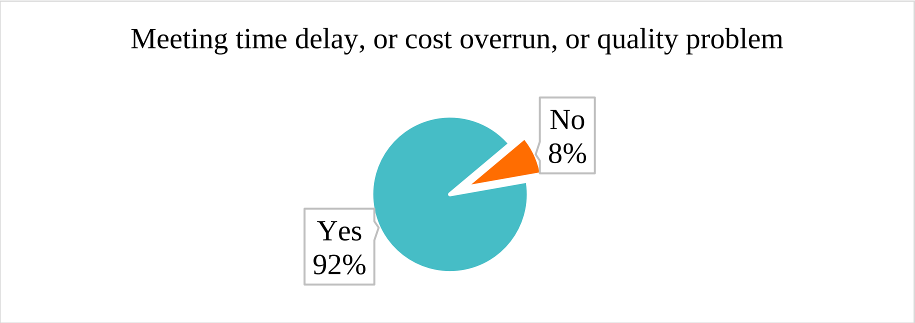

Figure 5.3. Percentage of respondents meets the time delay, or cost overrun or quality problem in their project experiences

5.3. Risk factor (RF) analysis and its assessment

In the previous section of the materials and methods chapter, we have described the scale rates (1-5 Likert scale) of risk probabilities and their impacts. In this section, the scale rates will be analyzed the data collections by considering the mean value and standard deviation of each factor.

Table 5.7 is the one of important objectives in the research. It represents 34 risk factors likelihood, its impact, and its assessment. Additionally, the risk category is added due to the determination of risk factors data to use in the next section. The most important is to detail all mean values and ranks of all risk factors to evaluate the risk construction projects in Cambodia through questionnaires. The risk factors of green color in Table 5.7 of column 7 are high degrees. And pink color means risk factors are in the medium degree. So, it’s deeply to eliminate the risk factors as much as possible in projects.

According to Table 5.7, the top five critical degrees of risk likelihood are: one is unqualified project manager, two is the financial failure/ lack of financial resource, three is the selecting low-bid of the contractor by the owner, four is the lack of skills and work organization by contractor sector, five is the mistakes during processing work of contractor sector. Regarding respondents, the probability of risk occurrence can impact on top five critical degrees of risk impacts. One is the unqualified project manager, two is the financial failure/ lack of financial resources. Three is the lack of skills and work management by contractor sectors, four is the change in scope of work. And five is the poor communication and coordination between participants. For more critical factors of risk occurrence and risk impact, let' go to Table 5.7.

Risk assessment was explained in the previous chapter that contains the degree of likelihood multiplied by the degree of its impact (L*I) in Table 5.7 below. Consequently, the top-five critical degrees of risk assessment are: one is the unqualified project manager, two is the financial issues. Three is the lack of skills and lack of work organization by contractor sectors. Four is the poor communication and coordination of participants in the projects, and five is the mistakes during processing work of contractor sectors.

Table 5.7. RFs degree of likelihood, impact, and its assessment

RCs	Risk factors (RFs)	Risk likelihood (L)		Risk impact (I)		Assessment (L*I)		RC likelihood		RC impact	
		Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank
Client/ Owner	Tight project on schedule, cost, and quality	0.5704	21	0.3009	25	0.1716	25	0.5870	8	0.3085	14
	Selecting low bid of contractor	0.6278	3	0.3426	9	0.2151	6				
	Leak of support team	0.5630	26	0.2819	31	0.1587	29				
Designer/ Architect	Inaccurate costs estimate and schedule programming	0.5889	12	0.3389	10	0.1996	10	0.5864	10	0.3304	7
	Lack of support team and experience	0.5907	10	0.3222	20	0.1903	16				
	Various design (design change, poor site information, material specification)	0.5796	19	0.3301	13	0.1913	15				
Contractor/Sub-contractor/ Supplier	Lack of skills and work organization	0.6259	4	0.3773	3	**0.2362**	**3**	0.6037	3	0.3372	6
	Mistakes during processing work	0.6167	5	0.3546	7	**0.2187**	**5**				
	Rework or defective work	0.5685	23	0.2796	32	0.1590	28				
Labour	Inadequate labour/ labour performance	0.5815	18	0.3241	18	0.1884	18	0.5981	4	0.3266	9
	Lack of skilled labour	0.6148	6	0.3292	14	0.2024	9				
Equipment/ material	Inadequate equipment/ equipment issues	0.5870	15	0.3231	19	0.1897	17	0.5895	6	0.3290	8
	Material shortages/ material damage	0.5944	9	0.3356	12	0.1995	11				
	Late delivery of materials	0.5870	13	0.3282	15	0.1927	14				
Finance	Financial failure/ lack of financial resources	0.6278	2	0.3935	2	**0.2470**	**2**	0.5977	5	0.3497	5
	Late payment by clients	0.5981	8	0.3556	6	0.2127	7				
	Cash flow problems by contractors	0.5907	11	0.3370	11	0.1991	12				
	Inaccuracy of cost estimations	0.5741	20	0.3125	24	0.1794	24				

Table 5.7. RFs degree of likelihood, impact, and its assessment (continued)

RCs	Risk factors (RFs)	Risk likelihood (L)		Risk impact (I)		Assessment (L*I)		RC likelihood		RC impact	
		Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank
Environment	Weather problem (flood, rainy seasons)	0.5370	31	0.2833	29	0.1522	31	0.5083	17	0.2597	16
	Issues of construction program (pollution, ecological damage, noise)	0.4796	34	0.2361	33	0.1132	34				
Site condition	Problem of site's topography and geo-technical investigation	0.5574	28	0.3259	17	0.1817	22	0.5593	14	0.3086	13
	Safe and health problems	0.5611	27	0.2912	28	0.1634	27				
Pandemic of Covid-19	Economic projects and worker's health	0.5648	25	0.3511	8	0.1983	13	0.5648	13	0.3511	4
Politic	Bribery and corruption	0.5500	29	0.2312	34	0.1271	33	0.5500	15	0.2312	17
Schedule	Delay schedule due to project size or complexity project	0.5444	30	0.3005	26	0.1636	26	0.5370	16	0.2927	15
	Missing update schedule based real work at site	0.5296	33	0.2949	27	0.1562	30				
	Insufficient schedule to see all major items	0.5370	32	0.2829	30	0.1519	32				
Quality	Misunderstanding/ unclear of quality control plan	0.5648	24	0.3181	22	0.1796	23	0.5676	12	0.3225	10
	Unclear specification and standard	0.5704	22	0.3269	16	0.1864	20				
Poor organization due to project stakeholder		0.5870	13	0.3171	23	0.1861	21	0.5870	7	0.3171	12
Poor management due to project resource		0.5864	16	0.3183	21	0.1867	19	0.5864	9	0.3183	11
Unqualified project manager		0.6426	1	0.4117	1	**0.2646**	**1**	0.6426	1	0.4117	1
Change in scope of work		0.5833	17	0.3622	4	0.2113	8	0.5833	11	0.3622	2
Poor communication/ coordination of participants		0.6074	7	0.3611	5	**0.2193**	**4**	0.6074	2	0.3611	3

5.4. Cronbach's Alpha and T-test analysis of RCs impact

Cronbach's Alpha or coefficient Alpha (internal coefficient) is to evaluate the test items for scales. As a result, the coefficient Alpha is equal to 0.960, 0.944, 0.898, 0.912, and 0.917. Finally, the Alpha is reliable for the study. T-test analysis of risk category impact is used to verify whether a significant difference between the mean value of RC impact from Table 5.7 and RC impact from Table 5.9. The confidence interval percentage is determined at 95% (Alpha value is 5%). Consequently, T-test analysis obtains as shown in Table 5.8. The p-value is 0.656 that is bigger than 0.05. Therefore, the signification of mean values between Table 5.7, Column 11, and Table 5.9, Column 8 is not the different values. Moreover, the Mean difference is 0.006 which means the groups of these mean values are the same.

Table 5.8. T-test analysis of RCs impact

Table 5.7, Column 11		Table 5.9, Column 8				
Mean	Std.	Mean	Std.	df	P-value	Mean diff.
0.32456	0.04066	0.31780	0.04693	32	0.65673	0.00676

5.5. Risk categories (RCs) impact on cost, time, and quality in CPs

Table 5.9 represents the degree of risk categories (RCs) impact on cost, time, and quality in construction projects through the respondents. In this study, RCs provide 17 factors focusing on the risk impact of these components (cost, time, and quality). The biggest impact on cost, time, and quality is the unqualified project manager. The second impact of cost is the financial issue; meanwhile, the second impact of time is the Pandemic of Covid-19. And the second impact of quality is the poor communication and coordination of participants while this is the third factor of time impact. The third impact of cost is the change in scope of work while this issue is the fourth factor of time impact. However, the third impact of quality is the issues of contractor and sub-contractor while this is the fifth factor of cost and time impact. The fourth impact of cost is the Pandemic of Covid-19; meanwhile, the fourth impact of quality is the project quality issue. Finally, the fifth impact of quality is labor. Therefore, the biggest impact of triangle components (cost, time, and quality) comes from the issues of the management system, contractor parties, Pandemic of Covid-19, and finance.

Table 5.9. RCs impact on cost, time, and quality in CPs

Risk categories (RCs)	Cost impact		Time impact		Quality impact		Global Impact	
	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank
Client/ Owner	0.3241	8	0.3171	10	0.2819	13	0.3077	12
Designer/ Architect	0.2722	14	0.2944	13	0.3046	10	0.2904	14
Contractor/Sub-contractor/ Supplier	**0.3421**	**5**	**0.3634**	**5**	**0.3537**	**3**	**0.3531**	**4**
Labour	0.2995	13	0.3106	11	**0.3477**	**5**	0.3193	8
Equipment/ materials	0.3111	11	0.2657	15	0.2995	11	0.2921	13
Finance	**0.3847**	**2**	0.3394	7	0.3065	9	**0.3435**	**6**
Environment	0.2366	17	0.2394	17	0.2204	16	0.2321	16
Site condition	0.2704	15	0.2810	14	0.2370	15	0.2628	15
Pandemic of Covid-19	**0.3667**	**4**	**0.4093**	**2**	0.2773	14	**0.3511**	**5**
Politic	0.2431	16	0.2463	16	0.2042	17	0.2312	17
Schedule	0.3106	12	0.3565	6	0.2875	12	0.3182	10
Quality	0.3199	9	0.3208	9	**0.3514**	**4**	0.3307	7
Poor organization due to project stakeholder	0.3128	10	0.3250	8	0.3134	7	0.3171	11
Poor management due to project resource	0.3318	6	0.3052	12	0.3179	6	0.3183	9
Unqualified project manager	**0.4000**	**1**	**0.4134**	**1**	**0.4218**	**1**	**0.4117**	**1**
Change in scope of work	**0.3782**	**3**	**0.3949**	**4**	0.3134	7	**0.3622**	**2**
Poor communication and coordination of participants	0.3310	7	**0.3972**	**3**	**0.3551**	**2**	**0.3611**	**3**

5.6. Risk categories (RCs) assessment analysis of cost, time, and quality

The probability of RC likelihood is obtained by the probability of RF likelihood in Table 5.7 of column 9. Risk categories assessment analysis of triangle components (cost, time, and quality) is one of the research objectives. The RC assessment in Table 5.10 is combined the analysis from Table 5.7 and Table 5.9. It indicates the risk assessment analysis of cost, time, quality, and global (combining cost, time, and quality). Consequently, the top-five critical RCs assessment of cost, time, and quality describe below:

The first RC assessment of cost, time, and quality is the unqualified project manager. The second RC assessment of time and quality is the poor communication and coordination of participants in CPs; meanwhile, financial issue is the second factor of cost assessment. The third RC assessment of cost is the change in scope of work while this is the fourth issue of time assessment. However, the third RC assessment of quality is the contractor parties while this is the fifth issue of cost and time assessment. The fourth RC assessment of cost is the Pandemic of Covid-19 while this is the third issue of time assessment. Further, labor and project quality are respective the fourth and fifth issues of the quality assessment in CCPs.

Therefore, the unqualified project manager, poor communication, the construction parties, the change in scope of work, and the finance in respectively are the biggest critical problems. This needs to eliminate these critical uncertain items in CPs. It won't work effectively in only one time, but it can do the step by step for reducing the time and cost increases of the project objectives. The quality of projects would enhance satisfaction for the owner with one standard. Nevertheless, the significant RCs assessment as global is almost in the high-risk situations. Except, environment and politics are in the medium-risk location. All RCs need to evaluate and revise the risks in the projects as soon as possible.

Table 5.10. RC assessment analysis of cost, time, quality, and global

Risk categories (RCs)	Cost (L*I)		Time (L*I)		Quality (L*I)		Global L*I	
	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank
Client/ Owner	0.1902	8	0.1862	9	0.1655	12	0.1806	11
Designer/ Architect	0.1596	14	0.1727	13	0.1786	10	0.1703	14
Contractor/Sub-contractor/ Supplier	**0.2065**	**5**	**0.2194**	**5**	**0.2135**	**3**	**0.2132**	**3**
Labour	0.1792	12	0.1858	10	**0.2080**	**4**	0.1910	7
Equipment/ material	0.1834	10	0.1567	15	0.1766	11	0.1722	12
Finance	**0.2299**	**2**	0.2028	6	0.1832	8	**0.2053**	**5**
Environment	0.1203	17	0.1217	17	0.1120	17	0.1180	17
Site condition	0.1512	15	0.1572	14	0.1326	15	0.1470	15
Pandemic of Covid-19	**0.2071**	**4**	**0.2312**	**3**	0.1566	13	0.1983	6
Politics	0.1337	16	0.1355	16	0.1123	16	0.1271	16
Schedule	0.1668	13	0.1914	7	0.1544	14	0.1709	13
Quality	0.1816	11	0.1821	11	**0.1994**	**5**	0.1877	8
Poor organization due to project stakeholder	0.1836	9	0.1908	8	0.1840	7	0.1861	10
Poor management due to project resource	0.1946	7	0.1790	12	0.1864	6	0.1867	9
Unqualified project manager	**0.2570**	**1**	**0.2657**	**1**	**0.2710**	**1**	**0.2646**	**1**
Change in scope of work	**0.2206**	**3**	**0.2304**	**4**	0.1828	9	**0.2113**	**4**
Poor communication and coordination of participants	0.2011	6	**0.2413**	**2**	**0.2157**	**2**	**0.2193**	**2**

5.7. Main risk (MR) assessment analysis of cost, time, and quality

Under the risk model structure, the main risks are like the body of a tree. Table 5.11 on page 53 concludes the value of all risk factors and risk categories in five risks; stakeholders, resources, construction site, management, and features. As a result, project management is the biggest main problem of project risk in all critical components. According to Table 5.11, the rank of main risks assessment in both cost and quality is the same priority of each main risk. They are the management, resource, stakeholder, feature, and construction site respectively.

Conversely, the respective rank of time assessment is the management, stakeholder, resource, construction site, and project feature. In conclusion, the all-main risks assessment is in the high-risk condition. It means that risk management may happen regularly in construction projects. It's not a strange outcome due to the recent problems occurring in the CCPs as reporting in chapter two of Section 2.2. So, there needs a strong willingness to minimize and improve the risk management in CPs in both the public and private sectors.

Therefore, all the project risks in construction projects are in a high-risk situation of likelihood-impact of cost, time, and quality. We need to eliminate those factors as high pro-activities before and during construction, full-skilled people, quality of resources, etc. In short, we will take the guide response strategies of main risks as the ideas to protect the high effective risk management in CPs.

5.8. Risk response strategies

Regarding the outcomes of the research, the likelihood of all risk events is likely to happen from 50% to 80% in the project work. The cost impact requires to increase from 20% to 40% of the project budgets. The time impact requires to rise from 10% to 20% of the project schedule. Moreover, the quality impact indicates that it doesn’t get satisfaction from the sponsor. It means the risk events that happened are in unacceptable situations. Nevertheless, in the research objectives, we consider the global risk events in CCPs. It doesn’t mean all the significant risks happened in only one project (Cooper et al., 2005).

And this perception is evaluated base on theoretical judgments because we don't have any exact measurements of risk management in Cambodia.

Nevertheless, the concepts of risk response are through the table below based on each main risk of each impact of quality, time, and cost. Thus, the construction risk management would attend to the next project in an ordering careful way for a successful project. However, to eliminate the unacceptable time impact and quality impact, it requires spending the cost as well. Here, we would like to recommend the risk response strategies to minimize the project risks of our risk events consideration in this study in Table 5.12, Table 5.13, and Table 5.14.

However, Cooper et al. (2005) have described the risk treatment options and the detailed risk action plains in Appendix-D to identify and evaluate the risk events in a specific project or own construction project. These models can describe well on the explanation, detailing risk events, and risk responses. It can determine our project risks to evaluate the risk level at the extremely high, high, medium, or low. So, we can find the best solution at a suitable time and minimize the project risks in the future construction project. We can examine the planning risk strategy based on concepts of risk responses and controls (section 3.4.3.).

Table 5.11. MRs likelihood, impact, and assessment analysis of cost, time, quality

Main risks (MRs)	Likelihood		Cost impact		Time impact		Quality impact	
	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank
Project stakeholder	0.5924	3	0.3128	3	0.3250	2	0.3134	3
Project resource	0.5951	2	0.3318	2	0.3052	5	0.3179	2
Construction site	0.5441	5	0.2912	4	0.3099	3	0.2449	5
Project feature	0.5515	4	0.2912	4	0.3079	4	0.2810	4
Project management	0.6014	1	0.3508	1	0.3672	1	0.3443	1
Risk assessment analysis								
Main risks (MRs)	Cost (L*I)		Time (L*I)		Quality (L*I)		Global L*I	
	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank
Project stakeholder	0.1853	3	0.1925	2	0.1857	3	0.1878	3
Project resource	0.1975	2	0.1817	3	0.1892	2	0.1894	2
Construction site	0.1585	5	0.1686	5	0.1333	5	0.1534	5
Project feature	0.1606	4	0.1698	4	0.1550	4	0.1618	4
Project management	0.2109	1	0.2208	1	0.2071	1	0.2129	1

Table 5.12. Risk response and control strategies for main risks of the quality impact

Main risks (MRs)	Descriptions
Project management	There needs to effective control and update work on time the detailing managing worker of participants, resource allocation, making clear work before changing the scope of work, providing the line managers' responsibility clearly, improve the communication and work strongly together. Project managers must have the full competence to manage and control the construction work.
Project resource	There needs client/ owner's decision more than other participants. If the quality of materials and equipment is the best, the price would be expensive as well. Technicians must know how to use equipment techniques as well. Skilled labor and worker need to train and improve as clear as possible. The better solution is to train workers in the separately clearly specific role of construction work.
Project stakeholder	There needs high responsibility of stakeholders in the effectiveness of the project to avoid quarrels during construction, especially the construction sector. The functions of participants need actual performance and qualified work roles.
Project feature	There needs to detail and clear the schedule method such as CPM (critical path method), PERT (program evaluation and review technique), etc., in an effective way. Quality of project needs to clear specification and standard as well. Planning of quality needs to comprehend the quality control plan. Bribery and corruption should have the negotiation as much as possible due to the effect on the business investment or quality project as well.
Construction site	There needs to reduce the voice and pollution of construction performance as well. Site safety needs to smooth control during processing projects. Rules and regulations of safety and security in worksites need to follow strictly. Maske, hygiene hands, and distance need to follow the government rules to avoid new pandemic diseases.

Table 5.13. Risk response and control strategies for main risks of the time impact

Main risks (MRs)	Descriptions
Project management	There needs to manage a detailing schedule of the project precisely from stakeholders. Clear managing schedules of arriving and available resources demand fast and certain decisions from project managers. Time discussions need to provide for meeting between participants to find the best solutions in one direction.
Project stakeholder	Participants must associate with time as well. Clients and owners should not select the contractors due to the only low bids, because it would be harmful to other parts of the project. Designers need to determine the accurate schedule for projects. The contractors have to reduce the mistakes during processing work and enhance the competence.
Project resource	If the scheduled program is perfect and the resource is not available, the project is empty. So, unskilled laborers, financial issues, late payment, or late delivery materials need to preserve and solve as soon as possible in the right way.
Construction site	The accurate schedule program needs flexible seasons too. There needs to manage the construction site in safe methods especially people factors. When contingency events happen, it should instead the available works to do. So, it won't waste the time of working procedures.
Project feature	There needs to update of the schedule program quickly so that it can process constructions on time. Especially, the detailing schedule to see the all majors of the procedure is necessary to conduct for the whole project.

Table 5.14. Risk response and control strategies for main risks of the cost impact

Main risks (MRs)	Descriptions
Project management	Cost impacts are affected by the managing procedure of schedule, quality control, and direct budget as well. So, management needs to high pro-activities both implementation and control for the project purposes. Project managers need to balance between competencies and payment by believing from the director or CEO as well.
Project resource	The price of resources bases on the owner or client as major to make the decision of the best alternatives. Using people and materials for building projects is exactly required money as well. The late payment, cash flow problems, and financial issues need to eliminate as much as possible.
Project stakeholder	There needs to improve an accurate cost estimate undertaken the project objectives. If the time and quality can control as well, the budget would be fine too. The owner/ client can clearly understand as well between short time with high-budget and cost with the standard. Moreover, contractors need to make the processing work in the following right way of the contracting work conditions.
Project feature	Cost impact here conducts on the level of standard projects and preparing accurate schedules as well. If the above strategies of Table 5.12 and Table 5.13 as project features can process well, the cost would be smoothly controlled. Bribery and corruption should have a strong negotiation.
Construction site	Insurances need to buy. So that they can protect the safety and the health of workers as strict rules of construction sites especially, new pandemics diseases.

6. AHP METHODS IN RISK MODELS

In this chapter, we will apply the AHP method for analysis of risk assessment to determine the risk weight of the quantitative approach. AHP method will explore the 3 alternatives as cost, time, and quality of risk management in CPs. Consequently, we can establish the risk weight and its ranks such as alternative classification per RC, RC classification per alternative, alternative classification per MR, and MR classification per alternative. These will come from the interaction between MR and alternatives, and the interaction between Sub-MR and alternatives.

As we described the procedure of the AHP method in the chapter MATERIALS AND METHODS of section 4.5, what we expected is going to find out the outcomes of research purposes as well. The data collection is transferred to one value from risk assessments of questionnaires. According to Figure 4.5, we have had the risk model structure for using the AHP applications in order obtain the better solutions.

6.1. Determination of main risks (main criteria)

Here the most important is to compare every two criteria by giving basic scale values of the pairwise comparison matrix in Table 4.4. All values of pairwise comparison are set by comparing mean values and decision making on the AHP method. We suppose that MR1, MR2, MR3, MR4, and MR5 are the project stakeholders, project resources, construction sites, project features, and project management respectively. MR is the main risk or main criteria as described above. Table 6.1 is a comparison matrix of main risks for setting in the research.

Total: is the summation of all criteria in each column of table below: $t_1=1+1+1/4+1/2+2=4.750$; $t_2=1+1+1/5+1/3+1=3.533$ $t_3=4+5+1+2+7=19.000$; $t_4=2+3+1/2+1+3=9.500$, and $t_5=1/2+1+1/7+1/3+1=2.976$

Table 6.1. Comparison matrix of main risks

Pairwise matrix					
MRij	MR1	MR2	MR3	MR4	MR5
MR1	1	1	4	2	1/2
MR2	1	1	5	3	1
MR3	1/4	1/5	1	1/2	1/7
MR4	1/2	1/3	2	1	1/3
MR5	2	1	7	3	1
Total	4.750	3.533	19.000	9.500	2.976

- Setting the normalized matrix of each criterion, as the equation: $c'_{ij} = \frac{c_{ij}}{\sum_{i=1}^{n} c_{ij}}$,

we can obtain: $c'_{11} = \frac{1}{4.750} = 0.211$, $c'_{13} = \frac{4}{19.000} = 0.211$, through these processes in every value in matrix, then we get as table below:

Table 6.2. Normalized matrix and weight of criteria of main risks

Normalized matrix								
Cij	MR1	MR2	MR3	MR4	MR5	w_i	x_i	d_i
MR1	0.211	0.283	0.211	0.211	0.168	0.217	1.089	5.032
MR2	0.211	0.283	0.263	0.316	0.336	0.282	1.419	5.037
MR3	0.053	0.057	0.053	0.053	0.048	0.052	0.264	5.037
MR4	0.105	0.094	0.105	0.105	0.112	0.104	0.527	5.042
MR5	0.421	0.283	0.368	0.316	0.336	0.345	1.740	5.047
n=		5	λ_{max}=	5.039	RI=	1.12	CI=	0.010
							CR=	**0.009**

- Setting the weight of criteria as the equation: $w_i = \sum_{i,j=1}^{n} c'_{ij} / n$, we can write

$$w_1 = \frac{0.211 + 0.283 + 0.211 + 0.211 + 0.168}{5} = 0.217$$

- $x_i = \sum_{i,j=1}^{n} c_i \times w_j \Rightarrow$

$$x_i = 0.217 \times \begin{bmatrix} 1 \\ 1 \\ 1/4 \\ 1/2 \\ 2 \end{bmatrix} + 0.282 \times \begin{bmatrix} 1 \\ 1 \\ 1/5 \\ 1/3 \\ 1 \end{bmatrix} + 0.052 \times \begin{bmatrix} 4 \\ 5 \\ 1 \\ 2 \\ 7 \end{bmatrix} + 0.104 \times \begin{bmatrix} 2 \\ 3 \\ 1/2 \\ 1 \\ 3 \end{bmatrix} + 0.345 \times \begin{bmatrix} 1/2 \\ 1 \\ 1/7 \\ 1/3 \\ 1 \end{bmatrix}$$

$$\Rightarrow \quad x_i = \begin{bmatrix} 1.089 \\ 1.419 \\ 0.264 \\ 0.527 \\ 1.740 \end{bmatrix}$$

- $d_i = \frac{x_i}{w_i} \Rightarrow d_1 = \frac{1.089}{0.217} = 5.032$

- Maximum of eigenvalue: $\lambda_{\max} = \frac{1}{n} \times \sum_{i=1}^{n} \left[\frac{\sum_{j=1}^{n} c_i \times w_j}{w_i} \right] = \frac{\sum_{i=1}^{n} d_i}{n}$

$$\Rightarrow \lambda_{\max} = \frac{5.032 + 5.037 + 5.037 + 5.042 + 5.047}{5} = 5.039$$

- Based on Table 4.6, RI=1.12 when n is equal to 5. So, the consistency index is: $\text{CI} = \frac{\lambda_{\max} - n}{n-1} \Rightarrow \text{CI} = \frac{5.039 - 5}{5 - 1} = 0.010$

- Therefore, $\text{CR} = \frac{\text{CI}}{\text{RI}} \Rightarrow \text{CR} = \frac{0.010}{1.12} = 0.009 < 0.1, \text{ok}$

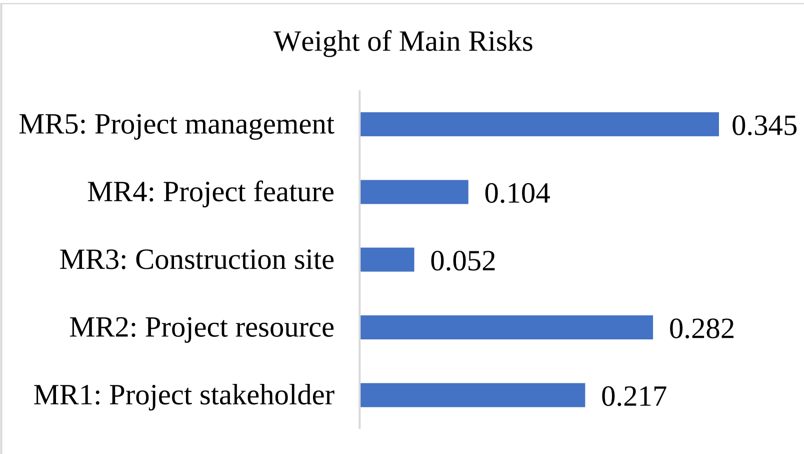

Figure 6.1. A summary of the weight and priority ranks of main risks

Figure 6.1 represents the summary of the weight and priority rank of main risks in CPs. According to the weight of MRs, it indicates that project management (MR5) has 34.50% of the most critical role in project risk. The project resource is 28.20% that is the second critical role in project risk after MR5. Then, the third critical role is the project stakeholder which has 21.70% of the project risk. The project feature and construction site are equal to 10.40% and 5.20% respectively in risk management of CPs.

6.2. Determination of sub-main risks (sub-main criteria)

The determination processes follow the same procedure as the main criteria's calculation above. Main criteria provide into 5 parts of sub-main criteria in order to determine their weight values.

- Sub- main risks of project stakeholder:

  The risks under project stakeholder (MR1) have three important elements. One is the client and owner, two is the designer and architect, and three is the contractor, sub-contractor and supplier. So, we replace that: MR1.1 = Client and owner;
MR1.2 = Designer and architect; and MR1.3 = Contractor, sub-contractor, and supplier.

Table 6.3. Comparison matrix of sub-MR of project stakeholder

MR1	MR1.1	MR1.2	MR1.3	Weight
MR1.1	1	3	1/2	0.320
MR1.2	1/3	1	1/4	0.123
MR1.3	2	4	1	0.557
λmax=	3.018	RI=	0.58	
CI=	0.009	**CR=**	**0.016**	< **0.10**

Table 6.3 represents the comparison matrix and weight of sub-main risks of project stakeholders. It illustrates that the contractor, sub-contractor, and supplier reaches 55.70% of the most critical performance in project risks. Then, the client and owner have 32.00% of critical performance in project risks. Last but not least, the designer and architect have 12.30% of important critical performance in project risk. It expresses that contractor sectors need pro-activities in CPs to avoid the risks than other participants.

- Sub-main risks of project resource:

The risks under project resource (MR2) have three important elements. One is the labor, two is the equipment and materials, and three is the finance. So, we replace that: MR2.1 = Labor ; MR2.2 = Equipment and materials; and MR2.3 = Finance.

Table 6.4. Comparison matrix of sub-MR of project resource

MR2	MR2.1	MR2.2	MR2.3	Weight
MR2.1	1	3	1/2	0.320
MR2.2	1/3	1	1/4	0.123
MR2.3	2	4	1	0.557
λmax=	3.018	RI=	0.58	
CI=	0.009	**CR=**	**0.016**	< **0.10**

Table 6.4 represents the comparison matrix and weight of sub-main risks of project resources. It illustrates that finance has 55.70% of the most important critical performance in construction project risks. Secondly, labor contents 32.00% of critical performance in project risks as the project resource. Finally, equipment and materials have 12.30% of played important performance in project risks.

- Sub-main risks of construction site:

The risks under construction site (MR3) have three important elements. One is the environment, two is the site condition, and three is the pandemic of Covid-19. So, we replace that: MR3.1 = Environment; MR3.2 = Site condition; and MR3.3 = Pandemic of Covid-19.

Table 6.5. Comparison matrix of sub-MR of construction site

MR3	MR3.1	MR3.2	MR3.3	Weight
MR3.1	1	1/3	1/5	0.110
MR3.2	3	1	1/2	0.309
MR3.3	5	2	1	0.581
λmax=	3.004	RI=	0.58	
CI=	0.002	**CR=**	**0.003**	< **0.10**

Table 6.5 represents the comparison matrix and weight of sub-main risks of the construction site. Among sub-MR of the construction site, the pandemic of Covid-19 is 58.10% of the most critical high-risk for CPs. This new pandemic disease is the fast harmful

economy in the whole world, especially in developing countries. However, the site condition has 30.90% of the critical risks in the construction. And the environment factor has 11.00% that affects the procedure of constructions.

- Sub-main risks of project feature:

The risks under project feature (MR4) have three important elements. One is the politics, two is the schedule, and three is the quality. So, we replace that: MR4.1 = Politics ; MR4.2 = Schedule; and MR4.3 = Quality.

Table 6.6. Comparison matrix of sub-MR of project feature

MR4	MR4.1	MR4.2	MR4.3	Weight
MR4.1	1	1/3	1/5	0.115
MR4.2	3	1	1	0.405
MR4.3	5	1	1	0.480
λmax=	3.029	RI=	0.58	
CI=	0.015	**CR=**	**0.025**	< **0.10**

Table 6.6 represents the comparison matrix of sub-main risks of the project feature. It indicates that the quality is 48.00% of the most critical risk importance working in sub-MR of project feature. The second critical risk is the schedule which has 40.50% of influence in CPs. So, the schedule is often delayed during doing construction. And the politics content 11.50% of project obstacles.

- Sub-main risks of project management:

The risks under project management (MR5) have five important elements. One is the poor organization due to project stakeholders, two is the poor management due to project resources, three is the unqualified project manager, four is the change in scope of work, and five is the poor communication and coordination of participants. So, we replace that:
MR5.1 = Poor organization due to project stakeholder; MR5.2 = Poor management due to project resource; MR5.3 = Unqualified project manager; MR5.4 = Change in scope of work; MR5.5 = Poor communication and coordination of participants.

Table 6.7. Comparison matrix of sub-MR of project management

MR5	MR5.1	MR5.2	MR5.3	MR5.4	MR5.5	Weight
MR5.1	1	1/2	1/7	1/4	1/5	0.051
MR5.2	2	1	1/4	1/2	1/3	0.095
MR5.3	7	4	1	2	2	0.402
MR5.4	4	2	1/2	1	1/2	0.182
MR5.5	5	3	1/2	2	1	0.271
λmax=	5.046	RI=	1.12	CI=	0.012	
				CR=	**0.010**	**< 0.10**

Table 6.7 represents the comparison matrix and weight of sub-main risks of project management. It indicates that the unqualified project manager contents 40.20% of important work in CPs. The poor communication and coordination of participants have 27.10% of critical risk management. The change in scope of work is 18.20%, the poor management due to project resource is 9.50%, and the poor organization due to project stakeholder content 5.10% of the critical risk management in CPs.

6.3. Determination of the risk alternatives

Risk alternatives are the necessary research objectives in our study. This method can make and enhance alternatives of the cost, time, and quality much clear and stronger. Here, we set the shortcut name of each risk alternative as C = cost, T = time, and Q = quality.

Table 6.8. Comparison matrix of risk alternative for client and owner (MR1.1)

MR1.1	C	T	Q	Weight
C	1	2	4	0.557
T	1/2	1	3	0.320
Q	1/4	1/3	1	0.123
λmax=	3.018	RI=	0.58	
CI=	0.009	**CR=**	**0.016**	**< 0.10**

Table 6.8 represents the comparison matrix and weight of risk alternatives for the client and owner. It indicates that cost is 55.70% that impacts on clients and owners in the risk management of CPs. However, time is 32.00%, and quality is 12.30% of bad influence on them in project risks.

Table 6.9. Comparison matrix of risk alternative for designer and architect (MR1.2)

MR1.2	C	T	Q	Weight
C	1	1/2	1/3	0.164
T	2	1	1/2	0.297
Q	3	2	1	0.539
λmax=	3.009	RI=	0.58	
CI=	0.005	**CR=**	**0.008**	< **0.10**

Table 6.9 represents the comparison matrix and weight of risk alternatives for the designer and architect. It indicates that quality is 53.90% that impacts on designers and architects in the risk management of CPs. However, time is 29.70%, and the cost is 16.40% of the bad influence on them in project risks.

Table 6.10. Comparison matrix of risk alternative for contractor, sub-contractor, and supplier (MR1.3)

MR1.3	C	T	Q	Weight
C	1	1/3	1/2	0.164
T	3	1	2	0.539
Q	2	1/2	1	0.297
λmax=	3.009	RI=	0.58	
CI=	0.005	**CR=**	**0.008**	< **0.10**

Table 6.10 represents the comparison matrix and weight of risk alternatives for the contractor, sub-contractor, and supplier. It indicates that time is 53.90% that impacts on contractor sectors in the risk management of CPs. However, quality is 29.70%, and the cost is 16.40% of the bad influence on them in project risks.

Table 6.11. Comparison matrix of risk alternative for labor (MR2.1)

MR2.1	C	T	Q	Weight
C	1	1/2	1/4	0.143
T	2	1	1/2	0.286
Q	4	2	1	0.571
λmax=	3.000	RI=	0.58	
CI=	0.000	**CR=**	**0.000**	< **0.10**

Table 6.11 represents the comparison matrix and weight of risk alternatives for the labor. It indicates that the quality is 57.10% that is impacted on laborers in the risk

management of CPs. However, time is 28.60%, and the cost is 14.30% of the bad influence on them in project risks.

Table 6.12. Comparison matrix of risk alternative for equipment and materials (MR2.2)

MR2.2	C	T	Q	Weight
C	1	4	2	0.557
T	1/4	1	1/3	0.123
Q	1/2	3	1	0.320
λmax=	3.018	RI=	0.58	
CI=	0.009	**CR=**	**0.016**	< **0.10**

Table 6.12 represents the comparison matrix and weight of risk alternatives for the equipment and material. It indicates that cost is 55.70% of the impact on equipment and materials in the risk management of CPs. However, quality is 32.00%, and time is 12.30% of the bad influence on them in project risks.

Table 6.13. Comparison matrix of risk alternative for finance (MR2.3)

MR2.3	C	T	Q	Weight
C	1	2	4	0.557
T	1/2	1	3	0.320
Q	1/4	1/3	1	0.123
λmax=	3.018	RI=	0.58	
CI=	0.009	**CR=**	**0.016**	< **0.10**

Table 6.13 represents the comparison matrix and weight of risk alternatives for the finance. It indicates that cost is 55.70% of the impact on budgets in the risk management of CPs. However, time is 32.00%, and quality is 12.30% of the bad influence on it in project risks.

Table 6.14. Comparison matrix of risk alternative for environment (MR3.1)

MR3.1	C	T	Q	Weight
C	1	1/2	3	0.320
T	2	1	4	0.557
Q	1/3	1/4	1	0.123
λmax=	3.018	RI=	0.58	
CI=	0.009	**CR=**	**0.016**	< **0.10**

Table 6.14 represents the comparison matrix and weight of risk alternatives for the environment. It indicates that the environment impacts 55.70% on time in the risk management of CPs. However, the cost is 32.00%, and quality is 12.30% of the bad influence on project risks.

Table 6.15. Comparison matrix of risk alternative for site condition (MR3.2)

MR3.2	C	T	Q	Weight
C	1	1/2	3	0.320
T	2	1	4	0.557
Q	1/3	1/4	1	0.123
λmax=	3.018	RI=	0.58	
CI=	0.009	**CR=**	**0.016**	< **0.10**

Table 6.15 represents the comparison matrix and weight of risk alternatives for the site condition. It indicates that time is 55.70% of the impact on site condition in the risk management of CPs. However, the cost is 32.00%, and quality is 12.30% of the bad influence on it in project risks.

Table 6.16. Comparison matrix of risk alternative for Pandemic of Covid-19 (MR3.3)

MR3.3	C	T	Q	Weight
C	1	1/2	3	0.309
T	2	1	5	0.581
Q	1/3	1/5	1	0.110
λmax=	3.004	RI=	0.58	
CI=	0.002	**CR=**	**0.003**	< **0.10**

Table 6.16 represents the comparison matrix and weight of risk alternatives for the pandemic of Covid-19. It indicates that Covid-19 impacts 58.10% on time in the risk management in CPs. However, the cost is 30.90%, and the quality is 11.00% of the bad influence on the project risk.

Table 6.17. Comparison matrix of risk alternative for politics (MR4.1)

MR4.1	C	T	Q	Weight
C	1	1	3	0.416
T	1	1	4	0.458
Q	1/3	1/4	1	0.126
λmax=	3.009	RI=	0.58	
CI=	0.005	**CR=**	**0.008**	< **0.10**

Table 6.17 represents the comparison matrix and weight of risk alternatives for politics. It indicates that politics is 41.60% of the cost impact on the risk management of CPs. However, time is 45.80%, and quality is 12.60% of the bad influence on it in project risks.

Table 6.18. Comparison matrix of risk alternative for schedule (MR4.2)

MR4.2	C	T	Q	Weight
C	1	1/2	3	0.320
T	2	1	4	0.557
Q	1/3	1/4	1	0.123
λmax=	3.018	RI=	0.58	
CI=	0.009	**CR=**	**0.016**	< **0.10**

Table 6.18 represents the comparison matrix and weight of risk alternatives for the schedule. It indicates that time is 55.70% of the impact on the risk management of CPs. However, the cost is 32.00%, and quality is 12.30% of the negative influence in project risks.

Table 6.19. Comparison matrix of risk alternative for quality (MR4.3)

MR4.3	C	T	Q	Weight
C	1	1/2	1/3	0.164
T	2	1	1/2	0.297
Q	3	2	1	0.539
λmax=	3.009	RI=	0.58	
CI=	0.005	**CR=**	**0.008**	< **0.10**

Table 6.19 represents the comparison matrix and weight of risk alternatives for the quality. It indicates that quality impacts 53.90% on risk management of CPs. However, the time is 29.70%, and quality is 16.40% of the negative influence in project risks.

Table 6.20. Comparison matrix of risk alternative for poor organization due to project stakeholder (MR5.1)

MR5.1	C	T	Q	Weight
C	1	1/3	1/2	0.164
T	3	1	2	0.539
Q	2	1/2	1	0.297
λmax=	3.009	RI=	0.58	
CI=	0.005	**CR=**	**0.008**	**< 0.10**

Table 6.20 represents the comparison matrix and weight of risk alternatives for the poor organization due to project stakeholders. It indicates that time is 53.90% that impacts on organization due to the project stakeholder in the risk management of CPs. However, quality is 29.70%, and the cost is 16.40% of the bad influence on them in project risks.

Table 6.21. Comparison matrix of alternative for poor managment due to project resource (MR5.2)

MR5.2	C	T	Q	Weight
C	1	4	2	0.571
T	1/4	1	1/2	0.143
Q	1/2	2	1	0.286
λmax=	3.000	RI=	0.58	
CI=	0.000	**CR=**	**0.000**	**< 0.10**

Table 6.21 represents the comparison matrix and weight of risk alternatives for the poor management due to the project resource. It indicates that cost impact is 57.10% that works in the management due to resources in the risk management of CPs. However, quality is 28.60%, and time is 14.30% of the negative influence in project risks.

Table 6.22. Comparison matrix of risk alternative for unqualified project manager (MR5.3)

MR5.3	C	T	Q	Weight
C	1	1/2	1/3	0.164
T	2	1	1/2	0.297
Q	3	2	1	0.539
λmax=	3.009	RI=	0.58	
CI=	0.005	**CR=**	**0.008**	**< 0.10**

Table 6.22 represents the comparison matrix and weight of risk alternatives for the unqualified project manager. It indicates that quality impact is 53.90% that works in project

managers in the risk management of CPs. Then, time is 29.70%, and the cost is 16.40% of the negative influence in project risks of project managers.

Table 6.23. Comparison matrix of risk alternative for change in scope of work (MR5.4)

MR5.4	C	T	Q	Weight
C	1	1/2	3	0.320
T	2	1	4	0.557
Q	1/3	1/4	1	0.123
λmax=	3.018	RI=	0.58	
CI=	0.009	**CR=**	**0.016**	< **0.10**

Table 6.23 represents the comparison matrix and weight of risk alternatives for the change in scope of work. It indicates that time is 55.70% that impacts on change in scope of work in the risk management of CPs. Nevertheless, the cost is 32.00%, and quality is 12.30% of the bad influence on it in project risks of project managers.

Table 6.24. Comparison matrix of risk alternative for poor communication and coordination of participants (MR5.5)

MR5.5	C	T	Q	Weight
C	1	1/4	1/2	0.143
T	4	1	2	0.571
Q	2	1/2	1	0.286
λmax=	3.000	RI=	0.58	
CI=	0.000	**CR=**	**0.000**	< **0.10**

Table 6.24 represents the comparison matrix and weight of risk alternatives for the poor communication and coordination of participants. It indicates that time is 57.10% that impacts communication coordination between participants in the risk management of CPs. However, quality is 28.60%, and the cost is 14.30% of the negative influence in project risks of project managers.

6.4. Weight results of risk evaluations in CPs

Table 6.25. Summary weight results of risk evaluations

MR	Weight of MR	Sub-MR	Weight of Sub-MR	Weight of alternatives			Weight of C	Weight of T	Weight of Q
				C	T	Q			
MR1	0.217	MR1.1	0.3202	0.5571	0.3202	0.1226	0.0386	0.0222	0.0085
		MR1.2	0.1226	0.1638	0.2973	0.5390	0.0043	0.0079	0.0143
		MR1.3	0.5571	0.1638	0.5390	0.2973	0.0198	0.0650	0.0359
MR2	0.282	MR2.1	0.3202	0.1429	0.2857	0.5714	0.0129	0.0258	0.0515
		MR2.2	0.1226	0.5571	0.1226	0.3202	0.0192	0.0042	0.0111
		MR2.3	0.5571	0.5571	0.3202	0.1226	0.0874	0.0503	0.0192
MR3	0.052	MR3.1	0.1096	0.3202	0.5571	0.1226	0.0018	0.0032	0.0007
		MR3.2	0.3092	0.3202	0.5571	0.1226	0.0052	0.0090	0.0020
		MR3.3	0.5813	0.3092	0.5813	0.1096	0.0094	0.0177	0.0033
MR4	0.104	MR4.1	0.1150	0.4160	0.4577	0.1263	0.0050	0.0055	0.0015
		MR4.2	0.4055	0.3202	0.5571	0.1226	0.0136	0.0236	0.0052
		MR4.3	0.4796	0.1638	0.2973	0.5390	0.0082	0.0149	0.0270
MR5	0.345	MR5.1	0.0506	0.1638	0.5390	0.2973	0.0029	0.0094	0.0052
		MR5.2	0.0949	0.5714	0.1429	0.2857	0.0187	0.0047	0.0094
		MR5.3	0.4022	0.1638	0.2973	0.5390	0.0227	0.0412	0.0748
		MR5.4	0.1816	0.3202	0.5571	0.1226	0.0201	0.0349	0.0077
		MR5.5	0.2707	0.1429	0.5714	0.2857	0.0133	0.0533	0.0267
Total							**0.3032**	**0.3929**	**0.3039**
Risk Alternatives							**3**	**1**	**2**

Along the way, we can determine the synthesis of AHP results to get the decision making. As a result, Table 6.25 represents the summary weight results of risk evaluations in CCPs. It indicates that the risk alternative of ‘Time’ is 39.29% that is the most critical risk impact in CPs. The second critical risk impact is the ‘Quality’ that contains 30.39% in risk management. Finally, ‘Cost’ is a 30.32% impact on risk management in CPs.

Table 6.26. The interaction between the sub-main criteria and risk alternatives

Main risks	Sub-main risks (RCs)	Risk impacts (percentage)			
		Cost	Time	Quality	Total
MR1	MR1.1	17.84	10.26	3.93	32.02
	MR1.1	2.01	3.64	6.61	12.26
	MR1.1	9.12	30.03	16.56	55.71
	Total	28.98	43.93	27.10	100
MR2	MR2.1	4.57	9.15	18.30	32.02
	MR2.2	6.83	1.50	3.93	12.26
	MR2.3	31.04	17.84	6.83	55.71
	Total	42.45	28.50	29.06	100
MR3	MR3.1	3.51	6.11	1.34	10.96
	MR3.2	9.90	17.22	3.79	30.92
	MR3.3	17.97	33.79	6.37	58.13
	Total	31.38	57.12	11.50	100
MR4	MR4.1	4.78	5.26	1.45	11.50
	MR4.2	12.99	22.59	4.97	40.55
	MR4.3	7.85	14.26	25.85	47.96
	Total	25.62	42.11	32.27	100
MR5	MR5.1	0.83	2.73	1.50	5.06
	MR5.2	5.42	1.36	2.71	9.49
	MR5.3	6.59	11.96	21.68	40.22
	MR5.4	5.81	10.12	2.23	18.16
	MR5.5	3.87	15.47	7.73	27.07
	Total	22.52	41.62	35.85	100

When we get the weight in Table 6.25, we can interact the sub-main criteria and main criteria conducting with alternatives. We multiply the weight of sub-MRs (Table 6.25, Column 4) and the weight of alternatives (Table 6.25, Column 5, 6, &7) in each cost, time, and quality respectively. Therefore, Table 6.26 represents the interaction between sub-main risks and risk alternatives. So, we can get the results of 17 risk categories associated with risk impacts on cost, time, and quality in quantitative approaches among 100%. In this table, we can also evaluate the important risk alternatives of the risk category.

Table 6.27. The interaction between main criteria and risk alternatives

Main risk factors	Risk impacts (percentage)			
	Time	Quality	Cost	Total
MR1	9.51	5.87	6.27	21.65
MR2	8.03	8.19	11.96	28.17
MR3	3.00	0.60	1.65	5.25
MR4	4.40	3.37	2.68	10.44
MR5	14.35	12.36	7.77	34.49
Alternatives	**39.29**	**30.39**	**30.32**	100

As we mentioned above, we can also get the quantitative approach for the main criteria and alternatives. However, to get this result, we can do the summation of each alternative (cost, time, and quality) in the last three columns in Table 6.25 of every main risk. Finally, we get the outcome of the interaction between the main criteria and risk alternatives as shown in Table 6.27. So, the result provides clarity for the risk management impacts on time, cost, and quality as the percentage.

6.5. Orientated priority ranks of risk impact on cost, time, and quality

After we have done the interaction between main risks and risk alternatives, the interaction between sub-main risks and risk alternatives, we determine the orientated priority rank for the risk model easily as indicating the two table below.

Table 6.28. Risk alternative classification per main risk and main risk classification per risk alternative

Main risk classification per Alternative					
Alternative/ MR	MR1	MR2	MR3	MR4	MR5
Cost	3	1	5	4	2
Time	2	3	5	4	1
Quality	3	2	5	4	1
Alternative classification per the Main risk					
Alternative/ MR	MR1	MR2	MR3	MR4	MR5
Cost	2	1	2	3	3
Time	1	3	1	1	1
Quality	3	2	3	2	2

The first part of Table 6.28 represents the main risk classification per risk alternative. It indicates that the first rank of cost risk is the resource (MR2). The first rank of time risk and quality risk is management (MR5). However, the second part of Table 6.28 illustrates the risk alternative classification per the main risk. We can see that the first rank of time risk is MR1 (stakeholder), MR3 (construction), MR4 (project feature), and MR5 (management). Therefore, the schedule is the most critical impact on the project risks.

Table 6.29. Risk alternative classification per sub-main risk and sub-main risk classification per risk alternative

Alternative classification per RC				RC classification per Alternative			
Sub-MR	C	T	Q	Sub-MR	C	T	Q
MR1.1	1	2	3	MR1.1	1	2	3
MR1.2	3	2	1	MR1.2	3	3	2
MR1.3	3	1	2	MR1.3	2	1	1
MR2.1	3	2	1	MR2.1	3	2	1
MR2.2	1	3	2	MR2.2	2	3	3
MR2.3	1	2	3	MR2.3	1	1	2
MR3.1	2	1	3	MR3.1	3	3	3
MR3.2	2	1	3	MR3.2	2	2	2
MR3.3	2	1	3	MR3.3	1	1	1
MR4.1	2	1	3	MR4.1	3	3	3
MR4.2	2	1	3	MR4.2	1	1	2
MR4.3	3	2	1	MR4.3	2	2	1
MR5.1	3	1	2	MR5.1	5	4	5
MR5.2	1	3	2	MR5.2	3	5	3
MR5.3	3	2	1	MR5.3	1	2	1
MR5.4	2	1	3	MR5.4	2	3	4
MR5.5	3	1	2	MR5.5	4	1	2

Table 6.29 represents two necessary parts of priority ranks between risk alternatives and sub-main criteria (risk categories). This table could show all the detailed priority rank information of risk categories among the cost, time, and quality impact on the project risk. Part one is the risk alternative classification per sub-main risk. For example, the most critical risk impact of MR1.1 is the project budget, schedule, and quality sequentially. However, for MR1.2, the most key risk impact is the project quality related to project safety. Moreover, part two is the sub-main risk classification per risk alternative. For example, the most critical risk of time impact is MR1.3 (contractor), MR1.1 (owner), MR1.2 (designer) respectively.

7. CONCLUSIONS AND SUGGESTIONS

Risk management is most popular for taking attention in construction projects. Wherever CPs have, risks always appear. This research purpose is to evaluate the risk management impacts on cost, time, and quality in construction projects. It provides the gab filling of the literature reviews. And its complete exact problems happened in the project experiences in Cambodia. It could believe that this is the new research in this area.

Significant risks recognize the literature, and it verifies by the pilot study to specific the risk events that happened in that region. The pilot study conducts the survey technique and semi-structured interviews Online. In order to control and evaluate the risk events, the risk model is prepared in one structure as the main risk, risk category, risk factor, and alternative. Moreover, the Delphi method is used for identifying risks to collect data. The 5-point Likert scales determine to evaluate risks in questionnaires. Survey questionnaires forward to civil engineers via Google Forms. Finally, risk analysis and assessments are done by the description of statistical analysis, t-test analysis, and reliability technique undertaken by the SPSS program. AHP method is also applied to make strong evaluations and complete research objectives.

Consequently, the survey result claims that the biggest respondent involved in the CPs come from the contractor sectors among stakeholders. Most respondents' knowledge about risk management is at a medium level. It also expresses that the project manager has a high role in preparing the risk strategies in CPs. Moreover, 95 percent of respondents clarify that risk management is an important role in the successful completion of the project. Unfortunately, more than 90% of respondents complain that their projects struggle with delay, quality issues, and cost overrun. That's why time, quality, and cost should take attention as much as possible before and during the construction.

The most critical rank of risk factors and risk categories detail in the previous chapter. In summary, the most critical risk factors happened in CPs are the unqualified project manager, financial issue, lack of skills and work organization by the construction sector, poor communication and coordination of participants, mistakes during processing work by contractors, selecting low bid of the contractor by clients or owners. However, the most critical problems of RCs assessment analysis are the project manager, communication and coordination of participants, contractor parties, change in scope of work, finance, the pandemic of Covid-19, labor, and quality respectively.

Briefly, the problems of risk assessment analysis are caused by the puzzle of the management, resource, stakeholder, project feature, and construction site respectively. The biggest problem of risk factors, risk categories, and main risks in this research is unacceptable and it's in a serious situation in construction projects. There need to avoid and eliminate them by doing the high-activities, creating the risk treatment options, making detailed risk action plans as described in the previous chapter. The laws and regulations must follow strictly. Especially, skills and knowledge of risk management must improve effectively.

Among the risk alternatives of the three components (Cost, Time, and Quality), the project schedule is the most critical issue that happened in construction projects. And then, the quality issue needs to concentrate on both people's health and project quality. In order to solve these risky projects, the project budget forces us to spend much as well.

In deep critical thinking, the unqualified project manager who could not manage the CPs well should improve and increase the knowledge level of both theory and practices. However, one behind this reason is that most CEO and director of the company would prefer to hire lower-payment for project managers with multi-skills. The other reason is the project manager would not have enough work teams to support the projects. Hence, when the management does not organize well, the construction project will not be easy to do and control. Some large projects have been required a technical foreigner like a fully skilled project manager to control the CP.

At the end of this outcome, participants need to be careful and comprehend risk management as much as possible. It can make the right decision for project objectives without any struggle. Project stakeholders could have more options to gain knowledge of risk management to solve the problems. It spends a little cost and time, but it can make better comfortable and acceptable standard for people and the environment. It is a better way to make it more attractive for foreign direct investment in that region either.

This study would alert future researchers to develop more specific projects. For the following research, risk management analysis would consider an exact project (the real project with practices). Risk management should base on the concept phase, design phase, tender, construction phase, and financial investment. Besides, studying risk management would divide the determination of time, cost, or quality impact separately in order to compare the estimated project and exact project.

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APPENDIX

Appendix-A. Most risk factors in the study

Table A.1. Most risk factors in the study

No	RCs	Risk factors (RFs)	References
1	Clients/Owners	Tight project on schedule, cost, and quality	(Zou et al., 2007); (Zou & Zhang, 2014); (Durdyev, Mohamed, et al., 2017)
2		Selecting low bid of contractor	By pilot study
3		Leak of support team	By pilot study
4	Designers/ Architects	Inaccurate costs estimate and schedule programing	(Zou et al., 2007); (Zou & Zhang, 2014); (Durdyev, Omarov, Ismail, et al., 2017)
5		Lack of support team and experience	(Dey, 2002); (El-Karim et al., 2019)
6		Various design (e.g., design change, poor site information, material specification)	(Kaming et al., 1997); (Dey, 2002); (Zou et al., 2007); (Chileshe, 2012); (Altoryman, 2014); (Zou & Zhang, 2014); (Srinivasan & Rangaraj, 2020)
7	Contractor parties	Lack of skills/ work organization	(Dey, 2002); (El-Karim et al., 2019)
8		Mistakes during performing work	(Ally, 2013); (Durdyev, Omarov, Ismail, et al., 2017)
9		Rework or defective work	(Durdyev, Omarov, & Ismail, 2017); (Durdyev, Omarov, Ismail, et al., 2017)
10	Labors	Inadequate labors/ labor performances	(Zou & Zhang, 2014); (Durdyev, Omarov, & Ismail, 2017); (Akinbile et al., 2018); (El-Karim et al., 2019)

Table A.1. Most critical risk factors in the study (continued)

No	RCs	Risk factors (RFs)	References
11	Labors	Lack of skilled labors	(Zou et al., 2007); (Durdyev, Mohamed, et al., 2017); (Durdyev, Omarov, & Ismail, 2017); (Durdyev, Omarov, Ismail, et al., 2017); (Durdyev & Mbachu, 2018); (El-Karim et al., 2019)
12	Equipment/ Materials	Inadequate equipment/ equipment issues	(Dey, 2002); (Karim et al., 2012); (Durdyev, Mohamed, et al., 2017); (Szymański, 2017); (Akinbile et al., 2018); (El-Karim et al., 2019); (Srinivasan & Rangaraj, 2020)
13		Material shortages and material damage	(Dey, 2002); (Chileshe, 2012); (Karim et al., 2012); (Onengiyeofori, 2016); (Durdyev, Omarov, & Ismail, 2017); (Durdyev, Omarov, Ismail, et al., 2017); (Durdyev & Mbachu, 2018); (El-Karim et al., 2019); (Srinivasan & Rangaraj, 2020)
14		Late delivery of materials	(Karim et al., 2012); (Altoryman, 2014); (Durdyev, Omarov, & Ismail, 2017)
15	Finances/ Budgets	Financial failure/ lack of financial resource	(Chileshe, 2012); (Karim et al., 2012); (Durdyev et al., 2020)
16		Late payment by client	By pilot study
17		Cash flow problem by contractor	By pilot study
18		Inaccuracy of cost estimation	(Zou et al., 2007); (Zou & Zhang, 2014)
19	Environments	Weather problem (flood, rainy seasons)	(Akintoye & Macleod, 1997); (Kaming et al., 1997); (Ehsan et al., 2011); (Ally, 2013); (Durdyev, Omarov, Ismail, et al., 2017); (Akinbile et al., 2018); (El-Karim et al., 2019)

Table A.1. Most critical risk factors in the study (continued)

No	RCs	Risk factors (RFs)	References
20	Environments	Environmental issues of construction program (e.g., pollution, ecological damage, noise)	(Zou et al., 2007); (Karim et al., 2012); (Ally, 2013); (Zou & Zhang, 2014); (Pialles, 2017); (El-Karim et al., 2019)
21	Site conditions	Problem of site's topography and geo-technical investigation	(Ehsan et al., 2011); (Ally, 2013); (Akinbile et al., 2018); (El-Karim et al., 2019)
22		Safety and Health problems	(Karim et al., 2012); (Zou & Zhang, 2014); (Durdyev, Mohamed, et al., 2017); (Pialles, 2017)
23	Pandemic of Covid-19		By pilot study
24	Politics	Bribery and corruption	(Akintoye & Macleod, 1997); (Zou et al., 2007); (Karim et al., 2012); (Zou & Zhang, 2014); (Szymański, 2017); (El-Karim et al., 2019)
25	Schedule	Delay schedule due to project size or complexity project	(Durdyev, Omarov, & Ismail, 2017)
26		Missing update schedule based real work at site	By pilot study
27		Insufficient schedule to see all major items	By pilot study
28	Quality	Misunderstanding or unclear of quality control plan	By pilot study
29		Unclear specification and standard	By pilot study
30	Poor organization due to project stakeholder		(Cooper et al., 2005); (Kendrick & PMP, 2015)

Table A.1. Most critical risk factors in the study (continued)

No	RCs	Risk factors (RFs)	References
31	Poor management due project resource		(Kendrick & PMP, 2015); (Szymański, 2017)
32	Unqualified project manager		(Zou & Zhang, 2014); (Kendrick & PMP, 2015)
33	Change in scope of work		(Ehsan et al., 2011); (Karim et al., 2012); (Szymański, 2017); (Akinbile et al., 2018)
34	Poor communication and coordination of participants		(Chileshe, 2012); (Altoryman, 2014); (Piyadasa, WM Sarath C Hadikusumo, 2014); (Zou & Zhang, 2014); (Kendrick & PMP, 2015); (Durdyev, Omarov, & Ismail, 2017); (Durdyev, Omarov, Ismail, et al., 2017); (Durdyev & Mbachu, 2018)

Appendix-B. Cronbach Alpha results (Reliability)

Table B.1. Cronbach Alpha results from SPSS

Risk Categories		Likelihoods	Impacts	Items
Risk Factors		**0.960**	**0.944**	**34**
Client/ Owner		0.686	0.665	3
Designer/ Architect		0.759	0.719	3
Contractor/Sub-contractor/ Supplier		0.752	0.709	3
Labour		0.840	0.809	2
Equipment/ material		0.787	0.805	3
Finance		0.816	0.748	4
Environment		0.715	0.587	2
Site condition		0.534	0.434	2
Pandemic of Covid-19		-	-	1
Politics		-	-	1
Schedule		0.790	0.789	3
Quality		0.560	0.532	2
Managements		0.831	0.864	5
Main risks		Likelihoods	Impacts	Items
Risk Factors		**0.960**	**0.944**	**34**
Project stakeholder		0.863	0.851	9
Project resource		0.907	0.902	9
Construction site		0.786	0.670	5
Project feature		0.823	0.775	6
Project management		0.831	0.864	5
Main risks	Cost impacts	Time impacts	Quality impacts	Items
Risk Categories	**0.898**	**0.912**	**0.917**	**17**
Project stakeholder	0.583	0.650	0.531	3
Project resource	0.602	0.673	0.680	3
Construction site	0.459	0.589	0.728	3
Project feature	0.511	0.520	0.598	3
Project management	0.809	0.861	0.855	5

Appendix-C. Detailed T-test analysis

Table C.1. Detailed T-test analysis from SPSS

Group Statistics					
Group		N	Mean	Std. Deviation	Std. Error Mean
RC impact Mean	1	17	0.32456049	0.04066012	0.00986153
	2	17	0.31780441	0.04692790	0.01138169

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
RC impact Mean	Equal variances assumed	0.376	0.544	0.449	32.000	0.657	0.007	0.015	-0.024	0.037
	Equal variances not assumed	-	-	0.449	31.364	0.657	0.007	0.015	-0.024	0.037

Appendix-D. Risk treatment options of response scenarios and detailed action plans

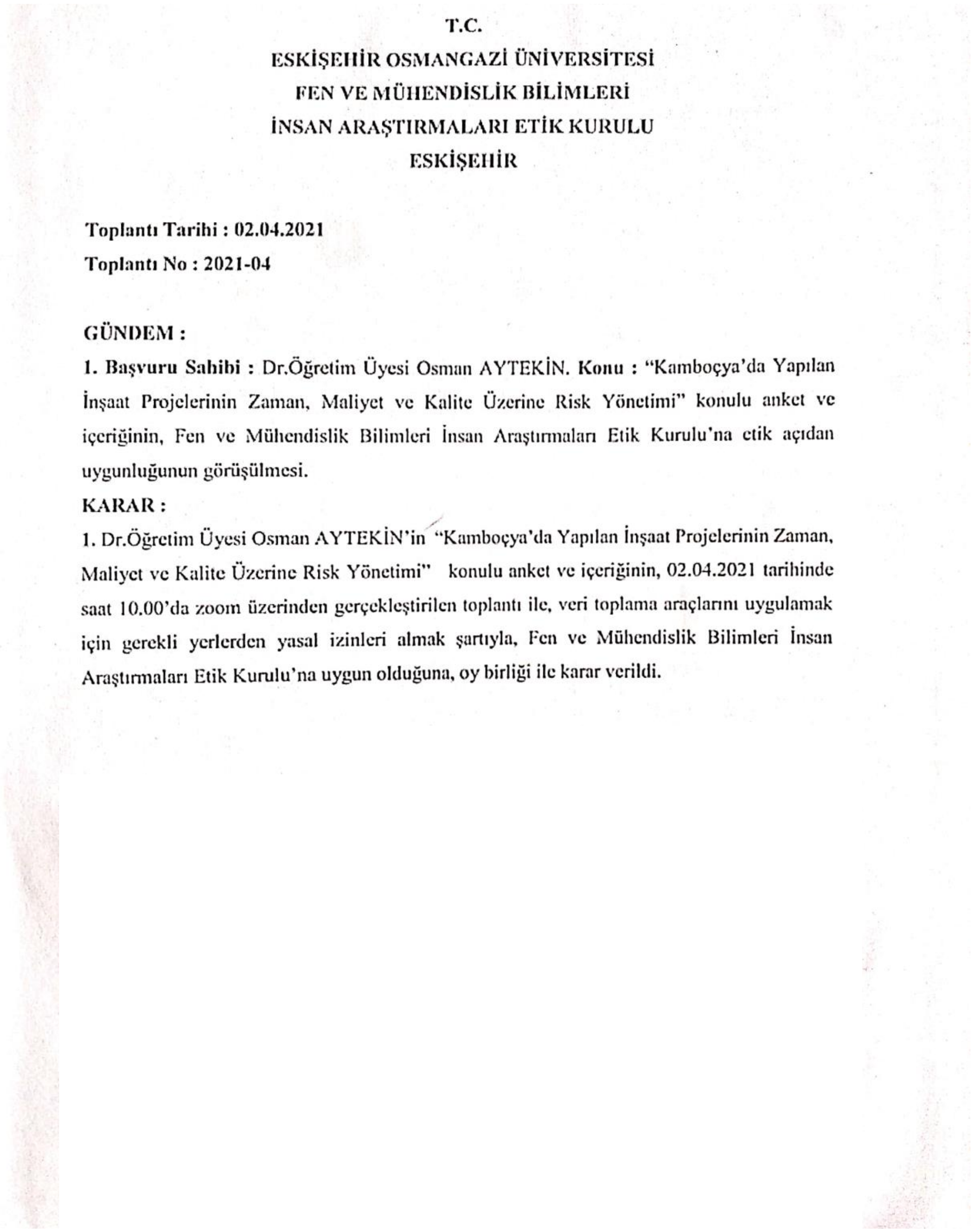
Table D.1. Risk treatment options worksheet (Cooper et al., 2005)

<table>
<tr><td>Element:</td><td colspan="2">Risk:</td><td>Action Sheet:
Risk Register number:</td></tr>
<tr><td>Likelihood:</td><td>Impact:</td><td>Agreed risk level:</td><td>Inherent risk level:</td></tr>
<tr><td colspan="4">Risk description (causes, consequences, implications):</td></tr>
<tr><td colspan="4">Current controls and plans:</td></tr>
<tr><td colspan="4">Possible additional actions:</td></tr>
<tr><td colspan="2">Response</td><td>Effectiveness</td><td>Cost</td></tr>
<tr><td colspan="2"></td><td></td><td></td></tr>
<tr><td colspan="4">Comments and recommendations:</td></tr>
<tr><td colspan="4">Sources of information and list of attachments:</td></tr>
<tr><td>Compiler:</td><td>Date:</td><td>Reviewer:</td><td>Date:</td></tr>
</table>

Table D.2. Detailed risk action plans (Cooper et al., 2005)

Element:	Risk:		Action Sheet: Risk Register number:
Likelihood:	Impact:	Agreed risk level:	Inherent risk level:
Risk description (causes, consequences, implications):			
Current controls and plans:			
Possible additional actions:			
Responsibility:			
Resources required:			
Timing (key milestones, closure):			
Reporting (to whom, when, in what form):			
References (to other documents or plans as appropriate):			
Compiled by:	Date:	Reviewed by:	Date:

Appendix-E. Eskişehir Osmangazi University Science and Engineering Sciences Scientific Research and Publication Ethics Board Decision



T.C.
ESKİŞEHİR OSMANGAZİ ÜNİVERSİTESİ
FEN VE MÜHENDİSLİK BİLİMLERİ
İNSAN ARAŞTIRMALARI ETİK KURULU
ESKİŞEHİR

Toplantı Tarihi : 02.04.2021
Toplantı No : 2021-04

GÜNDEM :

1. Başvuru Sahibi : Dr.Öğretim Üyesi Osman AYTEKİN. **Konu :** "Kamboçya'da Yapılan İnşaat Projelerinin Zaman, Maliyet ve Kalite Üzerine Risk Yönetimi" konulu anket ve içeriğinin, Fen ve Mühendislik Bilimleri İnsan Araştırmaları Etik Kurulu'na etik açıdan uygunluğunun görüşülmesi.

KARAR :

1. Dr.Öğretim Üyesi Osman AYTEKİN'in "Kamboçya'da Yapılan İnşaat Projelerinin Zaman, Maliyet ve Kalite Üzerine Risk Yönetimi" konulu anket ve içeriğinin, 02.04.2021 tarihinde saat 10.00'da zoom üzerinden gerçekleştirilen toplantı ile, veri toplama araçlarını uygulamak için gerekli yerlerden yasal izinleri almak şartıyla, Fen ve Mühendislik Bilimleri İnsan Araştırmaları Etik Kurulu'na uygun olduğuna, oy birliği ile karar verildi.

Appendix-F. Survey questionaries

(El-Karim et al., 2019; Onengiyeofori, 2016; UDAN, 2019)

"Risk management on time, cost and quality of Construction Project in Cambodia"

Dear all, highest respect from author

Firstly, I would like to say big thank to all of you for spending time on this survey. And please try to response all questions below carefully due to your answer will affect to outcome of the research. *Please be assured the response will be kept with the highest confidentiality. Your responses will be protected by author.*

Section 1. General information

Q1) What kind of project stakeholder do you do in your currently company's work?

a) Contractor b) Client c) Consultant/Architect

d) Sub-contractor e) other…...

Q2) How many years' experience have you worked (years)?

a) Less than 1 b) From 1 to 5 c) From 6 to 10

d) From 11 to 15 e) More than 15

Q3) What is your position in your currently work?

a) General/Site manager b) Project manager c) Designer/ Architect

d) Site engineer e) Quantity surveyor f) Other……

Section 2. Knowledge of risk management

Q1) Have you ever joined workshop or seminar or training on risk management of construction projects?

a) Yes b) No

Q2) What is your knowledge level of risk management?

a) Very low b) Low c) Moderate

d) High e) Very high

Q3) Who prepares risks strategy to avoid the risk in your construction project?

a) Construction manager b) Project manager c) Supervisor

d) Designer e) Specialized risk management team f) Other……

Q4) Do you think risk management plays an important role in successful completion of a construction project?

a) Strongly disagree b) Disagree c) Neither agree nor disagree

d) Agree e) Strongly agree

Q5) Did any of your projects meet the time delay, cost overrun or quality problem?

a) Yes b) No c) if No, please specify……

Section 3a. Risk categories (RC) impact on cost, time and quality

Please rate the risk factors occurring and impact in construction projects.

Scale for risk factors impacts on cost, time and quality **(1= Very Low, 2=Low, 3=Moderate, 4=High, 5=Very High)**

Risk sub-criteria	Impact														
	Cost					Time					Quality				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Client															
Designer/ Architect															
Contractor/Sub-contractor/ Supplier															
Labor															
Equipment/ materials															
Finance															
Environment															
Site condition															
Pandemic of Covid-19															
Politic															
Schedule															
Quality															
Unqualified project manager															
Change in scope of work															
Poor communication and coordination of participants															

Section 3b. Significant risk factors and their impacts in construction projects

Scale for risk factors occurrence and impacts: (1= Very Low, 2=Low, 3=Moderate, 4=High, 5=Very High)

Risk categories	Risk factors	Risk occurrences					Risk impacts				
Client/ Owner	Tight project on schedule, cost, and quality	1	2	3	4	5	1	2	3	4	5
	Selecting low bid of contractor										
	Leak of support team										
Designer/ Architect	Inaccurate costs estimate and schedule programing										
	Lack of support team and experience										
	Various design (design change, poor site information, material specification)										
Contractor/ Sub-contractor/ Supplier	Lack of skills and work organization										
	Mistakes during processing work										
	Rework or defective work										
Labor	Inadequate labor/ labor performance										
	Lack of skilled labor										
Equipment/ materials	Inadequate equipment/ equipment issues										
	Material shortages/ material damage										
	Late delivery of materials										
Finance/ Budget	Financial failure/ lack of financial resource										
	Late payment by client										
	Cash flow problem by contractor										

Section 3b. Significant risk factors and their impacts in construction projects (continued)

Risk categories	Risk factors	Risk occurrences					Risk impacts				
	Inaccuracy of cost estimation										
Environment	Weather problem (flood, rainy seasons)										
	Issues of construction program (pollution, ecological damage, noise)										
Site condition	Problem of site's topography and geo-technical investigation										
	Safe and health problems										
Pandemic of Covid-19*							-	-	-	-	-
Politics: Bribery and corruption*							-	-	-	-	-
Schedule	Delay schedule due to project size or complexity project										
	Missing update schedule based real work at site										
	Insufficient schedule to see all major items										
Quality	Misunderstanding/ unclear of quality control plan										
	Unclear specification and standard										
Unqualified project manager*							-	-	-	-	-
Change in scope of work*							-	-	-	-	-
Poor communication/ coordination of participants*							-	-	-	-	-

- Note "*" is no need to fill the risk impact due to it has in the **section 3a**.