INVESTIGATION OF CRITICAL SUCCESS FACTORS (CSFs) FOR THE DEPLOYMENT OF CONSTRUCTION RISK MANAGEMENT PRACTICES IN SRI LANKA

BY

Atham Lebbe Mohamed Risath

Supervised by

Dr. Chandana Sriwardana

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Department of Civil Engineering

University of Moratuwa

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I hope that the findings of this research will be beneficial to Construction Project Management discipline and it will deliver insights for further examination in and around the topic.

DECLARATION

I certify that this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any university to the best of my knowledge and believe it does not contain any material previously published, written or orally communicated by another person or myself except where due reference is made in the text. I also hereby give consent for my dissertation, if accepted, to be made available for photocopying and for inter library loans, and for the title and summary to be available to outside organizations.

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ABBREVIATIONS

IRMS	: Implementation of Risk Management Systems
RMS	: Risk Management Systems
CSF	: Critical Succes Factor
AHP	: Analytical Hierarchy Process
PMI	: Project Management Institute
PMBOK	: Project Management Body of Knowledge

ABSTRACT

Risk is an uncertain occurrence that, if befalls, has direct and indirect effects on project objectives. In particular, construction projects in developing countries are likely to face wide range of uncertainties. Risk management is a positive approach to control the level of risk. The evidence available for the effective implementation of risk management practices in developing countries is very little. The existing studies on risk management in developing countries have generally concentrated on identifying and evaluating risks rather than applying risk management systems. This research was aimed to answer the question "how the risk management practices could be promoted and enhanced in Sri Lankan construction industry?" The study applied Delphi technique and the study was conducted in three different rounds. The Delphi panel was comprised of fifteen construction industry experts with vast experience and knowledge to make judgments on risk management systems. The findings of the study reasonably disclose that the construction professionals in Sri Lanka are not conscious enough of the available sophisticated techniques for construction risk management. It is also established that the cost incurred for implementing risk management systems, poor awareness of risk management systems among construction professionals, and unavailability of risk management consultants or experts in the country are the major barriers for implementing risk management systems. The study further explored that 'Including the costs within project's budgets for IRMS' and 'Request for Implementation of Risk Management Systems (IRMS) on projects by clients and end users' are considered as exceedingly imperative Critical Success Factors (CSFs). In the meantime 'Attempting to deliver projects systematically on time and within project's budget', 'Inclusion of risk management systems in engineering education and training modules of construction practitioners', and 'Awareness of risk management systems among stakeholders' are regarded as important CSFs for IRMS. The study also revealed that a substantial alignment is not found between the current findings of the research and the previous findings of similar studies in developing world with regard to CSFs.

Key Words: Risk, Construction, Critical Success Factor, Risk Management Systems, IRMS

CHAPTER 1

INTRODUCTION

Risk management in construction projects is generally a less prioritized area in developing countries. Sri Lankan construction industry is not an exemption from this topic. The construction projects in Sri Lanka can be delivered with better success in terms of enhanced project objectives if proper risk management practices are engaged. Therefore, this research makes a contribution by providing insights on the currents status of risk management practices and proposing ways as to how risk management systems could be effectively implemented in Sri Lankan construction projects. This chapter outlines the full work carried out for this study.

1.1 Background

Project management is the methodical application of skills, tools and techniques to carry out project tasks to meet the expectations of the clients or project stakeholders (Deviprasadh, 2007). A typical project is always subject to modifications, a new invention, work or structure. The change brought by the project involves uncertainty, which cause projects to have a possibility of getting affected by a possible future event. Risks and uncertainties always exist in every part of the project (Odeyinka, 2001). According the way it is defined by Hillson (2004), risk is a computable uncertainty whereas uncertainty is an incomputable risk.

Risk management is a very comprehensive and methodical way of identifying, analyzing, and responding to risks in order to successfully accomplish the project objectives (Banaitiene & Banaitis, 2012). Risk management is an idea which turns into very important element across a number of businesses. Many companies often establish a risk management procedure in their projects for improving the performance and increase the earnings. Projects carried out in the construction sector are widely

multifaceted and have often significant budgets, and thus reducing risks linked should be a main concern for each project manager (Gajewska & Ropel, 2011).

In the light of construction industry, risk is the probability of the occurrence of a definite event or combination of events which occur during the whole process of construction. Construction comprises many variables, and it is often problematic to find root and effect, dependence and correlation. Hence, those risks play a major role in decision making and may affect the whole performance of a project (Wiguna & Scott, 2005).

According to the Project Management Institute (PMI, 2013), project risk management is one of the ten most pivotal parts of project commissioning. Project risk management includes the processes of conducting risk management planning, identification, analysis, response planning, and monitoring and control on a project. The objectives of project risk management are to upsurge the probability and impact of positive events, and drop the probability and impact of negative events in the project (PMI, 2008).

The construction industry is considered as a risky business due to its complexity and tactical nature. It incurs a numerous project stakeholders, internal and external factors which will lead to enormous risks (Renuka, et al., 2014). Regrettably, the construction industry has a poor status in risk analysis when compared to other industries (Lazzerini & Mkrtchyan, 2011).

According to the study carried out by Bowers and Khorakian (2014), the evidence available for the effective implementation of risk management system in developing countries is little. The existing studies on risk management in developing countries have mostly focused on identifying and evaluating risks rather than applying risk management systems.

Many issues faced by construction industry are avoidable through the execution of effective risk management in projects (Tadayon, Jaafar, & Nasri, 2012). To evaluate the success of these systems, the first step is to identify the Critical Success Factors

(CSFs) for Implementation of Risk Management Systems in developing countries (Hosseini, Chileshe, Jepson, & Arashpour, 2016).

The existing literature on risk management in developing countries shows that CSFs for implementing risk management is an area where researches are lacking. Against this background, investigating of the CSFs for implementation of risk management system in construction projects, their interactions and subsequent impact on project success is an overlooked area of study in almost all developing countries (Perera, Rameezdeen, Chileshe, & Hosseini, 2014).

In essence, exploring the perceptions of construction practitioners with regard to prerequisites of implementing risk management systems in developing countries has become an area in need of investigation (Iqbal, Choudhry, Holschemacher, & Tamosaitiene, 2015).

A review of published studies on risk management in developing countries discloses that CSFs for implementing risk management has remained an under-researched area of investigation (Hosseini, Chileshe, Jepson, & Arashpour, 2016).

Though there are few studies in the literature on critical success factors linked to risk management in developing countries, it has exclusively focused on one particular country. Thus further studies should be conducted on CSFs for the effective implementation of risk management in other developing countries to generalize the findings of previous studies.

In this regard, Sri Lankan construction industry, which has significantly boomed, is also of poor status in terms of implementing risk management systems in construction projects. Though the construction industry is a key supplier to the development of economies in Sri Lanka, it faces considerable challenges and problems which are exclusive to the specific industry (Rajakaruna, Bandara, & De Silva, 2005).

In the meantime, the available body of knowledge with regard to risk management systems in Sri Lanka has mainly focused only on exploring risk factors, the probability of risk occurrence and determining the shares of the parties involved in

projects to handle the identified risks. Only very fewer researches in Sri Lanka attempted to focus on the implementation matters associated with risk management practices in construction projects. In this background, this research is a significant addition to its kind.

1.2 Aim

This research is aimed to answer the question "how the risk management practices could be utilized and enhanced in Sri Lankan construction industry?"

1.3 Objectives

In order to achieve the aim of the research, the following objectives were established.

1. To study what risk management techniques are actually used at the project level or organization level.

2. To identify the barriers to the adoption, usage, and implementation of risk management systems in Sri Lankan construction projects.

3. To develop the Critical Success Factors (CSFs) for implementing risk management systems in Sri Lankan construction projects.

1.4 Scope and Limitation

Though this research attempted to set sights on effective implementation of risk management systems in construction projects, the research is only based on Sri Lankan construction projects. The conclusions and findings of the research were derived based on the feedbacks provided by the industry professionals comprising Senior Project Managers and Senior Engineers in three different rounds.

1.5 Structure of the report

The report is organized in the following order.

Chapter One Chapter one covers the background of the study, aim and objectives, scope and limitation of the research, and the structure of the report.

Chapter Two Chapter two is a review of the relevant literature of the study area. It covers the existing knowledge on the set objectives of the research. The literature review delivers the background for identification of the research gap and the preparation of the research questions.

Chapter Three Chapter three elaborates the research methodology and statistical analysis techniques used for the study.

Chapter Four Chapter four presents the details of data collected in each round of questionnaire survey and the statistical analysis explanation of the data.

Chapter Five Chapter five presents the conclusions and recommendations of the research.

1.6 Deliverables

- The findings and recommendations of the study will fill some gap existing in Risk Management Body of Knowledge in Sri Lanka and also it will be helpful to apply or compare the same Body of Knowledge in other developing nations such as Sri Lanka.

- To which extent the risk management techniques are currently used in Sri Lanka was known and recorded. It will be more beneficial to the industry to realize the current condition of risk management practices and take further measures to enhance it.

- The barriers to implement risk management systems and Critical Success Factors (CSFs) for effectively implementing risk management systems in Sri Lankan construction projects were explored and these findings will be more advantageous for the industry to take necessary measures and actions to successfully implement risk management systems.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Risk Management

Risk management is an idea which turns into very important element across a number of businesses. Many companies often establish a risk management procedure in their projects for improving the performance and increase the earnings. Projects carried out in the construction sector are widely multifaceted and have often significant budgets, and thus reducing risks linked should be a main anxiety for each project manager (Gajewska & Ropel, 2011). According to the Project Management Institute (PMI, 2013), project risk management is one of the ten most pivotal parts of project commissioning. Project risk management includes the processes of conducting risk management planning, identification, analysis, response planning, and monitoring and control on a project. The objectives of project risk management are to increase the probability and impact of positive events, and decrease the probability and impact of negative events in the project (PMI, 2008). The construction industry is often considered as a risky business due to its complexity and tactical nature. It incurs a numerous project stakeholders, internal and external factors which will lead to enormous risks (Renuka, et al., 2014). Regrettably, the construction industry has a poor status in risk analysis when compared to other industries (Lazzerini & Mkrtchyan, 2011).

Project risk has its origins in the uncertainty present in all projects. Known risks are those that have been identified and analyzed, making it possible to plan responses for those risks. Known risks that cannot be managed proactively, should be assigned a contingency reserve. Unknown risks cannot be managed proactively and therefore may be assigned a management reserve. A negative project risk that has occurred is considered an issue (PMI, 2013).

Individual project risks are dissimilar from overall project risk. Overall project risk represents the effect of uncertainty on the project as a whole. It is more than the sum

of the individual risks within a project, since it includes all sources of project uncertainty. It represents the exposure of stakeholders to the implications of variations in project outcome, both positive and negative. Organizations recognize risk as the effect of uncertainty on projects and organizational objectives. Organizations and stakeholders are willing to accept varying degrees of risk depending on their risk attitude. The risk attitudes of both the organization and the stakeholders may be influenced by a number of factors, which are broadly classified into three themes:

- Risk appetite, which is the degree of uncertainty which an entity is willing to take on in anticipation of a reward.
- Risk tolerance, which is the degree, amount, or volume of risk that an organization or individual will withstand.
- Risk threshold, which refers to measures along the level of uncertainty or the level of impact at which a stakeholder may have a specific interest. Below that risk threshold, the organization will accept the risk. Above that risk threshold, the organization will not tolerate the risk (PMI, 2013).

In the light of construction industry, it is the probability of the occurrence of a definite event or combination of events which occur during the whole process of construction. Construction includes many variables, and it is often difficult to find root and effect, dependence and correlation. Hence, those risks play a major role in decision making and may affect the performance of a project (Wiguna & Scott, 2005).

2.2 Risk Definition

A literature review was done to find out various definitions provided by different scholars about risk. Table 1 shows some of the major definitions provided by the scholars on risk.

Table 1: Definitions to risk

Author	Risk
Winch, 2002	*"A stage where there is a lack of information, but by looking at past experience, it is easier to predict the future. Events where the outcome is known and expected".*
Cleden, 2009	*"Risk is the statement of what may arise from that lack of knowledge. Risks are gaps in knowledge which we think constitute a threat to the project".*
PMI, 2013	*"Risk is an uncertain event or condition that, if it occurs, has an effect on at least one project objectives. Objectives can include scope, schedule, cost, and quality".*

The summary of above definitions concludes that risk is a situation where lack of something which can cause adverse effect to the project. Lacking in obtaining relevant information and inadequate knowledge are the main reasons for project failure as mentioned by many researchers in this study area. According to the definition mentioned by Cleden (2009) in Table 1, risk is defined as a gap in knowledge which causes adverse effects to the project, if it is not properly predicted and handled.

2.3 Project Risk Management

Risk management is a positive approach to control the level of risk and to diminish its effects. Effective management of project risks provides the project manager better mechanism over the future events and can meaningfully improve likelihoods of reaching project objectives on time, within budget, and meeting required technical/functional performance (Gray & Larson, 2008). Risk management has been one of the major concerns of executives and professionals involved with projects today, particularly after the financial crisis that vibrated the world in 2008. The outcomes of ex-post assessments of project or even confirmation of loss business opportunities for companies are clear signals that this evidence has turned

out to be more strong (Junior & Carvalho, 2013). The risk management is described as “systematic way of looking at areas of risk and willfully determining how each risk should be treated. It is a management tool that targets at identifying sources of risk and uncertainty, determining their impact, and developing apposite management reactions” (Uher, 2003). According to Gray & Larson (2008), the major components of risk management process are shown in Figure 1.

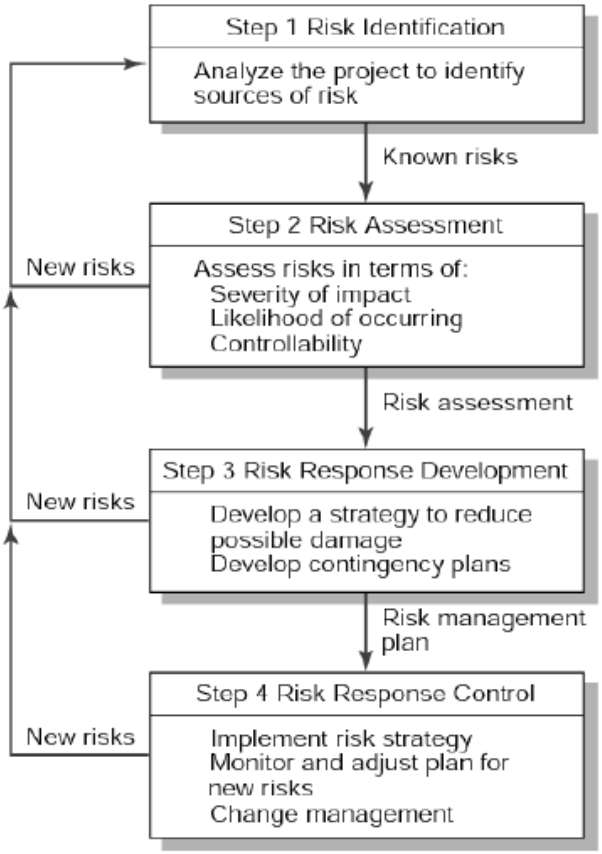

Figure 1: Risk Management Process adopted from Gray & Larson (2008)

As shown in Figure 1 the risk management process has four different steps namely (1) Risk Identification, (2) Risk Assessment, (3) Risk Response Development, and (4) Risk Response Control.

According to PMI, 2013, Project Risk Management comprises the processes of conducting risk management planning, identification, analysis, response planning, and controlling risk on a project. The objectives of project risk management are to increase the likelihood and impact of positive events, and lessening the likelihood

and impact of negative events in the project. Project risk management includes the following processes as shown in Figure 2.

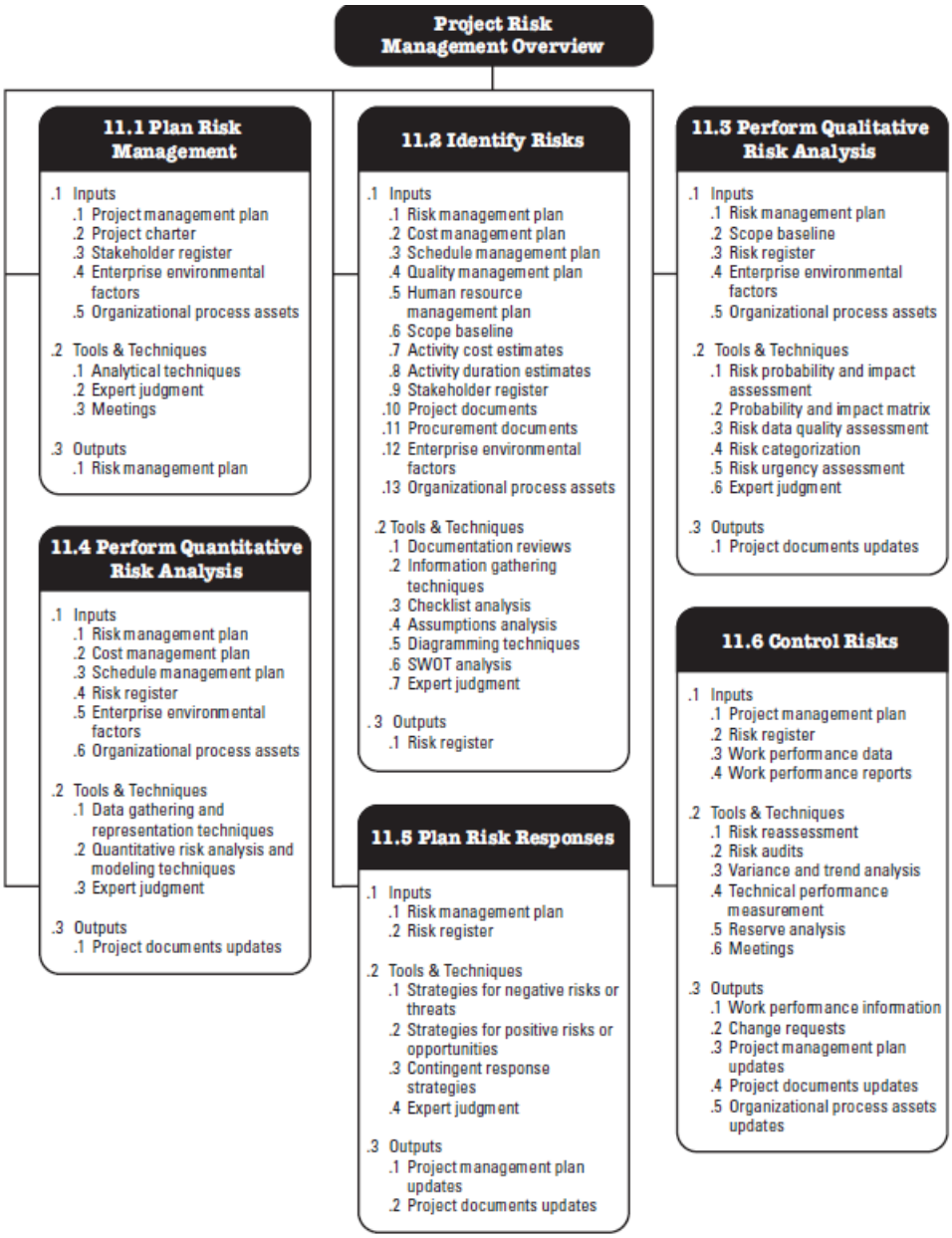

Figure 2: Project Risk Management Overview adopted from PMI, 2013

2.3.1 Plan Risk Management

Plan risk management is the process of defining how to conduct risk management activities for a project. Cautious and clear planning improves the probability of success for the five other risk management processes. Risk planning plays a very major role in determining and providing adequate resources and time for the risk

management activities. It will create a basis for assessing risks in a project. The plan risk management process should begin as the project kicks off and should be finished early during project planning (PMI, 2013).

2.3.2 Risk Identification

Risk identification is the process of defining which risks may distress the project and documenting their features. The key advantage of this process is the documentation of prevailing risks and the knowledge and ability it provides to the project team to foresee events (PMI, 2013). The following Figure 3 shows the inputs, tools and techniques, and outputs which are used for risk identification process.

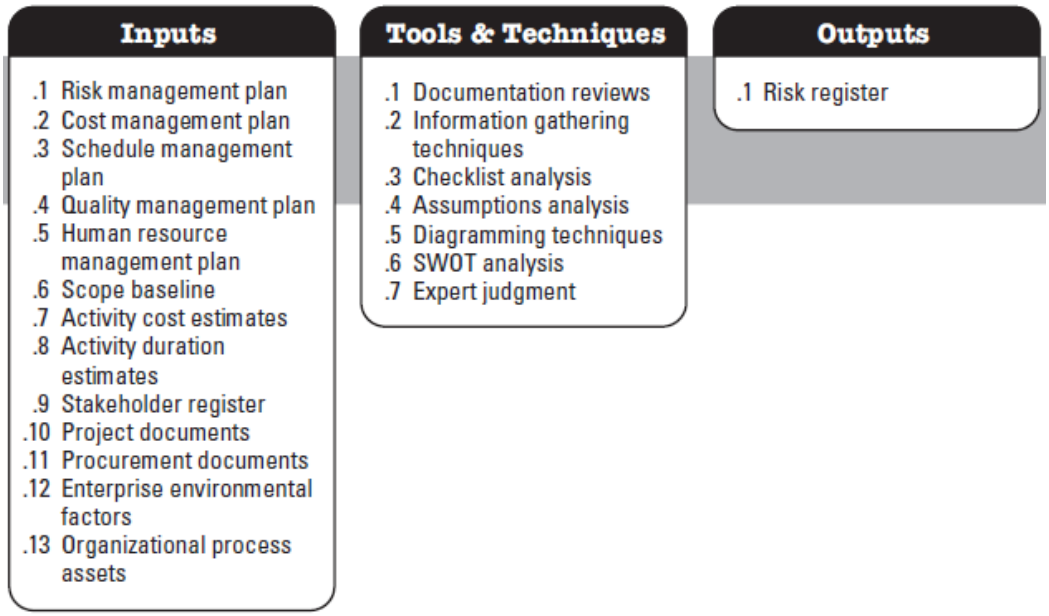

Figure 3: Risk identification process adopted from PMI, 2013

According to the study conducted by (Al-Bahar, 1990), the risk management process starts by generating a list of all the probable risks that could have effects on the project. Risks in construction can be classified into six categories as follows: (1) Acts of God (2) Physical risks (3) Financial and economic risks (4) Political and environmental risks (5) Design-related risks (6) Construction-related risks. According to the literature review on critical risk factors in the life cycle of construction projects summarized by Renuka (2014), the knowledge map

representing the sources of risk factors is shown in Figure 4. According to this knowledge map the flow chart covers numerous risk factors, in which engineering risks are foreseeable and those non engineering risks are unforeseeable.

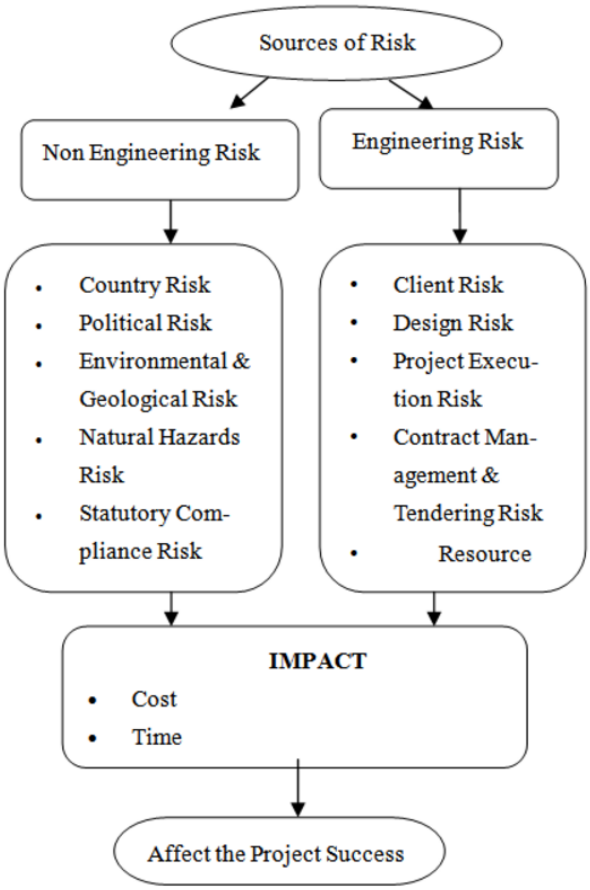

Figure 4: Knowledge map of risk sources adopted from Renuka, et al., 2014

Renuka (2014) suggested that efforts should be made to forecast the foreseeable risk factors during the early stage of the project whereas the unforeseeable risk factors should be assessed for the successful conclusion of the project as these risk factors will distress the cost, time, and quality of the project.

Garrido (2011), carried out a research to assess the use and knowledge maturity of risk identification techniques in the construction industry. The questionnaire survey was used to gather data from professionals in the construction industry. The conclusions of the study revealed that the most frequently used risk identification techniques are Check list, Flowchart, and Brainstorming out of the eighteen different

techniques presented to professionals. It was also found that all the techniques mentioned in the literature are not known by the professionals. The study directed by Hillson (2002) listed out brainstorming and workshops, checklists, questionnaires and interviews, and Delphi groups as the suitable methods for risk identification. Hillson (2002) further mentioned that there is no single "best method" for risk identification, and a fitting combination of techniques should be used.

2.3.3 Risk Assessment

Risk assessment helps in estimating potential impacts of risk and in making decisions regarding which risks to retain and which risks transferring to other parties. Risk assessment includes creating a probability consequences scale, performing supporting analysis, determining probability and significance levels or ratings, documentation of results and also to prioritize the risk. The risk analysis result is compared with the criteria for risk so as to decide if a certain risk level is tolerable or not. The primary objective for this assessment is to approximate risk by identifying undesired events; the likelihood of occurrence of these events and the result in case of occurrence or consequences (Aminu, 2013).

Perform Qualitative Risk Analysis is the process of prioritizing risks for further analysis or action by assessing and combining their probability of occurrence and impact. The key advantage of this process is to empower project managers to reduce the level of uncertainty and to concentrate on high-priority risks (PMI, 2013). The inputs, tools and techniques, and outputs of this process are shown in Figure 5.

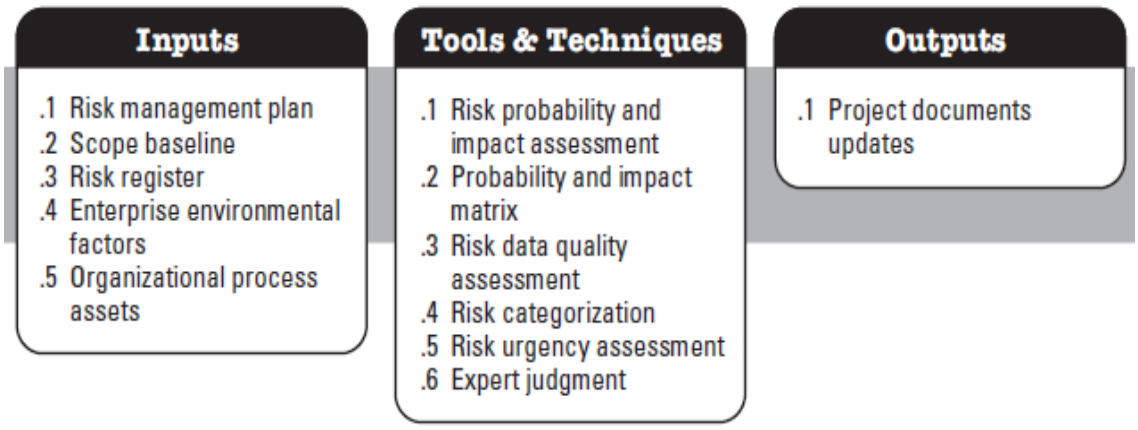

Figure 5: Process of qualitative risk assessment adopted from PMI, 2013

PMBOK Guide Fifth Edition defines Perform Qualitative Risk Analysis "The process of prioritizing risks for further analysis or action by assessing and combining their probability of occurrence and impact".

Perform Quantitative Risk Analysis is the process of mathematically analyzing the effect of identified risks on overall project objectives. The key advantage of this process is that it produces quantitative risk information to back decision making in order to diminish project uncertainty (PMI, 2013). The inputs, tools and techniques, and outputs of this process are shown in Figure 6.

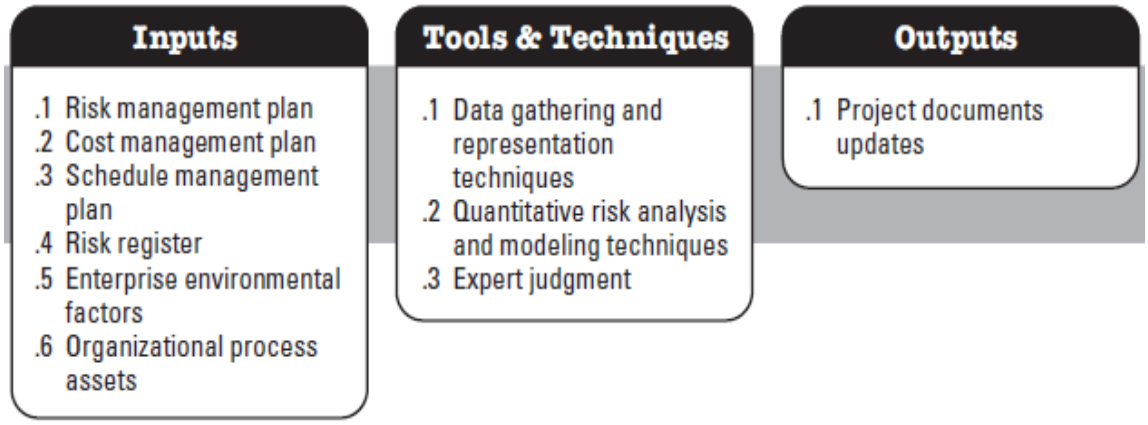

Figure 6: Process of quantitative risk analysis adopted from PMI, 2013

PMBOK Guide Fifth Edition defines Perform Quantitative risk Analysis as "—the process of numerically analyzing the effect of identified risks on overall project objectives". Both quantitative and qualitative techniques are available for risk assessment. The quantitative methods rely on probability distribution of risks and may give more accurate results than the qualitative methods, if the accessible data is robust and reliable. On the other hand, qualitative methods depend on personal judgment and past experiences of the analyst and the results may vary from person to person. Hence the quantitative methods should be given most importance if both choices are available (Ward & Chapman, 1997).

2.3.4 Risk Response Development

The research carried out by Panthi (2007) found four typical ways of responding to risks in a construction project, as follows: (1) Risk elimination (2) Risk transfer (3) Risk retention (4) Risk reduction.

According to the study conducted by Kremljak (2010) risk in construction projects can be coped through following methods:

1. Risk Avoidance

It is the answer to all risk but might lose potential gain attached to a specific risk. It involves eliminating any process that may cause risk towards achieving our objective independent of the gain it may bring.

2. Risk Reduction

It means reducing the extent of the loss or possibility of loss. Here, we find a balance between negative effect of risk and the benefits attached to the process.

3. Risk Sharing

In this process the risk is been shared with another party which means the loss burden or the benefit attached to it will be shared between the parties. In some cases, insurance is used so as to transfer the risk to a third party, but in case of default the original risk will likely revert to the first party.

4. Risk Retention

By default, all risks are retained if not avoided or transferred. This includes accepting the loss or benefit of gain from a specific risk. Mostly in this kind of situation the cost of managing the risk is far more than the negative effect of the risk. This includes risks that are so large that cannot be roofed against and premium would be infeasible.

2.3.5 Risk Response Control

The last step in the risk management process is risk response control which includes executing the risk response strategy, monitoring triggering events, initiating contingency plans, and watching for new risks. Establishing a change management

system to deal with events that require formal changes in the scope, budget, and/or schedule of the project is an essential element of risk control (Gray & Larson, 2008).

Control Risks is the process of implementing risk response plans, tracking identified risks, monitoring residual risks, identifying new risks, and evaluating risk process effectiveness throughout the project. The key benefit of this process is that it improves efficiency of the risk tactic throughout the project life cycle to continuously optimize risk responses (PMI, 2013). According to Aminu (2013), Risks change with time as project progress, new risks emerge or expected risks disappear. This is a process where identified risks are checked, residual risks are monitored and new risks are identified. It also ensures implementation of risk plan and evaluating how it reduces risk. A distinct report should be drafted regularly on the chance of having new risk and how to tackle it. This process will be continuing for the lifecycle of the project.

According to Kremljak (2010), managers in industries, governmental and private organizations deal with great level of uncertainties in their decision. The researcher argues that managers have imperfect data on future happenings events. In ending the researcher mentioned that addressing uncertainty encompasses creating experimental tools which can carry satisfactory solutions.

2.4 Risk Management in Construction Industry

2.4.1 Introduction

The necessity for infrastructural development brings about the speedy evolution in construction industries around the globe. Development of infrastructure is one of the key drivers in business over the globe; it increases the Gross Domestic Production (GDP) of a country (Odeyinka, 2007). Therefore most of the countries in the world give utmost priority to infrastructural development and pump significant amount of money in to it. This leads to new challenges considering the risks involved in the design and production (Okuwoga, 1998). Cost overruns will definitely affect project especially when involving a large amount of money (Odeyinka, 2007). To avoid or

diminish the damages, proper management system of risk is vital to any construction project.

In the early stages of the project, risk management procedures should be initiated. In later stages, risk management applied systemically, aids to control critical elements which can negatively impact project performance. In other words, to keep track of previously identified threats, will result in early warnings to the project manager if any of the objectives, time, cost or quality, are not being met (Michaela, 2011). Risk management in construction industry aims at identifying project risks, finding ways to tackle them and reducing their negative impact (Akindele & Macloed, 1997).

2.4.2 History of Construction Risk Management

According to the research carried out by Renuka (2014), the history of risk management in construction projects was divided in to three distinct time periods, namely 1) The 1990's-Origin of risk analysis in construction industry 2) The new millennium- Arrival of new systematic approaches 3) The post 2010's-Development of more sophisticated techniques.

During 1990 risk identification and assessment was a key research area. Many constructors were in a process of establishing new approaches to analyze and assess risk and its implications (Renuka, et al., 2014). These approaches consist of identifying risk causes, evaluating their effects on project objectives and picking ways to control them (Birnie & Yates, 1991). Also, efforts were taken by researchers to categorize the causes of risk with respect to controllable and uncontrollable influences which induce cost and time overrun in a construction project (Akincl & Fischer, 1998).

As a result of chain of studies in this nature, various risk assessment models were framed to analyze and assess construction project risks during the tendering stage of a project (Mustafa & Bahar, 1991).

Only a few research attempts were there on the identification and assessment of risk causes in construction projects till the year 2000. Therefore, a gap was identified in literature in systematic approaches to manage risk in construction projects. Then Chapman (2001) made an attempt to form groups to classify the risk factors, namely, 1) Environment; 2) Industry; 3) Client; 4) project while Shen (2001) grouped them in to six different ways, namely, 1) Financial; 2) legal; 3) Management; 4) market; 5) Policy; 6) Political. Zeng, et al., (2007) had classified risk causes as equipment, material, human, and site factors. After 2000, a rapid increase in the number of researches has been seen in literature.

The output of such studies has produced more sophisticated and comprehensive models to address the risk related issues. Rezakhani (2012) had formed risk factor groups in to three titles, namely, 1) External; 2) Legal; 3) Internal. This study had further sub divisions among major groups. External risk factors were given two subsets as unpredictable/uncontrollable and predictable/uncontrollable while internal risk factors were sub-divided as Non-technical/controllable and technical/controllable. In addition to this, the researcher has come up with a Risk Breakdown Structure.

Goh (2013) did a research, identifying nineteen risk factors in the life cycle of the project under different groups such as planning stage, design stage, procurement stage, construction stage, and handing over stage. This study further discussed the workshop tool as a way to identify and analyze risk factors which includes checklist, brainstorming, probability impact matrix, risk register, and subjective judgment.

According to Lazzerini & Mkrtchyan (2011), many attempts were made by various scholars to explore various approaches to handle the complex nature of risk and its complicated surrounding environment. Hawang (2013) established that implementation of risk management is relatively low in small construction projects due to numerous reasons such as lack of time and budget, low profit margin, and uneconomical ways of handling projects.

The findings of this research revealed that there is a strong positive link between active implementation of risk management and achieving project objectives such as cost, schedule, and quality of small projects. Ehsan (2010) discussed the factors which take projects to meet risk. Those factors are as follows.

1. History: New projects are always prone to risk because the process has not been experienced with over time. There is always uncertainty when something is been done for the first time. But if a similar project of that nature has been done before, then the prospect of a successful operation is enhanced.

2. Management Stability: When the entire management team shares the same thoughts and ideas, the project objectives will be achieved successfully with little or no setback in terms of risk. But when the management team is unstable, they will make a mess of the whole project and lead to compromise in cost, quality and other objectives of the project.

3. Experience and expertise of staffs: Whenever the project team members are ill-informed about the project or lack working knowledge and past experience of that particular work, there is always a possibility of cost overruns, delays in completion time and poor quality standard.

4. Team Size: Too many cooks spoil the broth. Whenever there are too many people involved in the project execution and decision making, the possibility of problem occurrence will be high. The major problems will be difficulty in communication, sabotage, over confidence etc.

5. Resource availability: If resources are available, there will be immediate response to problems. Money or cash availability makes it easier to secure labor, material and equipment resources. But plenty of resources does not guarantee risk free project, rather it equips the project team with means of eliminating or minimizing the threat of risk.

6. Time Compression: There are projects where completion time is very small compared to the nature of the project; risks are expanded in this kind of situation. When we have more time, there will be more flexibility and opportunity to reduce the impact of occurring risk.

7. Complexity: In extremely complex projects, the likelihood of risk occurrence is always high. The likelihood of making mistake is also high and a little mistake can cost you a great loss.

According to Ehsan (2010), risks can be linked to business, operational or technical part of projects. Construction project risks are classified into:

1. Technical risks: unfinished design, unsatisfactory site investigation, Suitability of specification, Uncertainty over the source and availability of materials.
2. Financial risks: changes fluctuation in foreign exchange, Return of funds, delays in payment, local Taxes and Inflation.
3. Management related risks: industrial related problems, unsure productivity of resources, clash of interest and wrong decisions.
4. Logistical risks: availability of necessary facilities for transportation and construction equipment that will be needed for the progress of the work.
5. Socio-political risks: difficulties in disposing of plant and equipment; limitations on the availability and employment of emigrant staff; and persistence on use of local firms, methods and agents
6. Environmental risks: climate changes, weather implications, and natural disasters

These sources of risk are related to project-specific and non-project-specific risks, as both these types of risk need to be considered when identifying the risks in a project or a process. The organization needs to outline the boundaries of these sources and to break down these sources into detailed risk elements. This will allow a general understanding among those who are trying to find the risks in a project (Abu Mousa, 2005).

Zou (2006) carried out research to identify key risks in construction projects from stakeholders and life cycle perspective. The researchers attempted to identify certain project risks, their likelihood of occurrence and impact. Based on their assessment, twenty different risks were identified with their likelihood of occurrence and influence on project goals. The risks were related to clients, designers or contractors whereas only few were linked to sub-contractors/suppliers, state bodies and other external issues. These twenty risks are then studied based on stakeholder's viewpoints and project life cycle viewpoint.

Four significant risks were identified as related to client including tight schedule in projects, client change order, high performance or quality expectation and incomplete or delays in approval and other documents. Four risks were also identified in connection with designers namely, variations in design, inaccurate cost estimate, poor program scheduling and poor soil test and site survey. Seven significant risks were known in relation to contractors which are poor program planning, program change, poor coordination among participants, unavailability of sufficient professionals and managers, shortage of skilled labor, dispute between participants, noise pollution from construction and accident occurrence. Lack of competency of sub-contractors is the only key risk associated to sub-contractors. Delays in approval procedures by state bodies are the two risks associated with government related risk. Only construction materials price inflation is related to the external environment which is also not controlled by stakeholders. The prices of materials are always subject to change as the change comes to inflation and demand and supply within the industry market.

Banaitiene & Banaitis (2012) researched risk management in Lithuanian construction projects and mentioned that risk management practice encourages construction companies in identifying and quantifying risks, and that risk reduction and control policies should be considered. The study found that Lithuanian contractors' lack of experience brings out a poor attitude towards risk management. The research further recommended that construction firms should include risk management as a significant part of their construction management process. Ehsan (2010) researched to assess current risks and uncertainties in the construction industry of Pakistan using

questionnaire and literature survey. The research revealed that proper risk management techniques and risk analysis are hardly used in Pakistani construction firms due to lack of experience and awareness in the region. The researchers suggested that construction professionals should be educated on risk management, and formal and informal training for risk management should be delivered.

2.4.3 Risk Management Challenges in Construction Industry

The implementation of Risk Management and Assessment Practices is usually troubled by barriers although the wide-ranging researches on barriers affecting Risk Management and Assessment Practices (Chileche & Kikwasi, 2013). Lack of practice of risk management practices is not just confined to only developing nations but it also affects nations like Australia, a developed country (Lynos & Skitmore, 2004). A number of researchers have examined the obstacles distressing the execution of risk management practices as shown in Table 2.

Table 2: Summary of previous studies on barriers to risk management practices

Researchers	Context of research	Findings:
Kim & Bajaj (2000)	Interviewed 13 Korean managers of general contracting organization.	1. Lack of familiarity with techniques 2. Most clients want to see tangible calculations and unambiguous evidence of risk 3. Lack of expertise with techniques
Chileshe & Yirenyi (2012)	Research was carried out using a general survey of 34 contractors, 46 consultants and 23 clients engaged in construction projects in Ghana.	1. Awareness 2. Lack of experience 3. Lack of coordination between different players 4. Lack of information 5. Unavailability of specialist risk management consultants 6. Time constraints

		7. Lack of knowledge and expertise
Kikwasi (2011)	Interviewed 55 consultants, architects, and quantity surveyors in Tanzania.	1. Not being a priority in client's requirements 2. Lack of holistic approach to risk management 3. Reluctance of consultants to lead risk management process
Hwang (2013)	Data was collected through questionnaire survey based on data collected from 668 small projects in Singapore.	1. Competition among small and medium contractors 2. Complexity of analytical tools 3. Lack of potential benefits 4. Lack of budget 5. Lack of government legislation 6. Lack of knowledge 7. Lack of manpower 8. Lack of time 9. Low profit margin 10. Not economical
Chileche & Kikwasi (2013)	Data was collected through a questionnaire survey using a sample of 67 construction professionals comprising clients, consultants, and contractors.	1. Awareness of risk management processes 2. Lack of experience 3. Lack of information 4. Lack of coordination between parties involved 5. Availability of risk management consultants 6. Implementation cost 7. Time constraints
Shunmugam & Rwelamila (2014)	Data was collected through Questionnaire	1. Time constraints 2. Attitude 3. Insufficient knowledge

	from 181 construction professionals. Research used mixed methodologies comprising qualitative and quantitative.	4. Communication barriers 5. Cost constraints 6. Insufficient attention given to risk identification process 7. Lack of skills 8. Resource constraints 9. Formal RM process not in place 10. Identified risks are not responded to or monitored 11. Unclear roles and responsibilities

Aminu (2013) studied risk management in Nigeria in order to improve the risk management practices and find the bottlenecks associated with poor deployment of construction risk management. Questionnaire survey was conducted to gather primary data.

The study revealed that the major issue associated with poor risk management in Nigeria is lack of knowledge. The other major knowledge areas which will promote the effective deployment of construction risk management practices are cost management and quality management. It is also recommended that positive change in construction participants' attitude will highly improve present status of construction risk management practices in Nigeria.

2.4.4 Critical Success Factors (CSFs) for Implementing Risk Management Systems

The concept of Critical Success Factor (CSF) first came to the body of knowledge in 1979 introduced by Rochart. It was defined as 'the limited number of areas in which results, if they are satisfactory, will ensure successful competitive performance for the organization. Pinto & Covin (1989) defined CSF as certain rules, executive procedures and environmental conditions. Deros (2006) defined CSF as a range of enablers which, when put in to practice will enhance the chance for successful

benchmarking implementation and adoption in an organization. Considering all the definitions within the context of this study, CSFs could be said as the powers of the successful implementation of risk management systems. Zhao (2013) carried out a research titled Critical Success Factors for Enterprise Risk Management (ERM) in Chinese Construction Companies. A literature review was conducted to find out the CSFs for ERM. Using the identified CSFs from the literature, a questionnaire survey was conducted to collect the construction professionals' view on CSFs. The Figure 7 shows the research method used in the study.

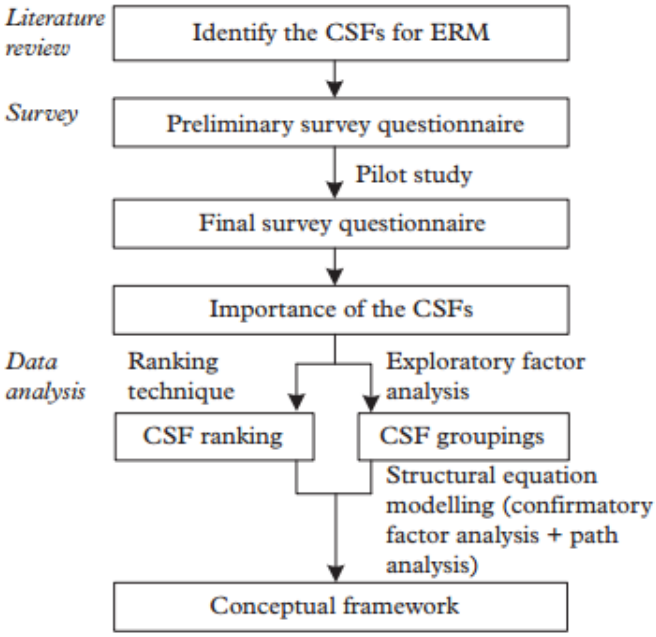

Figure7: Research method used by Zhao (2013)

This study established that the three utmost key CSFs are 'commitment of the board and senior management', 'risk identification, analysis and response' and 'objective setting'. Also, the three fundamental CSF groups are (1) execution and integration; (2) communication and understanding; and (3) commitment and involvement of top management. The commitment and involvement of top management positively contributed to the communication and understanding as well as the execution and integration of ERM, while the communication and understanding eased the execution and integration of ERM.

Hosseini, et al., (2016) carried out a study titled Critical success factors for implementing risk management systems in developing countries. This study was based in Iran, as a developing country. Also, this research was one of the first studies in similar nature. The aim of the study was to explore the perceptions of construction professionals regarding the CSFs for the execution of risk management systems.

This study adapted a validated questionnaire already used by Chileche & Kikwasi (2013) within Tanzanian construction industry. The adapted instrument was presented to four Iranian experienced project managers in order to check the usability and easiness of the questionnaire. The suggestion made by the project managers included into the instrument. The study used 87 completed questionnaires for analysis. The identified CSFs from the literature were presented to construction professionals, representation client, consultant, and contractor organizations. The relative importance index (RII) was used to rank the CSFs. Correlations among CSFs were also analyzed.

The study found that four factors are as highly critical: 'support from managers', 'inclusion of risk management in construction education and training courses for construction practitioners', 'attempting to deliver projects systematically', and 'awareness and knowledge of the process for implementing risk management'.

Evaluating the relatives between CSFs also emphasized the vigorous role of improving the effectiveness of knowledge management practices in construction organizations. The agreement on the level of importance of CSFs for implementing risk management in developing countries was not seen among different parties involved in construction projects. The researches further concluded that studies in similar nature should be carried out in other developing countries in order to test the generalisability of these CSFs.

Chileshe & Kikwasi (2014) conducted a study titled CSFs for implementation of risk assessment and management practices within the Tanzanian construction industry. The aim of the study was to investigate the perceptions of construction professionals on CSFs relating to the deployment of risk assessment and management practices.

The primary data were composed from 67 construction professionals working with clients (private and public), consultants, and contractor organizations (foreign and local) within the Tanzanian construction. Response data was subjected to descriptive and inferential statistics with one-way analysis of variance to examine the differences in the perception of the identified CSFs.

The descriptive and empirical analysis confirmed a difference of the ranking of the ten CSFs among the groups; however, the differences were not significant. Based on the overall sample, the results of the mean score ranking show that "awareness of risk management processes"; "team work and communications"; and "management style" were the three highly ranked CSFs. "Co-operative culture"; "customer requirement"; and "positive human dynamics" were found to be the least significant.

Yaraghi (2011) had studied CSFs for risk management in various types of Swedish companies. The title of the research is Critical Success Factors for Risk Management Systems (RMS). Total of 19 CSFs were identified and grouped into three different classes: (1) the factors that have influence on the inclination and readiness of corporation for implementing RMS. (2) the factors that are important during the design and implementation of RMS in corporation and can significantly affect the success of RMS design and implementation and (3) the factors that are crucially important to successfully run, maintain and administrate RMS after the closure of the project of RMS design and Implementation. A structured questionnaire survey was conducted to obtain the perceptions and ideas of risk management practitioners about the level of importance of the identified 19 CSFs at three different stages of RMS. The target population for this study consists of 250 registered Swedish companies. The sample was arbitrarily picked from the companies with the following circumstances: (a) the firm practicing active Risk Management System and (b) existing for minimum 5 years.

The analysis concluded that in all of the three stages, strategy is the most important factor for success. Realizing the need and necessity of RMS by organization and deciding seriously to have this system is the first step toward successful RMS. During the implementation phase, strategy plays an important role since the

allocation of resources and contribution of efforts to the project of RMS implementation should be addressed as a vital constituent of overall organization's strategy.

After having the system implemented and during its lifecycle, strategy is again the most important factor. Organizations need to have a prolong strategy toward risk management and keep developing the RMS. The strategy has a vital role in changing and shaping the organizational culture and structure through all the phases of RMS. Without a carefully designed and thoroughly conveyed strategy toward RMS, it would be much more problematic to manage the change in the organization and align the resources, operations, functions, staff and their willingness with RMS requirements. In addition to strategy, organizational culture and structure, the support of top management were found to be more influencing factors.

Top management is the first component of the organization which should be aware of RMS, its tools and techniques, applications, requirements and benefits. Top management's competency, education, and awareness about RMS play an undeniable role in having a productive strategy and combining it with risk management strategy in future. Table 3 shows the summary of identified CSFs for the deployment of risk management systems in construction projects of developing countries.

Table 3: Summary of identified CSFs in developing countries

Studies	**Identified CSFs**
Chileche & Kikwasi (2013)	- Support from managers. Awareness and knowledge of the process for implementing risk management. Promoting collaboration & culture environment among involved parties. Request for IRMS on projects by clients and end users. Incorporating IRMS among the strategic objectives of organizations involved in projects. Taking into account the effects of the business environment

	surrounding projects. To deliver projects systematically. Promoting team working and effective communication among the parties involved. Access to risk management systems consultants. Factoring in the costs of IRMS within project's budgets. Inclusion of risk management systems among education and training subjects of construction practitioners.
Chileshe & Kikwasi (2014)	Management style Awareness of RMP Cooperative culture Positive human dynamics Customer requirements Goals and strategic objective Impact of environment Usage of tools Teamwork and communication Availability of specialist risk management

The existing literature shows that the number of studies in CSFs of risk management practices is very less in developing countries. As mentioned by Chileche & Kikwasi (2013), there is a strong need to go for further studies of similar nature in order to establish and generalize the previous findings.

2.5 Construction Industry in Sri Lanka

According to *Oxford Business Group* (2016), Sri Lanka's construction industry has been a major beneficiary of the country's speedy economic development over the past six years. Since the end of the civil war in May 2009, the country has hurried to make up for more than two and a half decades of building activity across most segments, from high-end residential housing to commercial and office space to a range of key infrastructure segments.

According to NDB Securities (NDBS), a brokerage based in Colombo, in 2014 Sri Lanka's construction sector stretched by more than 20%. Indeed, since 2009 the industry has grown twice as fast as the nation's GDP, which has increased by just over 7% on an average annual basis over the same period. According to NDBS data, in 2014 the construction industry accounted for 9.6% of Sri Lanka's GDP, which represented a significantly greater proportion of the economy than most other countries in Asia.

GDP of the Construction industry in Sri Lanka increased to 157,734 LKR Million in the third quarter of 2016 from 142, 133 LKR Million in the second quarter of 2016. GDP From Construction in Sri Lanka averaged 128312.48 LKR Million from 2010 until 2016, reaching an all-time high of 170122 LKR Million in the first quarter of 2013 and a record low of 77176 LKR Million in the second quarter of 2010.

The construction industry is a key supplier to the development of economies in Sri Lanka. However, it faces substantial challenges and difficulties which are unique to the specific industry. Therefore, it is a vital role to recognize them and offer solutions (Rajakaruna, et al., 2005).

2.6 Construction Risk Management in Sri Lanka

Perera, et al., (2009) carried out a research aiming to identify the risk accountabilities of contractual parties to improve their risk handling strategies with regard to Sri Lankan road projects. The research adopted the Multiple Case studies method. Semi-structured interviews were used for the primary data collection. This was complemented by documentary evidence. Various sources of evidence comprising semi-structured interviews, documents such as letters, weather records, bill of quantities, claim reports, non-conformity reports, variation orders, project programme, public complaint reports, certified monthly bills and monthly progress reports, and archival records such as past weather records were used in this study for data collection.

The study revealed that road projects in Sri Lanka are subject to several risk sources while most risks are tolerated by parties who were assigned with risks through contract clauses. However, parties not allocated with risks too happened to bear the consequences of such risks. Therefore, it is concluded that there is no one best way to respond to a risk and that different risk handling strategies should be implemented to deal effectively with risks.

Perera, et al., (2014) did research on enhancing the effectiveness of risk management practices in Sri Lankan road construction projects using Delphi approach. The study had two purposes: (1) Identifying the risks that are critical for risk management of road construction projects in Sri Lanka on a life cycle basis and (2) defining the shares of the parties involved in projects in terms of handling the identified risks.

A Delphi study was conducted among 33 Sri Lankan well experienced construction professionals (consultants, project managers, contractors) in three rounds. The study revealed that the construction and design phases are prone to many major risks. Moreover, 'delays in payment by the client' was the most critical risk factor in the construction stage. It was also known that some major risks could happen in more than one phase of the project life cycle, emphasizing the need of managing these risk factors towards project success.

A study was conducted by Perera K. S (2012) to identify the harsh risk factors and approaches to managing them at each stage of the project life cycle. This study was scoped to road construction projects in Sri Lanka and three round of Delphi survey was used to gather data from construction professionals. The findings of the study showed that the construction phase is the riskiest phase followed by the design phase. The study further found that the most commonly deployed risk response measures by the major parties were the allocation of contingency plans and claim for damages.

2.7 Summary

It is found that there are a significant amount of researches on risk management in construction industries around the world but there are a couple of researches found in

connection with construction risk management in Sri Lanka. It clearly indicates that there is a strong need to conduct more researches in order to examine risk management practices in Sri Lankan construction industry and enhance risk management maturity.

Though there is a little amount of work done on the study area, the existing studies in Sri Lanka have focused only on exploring risk factors, likelihood of risk occurrence and determining the shares of the parties involved in projects to handle the identified risks (Perera, et al., 2014).

From the literature evidence and observations, it can be said that risk management in Sri Lankan construction industry is relatively a less matured knowledge area and most of the projects do not pay significant attention to risk and its mitigation measures, which resulted in bad consequences on construction projects. Therefore the present study is conducted in order to answer the question “How the risk management practices could be promoted and enhanced in Sri Lankan construction industry?”

In order to provide answers to this question, the present study will explore the current practices regarding risk management systems and the barriers to the implementation of risk management practices. The study will also attempt to propose suggestions to overcome barriers to risk management implementation by exploring the Critical Success Factors (CSF) which will play an immense role to enhance the risk management practices.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The research methodology defines the research methods and techniques used in the research. According to Kothari (2008), research design is the theoretical arrangement within which research is conducted; it establishes the blueprint for the collection, measurement, and analysis of data. The data for the study needs to be clear-cut and accurate to fulfill the objectives of the research. This chapter will elaborate the processes of data collection for the research. This chapter will also justify the reasons behind the selection of the data collection method. This survey attempts to explore the opinions of construction professionals engaged in construction projects in Sri Lanka. The survey was focused on the application of risk management techniques in construction projects of Sri Lanka, identifying the barriers which demotivate the application risk management, and identifying the critical success factors of risk management. The information required for this study was composed through a detailed literature review from reputed journals, published books, and websites. The literature survey and the information gathered from the sources were the basis to get a profound understanding of risk management applications from various part of the world.

3.2 Survey Method

Considering the nature of the study area the Delphi technique was used to gather primary data for the research. Despite the most of the previous researchers had used questionnaire surveys and interviews to gather primary data, this current research selected Delphi technique over other methods considering the following reasons as to why questionnaire survey or interview is not selected to gather primary data.

- The Construction Risk Management is not a well-matured knowledge area. Therefore the opinions of general construction practitioners, gathered through

questionnaire survey or interview, will not be adequate enough to draw conclusions on the research objectives.

- The limited time available for thinking.
- Questionnaire survey or interview does not provide enough room to reconsider the opinion provided.
- No opportunity is provided for them to see the common harmony among agreements through questionnaire survey or interview.
- Less experience and exposure in construction risk management systems.

Therefore, Delphi technique was considered as the superlative method suited to the current context since this method target experts' feedbacks through several rounds of the survey.

3.3 Delphi Technique

The Delphi method is a recognized technique used by scholars of various disciplines for gathering data from experts in the study area. This technique is established as a group communication procedure which achieves a convergence of opinion on a real issue (Hsu & Sandford, 2007). The Delphi technique is a suitable method for consensus building through a series of questionnaires to gather data from a panel of selected experts (Delkey & Helmer, 1963)

The Delphi method was first introduced by Dalkey & Helmer (1962) in their work for the Rand Corporation. At the initial stage of its emergence, a four or five round Delphi method was in use. Later, Brooks (1979) and Pfeiffer (1968) established that Delphi survey with only three rounds is adequate for consensus building. Currently, the Delphi method is extensively utilized in studies related to health care, communications, public relations, education, and scientific disciplines (Kennedy, 2004).

Delphi technique uses multiple repetitions designed to develop a consensus of opinion about a particular topic. In particular, the feedback process provides enough

room for the selected Delphi experts to reconsider their earlier judgments about the information provided in previous iterations (Hsu & Sandford, 2007).

The Delphi method is used in many complex areas targeted to achieve a consensus of the topic. As it is stated by Chan (2001) the Delphi method is a highly dignified way of communication that is planned to extract the maximum amount of unbiased information from a panel of experts. Moreover, the Delphi participants are not interected among them. The responses given by the experts are kept anonymous, and the experts are given further opportunity to reconsider their responses once the collective feedback is received.

3.4 Selection of Delphi expert panel

Selecting a suitable panel of experts is the major aspect which ensures a successful survey. The key aspects of the selection process include selecting experts with the right qualifications, size of the panel, and participant commitment towards the research. The number of participants of Delphi survey widely varies in previous studies. It is not definite of what constitutes a suitable size of the Delphi panel. Clayton (1997) stated that having 15 to 30 participants is the widely accepted norm for a homogeneous group, comprising members from the same discipline. Ziglio (1996) has a similar view to Clayton (1997), reporting that 10 to 15 Delphi participants produce better results in a homogeneous panel. This study had taken feedbacks from 15 Delphi participants as a homogeneous group. The panel comprised of Senior Project Managers, Senior Engineers, Senior Quantity Surveyors, Senior Academics, Senior Architects from private and public sectors**.**

3.5 Design of Delphi Survey

The Delphi method is continuously repeated until consensus is reached on the topic. However, Cyphert & Gant (1971), Brooks (1979), and Ludwig (1997) stated that three rounds of Delphi survey are adequate enough to gather required information and to achieve a consensus in most cases. This study was conducted in three rounds of Delphi survey as follows:

3.5.1 Delphi round one

In the first round of survey, the preliminary questionnaire was presented to the panel. The risk management practices, barriers faced in the implementation of risk management practices, and critical success factors identified from detailed literature survey were presented in the questionnaire. Also, experts were asked to introduce new factors or parameters as an addition to the preliminary questionnaire based on their knowledge and experience.

The preliminary questionnaire had four different parts as follows:

Part 1:

Background information of the respondents such as the name of the organization, position/designation, qualification, working experience, and type of construction projects involved and type/grade of the company.

Part 2:

Current Practices Regarding Risk Management in Sri Lankan Construction Projects: The first objective of the study is to determine the current practices which are used by construction professionals in construction projects. This section of the preliminary questionnaire was dealt with knowing the construction professionals' degree of use of the identified risk management techniques.

The participants were requested to rate the risk management techniques using 1-5 Likert-scales as follows:
1= Very low use
2= low use
3= Neutral
4= High use
5= Very high use

The Relative Importance Index (RII) was computed as:

$$RII = (W1 + W2 + \ldots + Wn) / A * N \ldots\ldots\ldots\ldots\ldots\ldots \textbf{(A)}$$

Where W = weights given to each CSF by the respondents from 1 to 5, ('1' is Very low use and '5' is Very high use), A = highest weight (i.e. 5 in this case), and N = total number of respondents.

Part 3:

Barriers to the implementation of Risk Management practices in Sri Lankan construction projects: The second objective of the study is to explore the barriers to the implementation of Risk Management practices in Sri Lankan construction projects.

In order to accomplish this objective, this section of the questionnaire approached to explore the construction professionals' view on barriers to the implementation of risk management practices. The literature review part of this study has thoroughly reviewed the studies conducted from the different part of the world aiming to find the barriers of the implementation of Risk Management practices. The factors, identified from the literature, were presented to the respondents of the survey.

The participants of the survey were requested to rate the barriers using 5 points Likert scale as follows:

1= Strongly disagree
2= Disagree
3= Neutral
4= Agree
5= Strongly agree

The Relative Importance Index (RII) was computed using equation (A).

Part4:

Critical Success Factors for the implementation of Risk Management practices in Sri Lankan building construction industry. The last and third objective of the study is to explore the Critical Success Factors (CSF) of implementing Risk Management systems in Sri Lankan construction projects. In order to accomplish this objective, a section of the questionnaire dealt with exploring the construction professionals' view on Critical Success Factors of implementing risk management systems.

The literature review part of this study has thoroughly reviewed the studies conducted from the different part of the world aiming to identify the CSFs. The basis of the questionnaire for this objective was adapted from a validated instrument (questionnaire) used by Hosseini, et al., (2016) within the Iranian construction industry.

According to Carless & De Paola (2000), customizing available instruments for a specific environment is acceptable in order to gather primary data for a research. The following factors, identified from the literature, were rephrased to be more elaborative and presented to the respondents of the survey.

Respondents were requested to rate the identified CSFs using a five points Likert-scale. The Relative Importance Index (RII) was computed using equation (A).

3.5.2 Delphi round two

In the second round, the same questionnaire used in round one was again presented to the same experts to pose their rating or opinions for the second time. The first round survey analysis‘s summary and feedback of the first round were also presented to them. The panel feedback from the first round survey was provided to the panel as the number of responses in the percentage of the total responses. The answer provided by the respondents in round one was also indicted by a different colour.

Then the panel members were requested to reconsider their opinion on the level of importance given in the first round of survey and further asked to change or confirm their view after reviewing the analysis and feedback. The same rating mechanism as used in round one was again in place for analysing the second round feedback.

3.5.3 Delphi round three

From the facts established in round two, the top five CSFs were selected for the third round where it was tested by means of Analytical Hierarchical Process (AHP). The CSFs were tested using AHP by pairwise comparison. AHP software, version 04.05.2016, offered by Business Performance Management Singapore was used to analyze the data received by means of 1-9 rating scales between any two CSF.

This software was an AHP Excel template with maximum 20 inputs. The Excel template consists of worksheets for pair-wise comparison, a sheet for the consolidation of all feedbacks, a summary sheet to display result, a sheet for solving the eigenvalue problem using eigenvector method (EVM), and a sheet with reference tables which include random index, limits for geometric consistency index GCI, and judgment scales.

3.6 The Analytical Hierarchy Process- AHP

The Analytic Hierarchy Process (AHP), introduced by Thomas Saaty (1980), is an active tool for dealing with complex decision-making scenarios. It aids the decision maker to set priorities and make the best decision by reducing complex decisions to a series of pairwise comparisons, and then constructing the results. The AHP benefits to attain both the subjective and objective facets of a decision. Also, the AHP

integrates a beneficial technique for checking the consistency of the decision maker's assessments, thus reducing the partiality in the decision-making process.

Process of the AHP

The AHP is executed in three simple serial steps:

1) Computing the vector of criteria weights.
2) Computing the matrix of option scores.
3) Ranking the options.

Computing the vector of criteria weights

To figure out the weights for the different criteria, the AHP commences with creating a pairwise comparison matrix A. The matrix A is an $m \times m$ real matrix, where m is the number of evaluation criteria to be considered.

Each entry ajk of the matrix A represents the importance of the j^{th} criterion relative to the k^{th} criterion. If $a_{jk} > 1$, then the j^{th} criterion is more important than the k^{th} criterion, while if $a_{jk} < 1$, then the j^{th} criterion is less important than the k^{th} criterion. If two criteria have the same importance, then the entry $a_{jk} = 1$. The entries a_{jk} and a_{kj} satisfy the following constraint:

$$a_{jk}.\ a_{kj} = 1 \quad \textbf{(B)}$$

Obviously, $a_{jj} = 1$ for all j. The relative importance between two criteria is valued based on a numerical scale ranging from 1 to 9, as shown in Table 4. The expressions in the "Interpretation" column of Table 1 are only suggestive, and may be used to transform the decision maker's qualitative evaluations of the relative importance between two criteria into numbers.

Table 4: AHP relative scores

AHP rating scale for pair comparison (a_{ij})	**Numeric Rating**
Extreme Importance	9
Very strong to Extreme	8
Very Strong Importance	7
Strongly to Very Strong	6
Strong Importance	5
Moderately to Strong	4
Moderate Importance	3
Equally to Moderate	2
Equal Importance	1

The paired comparison scale between the comparison pair (a_{ij}) of two items (items i and item j) is as follows:

(Item i) 9-8-7-6-5-4-3-2-1-2-3-4-5-6-7-8-9 (Item j)

The preference scale for pair-wise comparisons of two items ranges from the maximum value 9 to 1/9 (0.111 in decimal from). Let aij represent the comparison between item-i (left) and item-j (right). If item-i is 5 times (strong importance) more important than item-j for a given criteria or product, then the comparison $a_{ji} = 1/a_{ij} = 1/5$ (0.200) or the reciprocal value for the paired comparison between both items.

After the Comparison matrix is formed, AHP terminates by computing an eigenvector (also called a priority vector) that represents the relative ranking of importance (or preference) attached to the criteria or objects being compared.

CHAPTER 4

ANALYSIS AND RESULTS

4.1 Introduction

The purpose of this research was to set directives to enhance the implementation of effective risk management practices in Sri Lankan construction projects. The research questions (RQ) framed in this study are as follows:

RQ 1: How the risk management techniques are currently used in the Sri Lankan construction projects with respect to risk identification techniques, risk analysis techniques, risk response techniques, and risk monitoring techniques?

RQ2: What are the barriers to the adoption, usage, and implementation of risk management practices in Sri Lankan construction projects?

RQ3: What are the Critical Success Factors (CSFs) for implementing risk management systems in Sri Lankan construction projects?

This research was carried out using the Delphi method. The Delphi method necessitates numerous rounds of anonymous data gathering, and in this study, three rounds were used to gather the data required for the research.

4.2 Delphi Round One

The purpose of the first round is to gather data on all three objectives of the research. In this round, twenty-one experts were identified to take part in the Delphi panel and a structured questionnaire, containing the relevant secondary data identified from the literature review, was distributed to the panel members. Out of 21 questionnaires distributed in total, 6 were distributed to the members in person and the other questionnaires were emailed to the members. In total, fifteen members had successfully responded to the survey in round one.

The response rate is 71.4 %. The panel members were identified based on their working experience in Sri Lankan construction industry and maturity to understand the current status of risk management practices in Sri Lanka.

Figure 8 shows the details of the Delphi panel members of the first round in terms of their experience in Sri Lankan Construction projects.

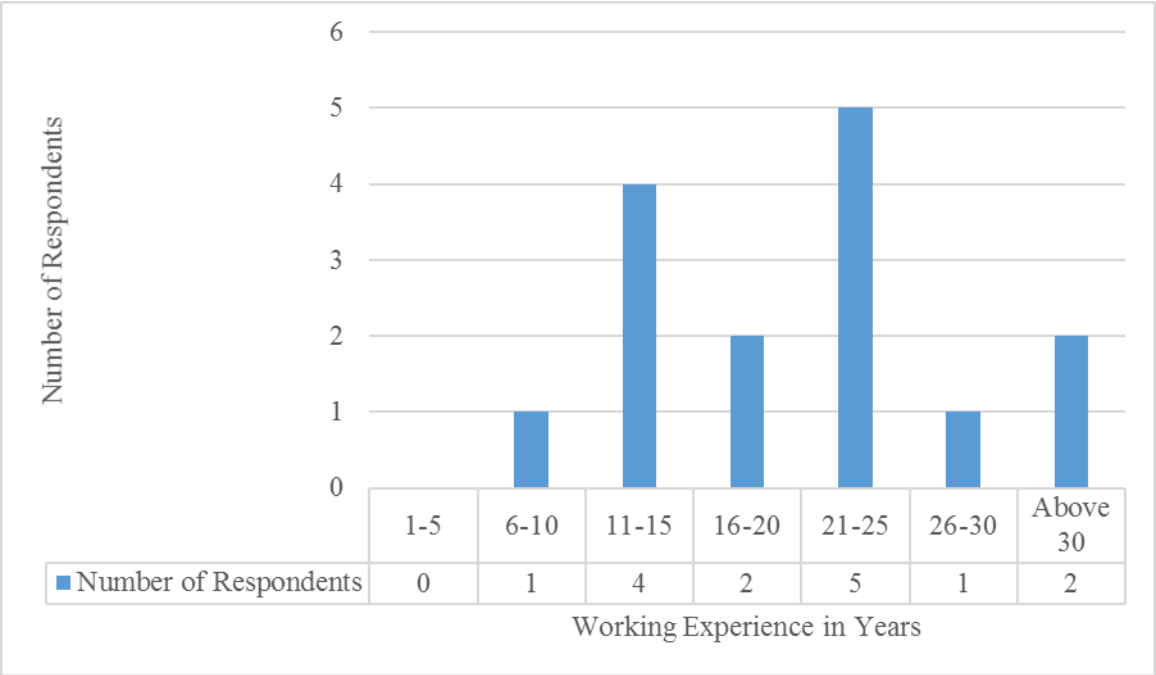

Figure 8: Experience details of the Delphi panel

The identified panel for the Delphi survey comprised of construction professionals from various disciplines of civil engineering such as road, building, irrigation and water supply with exposure to state and private sector construction projects.

All the panel members have the bachelor degree in civil engineering and a total of 10 members have postgraduate qualifications in construction project management while two other members have postgraduate qualifications in other civil engineering disciplines.

4.2.1 Current status of the use of Risk management techniques

This section presents the current status of the use of the available risk management techniques as rated by the panel members using five points Likert scale as follows after round one. The rank was given using Relative Importance Index.

4.2.1.1 Risk identification techniques

As it is shown in Table 5, the first round study revealed that out of many risk identification techniques available 'review of historical information' is the technique which is mostly used by construction professionals in identifying the risk factors in construction projects in Sri Lanka. At the next usage level, 'judgment based on experience' and 'check list' were ranked as second and third respectively. The 'Delphi technique' was found to be in very least level usage.

Table 5: Ratings of risk identification techniques in round one

Risk Identification Techniques	1	2	3	4	5	RII	Rank
1. Brainstorming	47%	13%	13%	20%	7%	0.454	5
2. Check list	7%	13%	60%	13%	7%	0.600	3
3. Review of historical information	13%	0%	20%	47%	20%	0.746	1
4. Judgment based on experience	0%	7%	27%	60%	7%	0.706	2
5. Root cause identification	0%	27%	60%	7%	7%	0.586	4
6. Delphi technique	73%	20%	0%	0%	7%	0.294	7
7. SWOT analysis	40%	33%	7%	20%	0%	0.414	6

4.2.1.2 Risk analysis techniques

Table 6 illustrates that 'judgment based on experience' is the only risk analysis technique used on a moderate scale in Sri Lanka while all the other techniques are not much in use with very low RII.

Table 6: Ratings of risk Analysis techniques in round one

Risk Analysis Techniques	1	2	3	4	5	RII	Rank
1. Probability and Impact model	60%	13%	13%	7%	7%	0.374	2
2. Analytical Hierarchy process	67%	20%	7%	0%	7%	0.320	3
3. Monte Carlo Simulation	67%	27%	0%	7%	0%	0.294	4
4. Judgment based on experience	20%	0%	13%	20%	47%	0.746	1

4.2.1.3 Risk response techniques

As illustrated in Table 7, the study revealed that 'risk avoidance' is the technique which is moderately used in practice while 'risk transfer' and 'risk reduction are also in the same level of use.

Table 7: Ratings of Risk Response Techniques in round one

Risk Response Techniques	1	2	3	4	5	RII	Rank
1. Risk avoidance	0%	13%	20%	67%	0%	0.706	1
2. Risk reduction	20%	13%	20%	40%	7%	0.600	3
3. Risk transfer	7%	13%	20%	53%	7%	0.680	2
4. Risk retention	67%	13%	13%	7%	0%	0.320	4

4.2.1.4 Risk monitoring techniques

As shown in Table 8, the findings of the first round survey regarding risk monitoring technique reveal that though there are various techniques available for risk monitoring, only 'status meeting' is widely used in the construction industry while 'corrective action' is also quite used as a tool for risk monitoring. All the other techniques available for risk monitoring have gained a very low score in terms of RII.

Table 8: Ratings of risk monitoring techniques in round one

Risk Monitoring Techniques	1	2	3	4	5	RII	Rank
1. Risk Reassessment	53%	13%	20%	7%	7%	0.400	5
2. Milestone Tracking	47%	13%	13%	20%	7%	0.454	4
3. Corrective Actions	0%	27%	20%	53%	0%	0.654	2
4. Top 10 Tracking	27%	13%	47%	0%	13%	0.520	3
5. Status Meetings	0%	20%	7%	27%	47%	0.800	1

4.2.2 Barriers to the adoption, usage, and implementation of Risk Management Systems

The following Table 8 shows the particulars of barriers to the adoption, usage, and implementation of Risk Management Systems as rated by the panel experts using five points Likert scale.

The first round survey of this study, as shown in Table 9, revealed that 'implementation cost' and 'poor awareness of risk management systems are the main reasons as to why the adoption, usage, and implementation of Risk Management Systems are very poor in Sri Lanka with very higher RII. 'Unavailability of risk management consultants', 'lack of information' and 'time constraints' are also equally considered to be major barriers to the adoption, usage, and implementation of Risk Management Systems with relatively higher RII.

Table 9: Ratings of barriers to the adoption, usage, and implementation of Risk Management Systems in round one

Barriers	1	2	3	4	5	RII	Rank
1. Poor-awareness of risk management systems	0%	7%	13%	20%	60%	0.866	2
2. Lack of experience	0%	13%	13%	60%	13%	0.746	6
3. Lack of coordination between stakeholders	0%	13%	7%	73%	7%	0.746	6
4. Lack of information	7%	7%	13%	27%	47%	0.800	4
5. Unavailability of risk management consultants	0%	7%	20%	20%	53%	0.840	3
6. Implementation cost	0%	0%	7%	33%	60%	0.906	1
7. Time constraints	0%	7%	13%	53%	27%	0.800	4

4.2.3 Critical Success Factors (CSFs) for implementing risk management systems

Table 10 displays the details of the first round survey in analyzing the Critical Success Factors (CSFs) for implementing risk management systems in Sri Lankan construction projects as rated by the Delphi panel members. Five points Likert scale was used to rate the CSFs.

Table 10: Ratings of Critical Success Factors (CSFs) for implementing risk management systems

Critical Success Factors (CSFs)	**1**	**2**	**3**	**4**	**5**	**RII**	**Rank**
CSF1: Support from managers for implementing risk management systems.	0%	13%	7%	60%	20%	0.774	5
CSF2: Awareness of risk management systems among stakeholders.	0%	13%	13%	13%	60%	0.840	1
CSF3: Request for Implementation of Risk Management Systems (IRMS) on projects by clients and end users.	0%	7%	27%	13%	53%	0.826	2
CSF4: Incorporating IRMS among the strategic objectives of organizations involved in projects.	0%	20%	20%	47%	13%	0.706	7
CSF5: Taking into account the effects of the business environment surrounding projects.	7%	13%	47%	20%	13%	0.640	10
CSF6: Attempting to deliver projects systematically on time and within project's budget.	7%	7%	20%	20%	47%	0.786	4

CSF7: Promoting teamwork and communication among the stakeholders.	7%	13%	20%	47%	13%	0.694	8
CSF8: Availability of specialist risk management consultants.	7%	13%	47%	13%	20%	0.654	9
CSF9: Including the costs within project's budgets for IRMS.	7%	0%	13%	67%	13%	0.760	6
CSF10: Inclusion of risk management systems in engineering education and training modules of construction practitioners.	13%	0%	7%	27%	53%	0.814	3

The first round study of this research depicts that the top three CSFs, (CSF2: Awareness of risk management systems; CSF3: Request for Implementation of Risk Management Systems (IRMS) on projects by clients and end users; CSF10: Inclusion of risk management systems in engineering education and training modules of construction practitioners), are so imperative for implementing risk management systems in Sri Lanka as the RIIs for these three CSFs are 0.840, 0.826, and 0.814 respectively.

The study further reveals that all the other CSFs ranked in the study are also considered to be fairly significant in the process of implementing risk management systems in Sri Lanka as far as the corresponding RII values of the CSFs are concerned.

4.3 Delphi Round Two

In Delphi round two, the panel members were presented the summarized panel feedback from questionnaire one. It was presented as the number of responses in the percentage of the total responses. The objective of the Delphi round questionnaire two was to offer a chance for the panel experts to reassess their feedback, provided in questionnaire one, and to confirm or revise the feedback having reviewed the consensus of the experts. The panel members were requested to let the answer box as

it is if they still stand with the same answer or else to coulor a different box if they decide to change the previous answer. A total of 15 questionnaires were distributed to the experts who were responsive in round one and all the questionnaires were collected on time with 100% response rate.

4.3.1 Current status of the use of risk management techniques

4.3.1.1 Risk identification techniques

In the second round, the common consensus was achieved among the experts establishing that 'judgment based on experience' is the risk identification technique constantly used in Sri Lanka while 'review of historical information' was ranked two as the second best in practice. The third rank established on 'checklist' was not changed in the second round. Table 11 shows the ratings obtained after the second round of survey.

Table 11: Ratings of risk identification techniques in round two

Risk Identification Techniques	1	2	3	4	5	RII	Rank
1. Brainstorming	47%	13%	13%	20%	7%	0.454	5
2. Check list	7%	7%	67%	13%	7%	0.614	3
3. Review of historical information	7%	7%	20%	47%	20%	0.734	2
4. Judgment based on experience	0%	0%	20%	80%	0%	0.760	1
5. Root cause identification	0%	20%	73%	0%	7%	0.586	4
6. Delphi technique	73%	20%	0%	0%	7%	0.294	7
7. SWOT analysis	47%	27%	7%	20%	0%	0.400	6

Table 12 depicts the comparison between the first round and second round ranking.

Table 12: Comparison of risk identification techniques between round one and round two

Risk Identification Techniques	First Round		Second Round	
	RII	Rank	RII	Rank
1. Brainstorming	0.454	5	0.454	5
2. Check list	0.600	3	0.614	3
3. Review of historical information	0.746	1	0.734	2
4. Judgment based on experience	0.706	2	0.760	1
5. Root cause identification	0.586	4	0.586	4
6. Delphi technique	0.294	7	0.294	7
7. SWOT analysis	0.414	6	0.400	6

4.3.1.2 Risk analysis techniques

After round two, the experts' views confirmed the results obtained in round one with slide changes in RII values as shown in Table 13. Hence it has been established that risk factors associated with construction projects in Sri Lanka are basically analyzed using 'judgment based on experience'. Other available techniques in the body of knowledge are very rarely placed into practice.

Table 13: Ratings of risk analysis techniques in round two

Risk Analysis Techniques	1	2	3	4	5	RII	Rank
1. Probability and Impact model	67%	7%	13%	7%	7%	0.360	2
2. Analytical Hierarchy process	67%	20%	7%	0%	7%	0.320	3
3. Monte Carlo Simulation	73%	20%	0%	7%	0%	0.280	4
4. Judgment based on experience	20%	0%	13%	7%	60%	0.774	1

Table 14 depicts the comparison between first round and second round ranking.

Table 14: Comparison of risk analysis techniques between round and round two

Risk Analysis Techniques	First Round		Second Round	
	RII	Rank	RII	Rank
1. Probability and Impact model	0.374	2	0.360	2
2. Analytical Hierarchy process	0.320	3	0.320	3
3. Monte Carlo Simulation	0.294	4	0.280	4
4. Judgment based on experience	0.746	1	0.774	1

4.3.1.3 Risk response techniques

In the second round of survey as shown in Table 15, the ranks obtained in round one have not been changed for risk response techniques.

Table 15: Ratings of risk response techniques in round two

Risk Response Techniques	1	2	3	4	5	RII	Rank
1. Risk Avoidance	0%	0%	20%	80%	0%	0.760	1
2. Risk reduction	20%	7%	13%	60%	0%	0.626	3
3. Risk transfer	7%	7%	27%	53%	7%	0.694	2
4. Risk retention	67%	13%	13%	7%	0%	0.320	4

Table 16 shows the comparison between round one and round two.

Table 16: Comparison of risk response techniques between round and round two

Risk Response Techniques	First Round		Second Round	
	RII	Rank	RII	Rank
1. Risk Avoidance	0.706	1	0.760	1
2. Risk reduction	0.600	3	0.626	3
3. Risk sharing	0.680	2	0.694	2
4. Risk retention	0.320	4	0.320	4

4.3.1.4 Risk monitoring techniques

As shown in Table 17, the second round study has established that 'status meeting' and 'corrective actions' are moderately used in Sri Lanka for risk monitoring purpose. Other techniques are not much used in Sri Lanka.

Table 17: Ratings of Risk Monitoring Techniques in round two

Risk Monitoring Techniques	1	2	3	4	5	RII	Rank
1. Risk Reassessment	60%	7%	20%	7%	7%	0.386	5
2. Milestone Tracking	60%	13%	0%	20%	7%	0.400	4
3. Corrective Actions	0%	13%	20%	67%	0%	0.706	2
4. Top 10 Tracking	27%	13%	47%	0%	13%	0.520	3
5. Status Meetings	0%	20%	7%	20%	53%	0.814	1

Table 18 shows the rating comparison between round one and round two.

Table 18: Comparison of risk monitoring techniques between round and round two

Risk Monitoring Techniques	First Round		Second Round	
	RII	Rank	RII	Rank
1. Risk Reassessment	0.400	5	0.386	5
2. Milestone Tracking	0.454	4	0.400	4
3. Corrective Actions	0.654	2	0.706	2
4. Top 10 Tracking	0.520	3	0.520	3
5. Status Meetings	0.800	1	0.814	1

4.3.2 Barriers to the Adoption, Usage, and Implementation of Risk Management Systems

The second round survey of this study has established that 'implementation cost' and 'poor awareness of risk management systems are the main reasons as to why the adoption, usage, and implementation of Risk Management Systems are very poor in Sri Lanka with very higher RII.

'Unavailability of risk management consultants', 'lack of information' and 'time constraints' are also equally considered to be major barriers to the adoption, usage, and implementation of Risk Management Systems with relatively higher RII. The findings of the second round study have not changed considerably from the round one study as shown in Table 19.

Table 19: Ratings of Barriers to the Adoption, Usage, and Implementation of Risk Management Systems in round two

Barriers	1	2	3	4	5	RII	Rank
1. Poor-awareness of risk management systems	0%	0%	13%	20%	67%	0.906	2
2. Lack of experience	0%	7%	13%	73%	7%	0.760	6
3. Lack of coordination between stakeholders	0%	13%	0%	80%	7%	0.760	6
4. Lack of information	7%	7%	13%	27%	47%	0.800	5
5. Unavailability of risk management consultants	0%	7%	20%	13%	60%	0.854	3
6. Implementation cost	0%	0%	7%	27%	67%	0.920	1
7. Time constraints	0%	7%	7%	60%	27%	0.814	4

Table 20 shows the comparison between round one and round two.

Table 20: Comparison of the Ratings of Barriers to the adoption, usage, and implementation of risk management in round one and two

Barriers	First Round		Second Round	
	RII	Rank	RII	Rank
1. Poor-awareness of risk management systems	0.866	2	0.906	2
2. Lack of experience	0.746	6	0.760	6
3. Lack of coordination between stakeholders	0.746	6	0.760	6
4. Lack of information	0.800	4	0.800	5
5. Unavailability of risk management consultants	0.840	3	0.854	3
6. Implementation cost	0.906	1	0.920	1
7. Time constraints	0.800	4	0.814	4

4.3.3 Critical Success Factors (CSFs) for implementing risk management systems

Table 21 displays the details of the first round survey in analyzing the Critical Success Factors (CSFs) for implementing risk management systems in Sri Lankan construction projects as rated by the Delphi panel members.

Table 21: Ratings of Critical Success Factors (CSFs) for implementing risk management systems in round two

Critical Success Factors (CSFs)	1	2	3	4	5	RII	Rank
CSF1: Support from managers for implementing risk management systems.	0%	13%	7%	80%	0%	0.734	7
CSF2: Awareness of risk management systems among stakeholders.	0%	7%	13%	13%	67%	0.880	3
CSF3: Request for Implementation of Risk Management Systems (IRMS) on projects by clients and end users.	0%	0%	20%	7%	73%	0.906	1
CSF4: Incorporating IRMS among the strategic objectives of organizations involved in projects.	0%	13%	7%	73%	7%	0.746	6
CSF7: Promoting team work and communication among the stakeholders.	0%	13%	20%	53%	13%	0.734	7
CSF5: Taking into account the effects of the business environment surrounding projects.	7%	0%	60%	20%	13%	0.666	9
CSF6: Attempting to deliver projects systematically on time and within project's budget.	7%	7%	20%	13%	53%	0.800	4

CSF8: Availability of specialist risk management consultants.	7%	13%	53%	13%	13%	0.626	10
CSF9: Including the costs within project's budgets for IRMS.	7%	0%	7%	80%	7%	0.760	5
CSF10: Inclusion of risk management systems in engineering education and training modules of construction practitioners.	7%	0%	7%	13%	73%	0.894	2

The second round study found the following top five CSFs for the implementation of risk management systems in Sri Lankan construction projects.

Rank 1- CSF3: Request for Implementation of Risk Management Systems (IRMS) on projects by clients and end users.

Rank 2- CSF10: Inclusion of risk management systems in engineering education and training modules of construction practitioners.

Rank 3 - CSF2: Awareness of risk management systems among stakeholders.

Rank 4 - CSF6: Attempting to deliver projects systematically on time and within project's budget.

Rank 5 - CSF9: Including the costs within project's budgets for IRMS.

The study further reveals that all the other CSFs ranked in the study are also considered to be impartially significant in the process of implementing risk management systems in Sri Lanka as far as the corresponding RII values of the CSFs are concerned. Table 22 shows the comparison between round one and round two.

Table 22: Comparison of the ratings of Critical Success Factors (CSFs) for implementing risk management systems in round one and two

Critical Success Factors (CSFs)	First Round		Second Round	
	RII	**Rank**	**RII**	**Rank**
CSF1: Support from managers for implementing risk management systems.	0.774	5	0.734	7
CSF2: Awareness of risk management systems among stakeholders.	0.840	1	0.880	3
CSF3: Request for Implementation of Risk Management Systems (IRMS) on projects by clients and end users.	0.826	2	0.906	1
CSF4: Incorporating IRMS among the strategic objectives of organizations involved in projects.	0.706	7	0.746	6
CSF5: Taking into account the effects of the business environment surrounding projects.	0.640	10	0.666	9
CSF6: Attempting to deliver projects systematically on time and within project's budget.	0.786	4	0.800	4
CSF7: Promoting teamwork and communication among the stakeholders.	0.694	8	0.734	7
CSF8: Availability of specialist risk management consultants.	0.654	9	0.626	10
CSF9: Including the costs within project's budgets for IRMS.	0.760	6	0.760	5
CSF10: Inclusion of risk management systems in engineering education and training modules of construction practitioners.	0.814	3	0.894	2

4.4 Delphi round three

4.4.1 Critical Success Factors (CSFs) for implementing risk management systems

From the facts established in round two, the top five CSFs were chosen for the third round where it was tested by means of Analytical Hierarchical Process (AHP). The CSFS were tested with AHP under pairwise comparison. The freely available AHP software, version 04.05.2016, offered by Business Performance Management Singapore was used to analyze the data received by means of 1-9 rating scales between any two CSF.

This software was an AHP Excel template with maximum 20 inputs. The work consists of worksheets for pair-wise comparison, a sheet for the consolidation of all feedbacks, a summary sheet to display result, a sheet for solving the eigenvalue problem using eigenvector method (EVM), and a sheet with reference tables which include random index, limits for geometric consistency index GCI, and judgment scales.

For AHP analyses, a perfectly consistent decision maker should always obtain Consistency Index (CI) = 0, but small values of inconsistency may be tolerated. In particular, if Consistency Ratio (CR) < 0.1 (CR=CI/RI); whereas RI means Random Index. RI value for five criteria (small problems) is 1.12 (Saaty, 1980).

Hence, Consistency Index (CR) obtained in every input of the study was figured out and found to be in acceptable limit except only two inputs with CI/RI values 0.11 and0.12; whereas CI/RI value below 0.1 is generally acceptable.

Figure 9 and Figure 10 shows the weighted geometric mean of participants and comparison matrix respectively as generated by the spreadsheet sheet.

	1	2	3	4	5	6	7	8	9	10
1		3.331	3.329	1.939	0.993	0	0	0	0	0
2	0.3		0.993	0.808	0.318	0	0	0	0	0
3	0.3	1.007		0.558	0.228	0	0	0	0	0
4	0.516	1.238	1.792		0.683	0	0	0	0	0
5	1.007	3.144	4.389	1.464		0	0	0	0	0
6	0	0	0	0	0		0	0	0	0
7	0	0	0	0	0	0		0	0	0
8	0	0	0	0	0	0	0		0	0
9	0	0	0	0	0	0	0	0		0
10	0	0	0	0	0	0	0	0	0	

Figure 9: Weighted geometric mean of participants

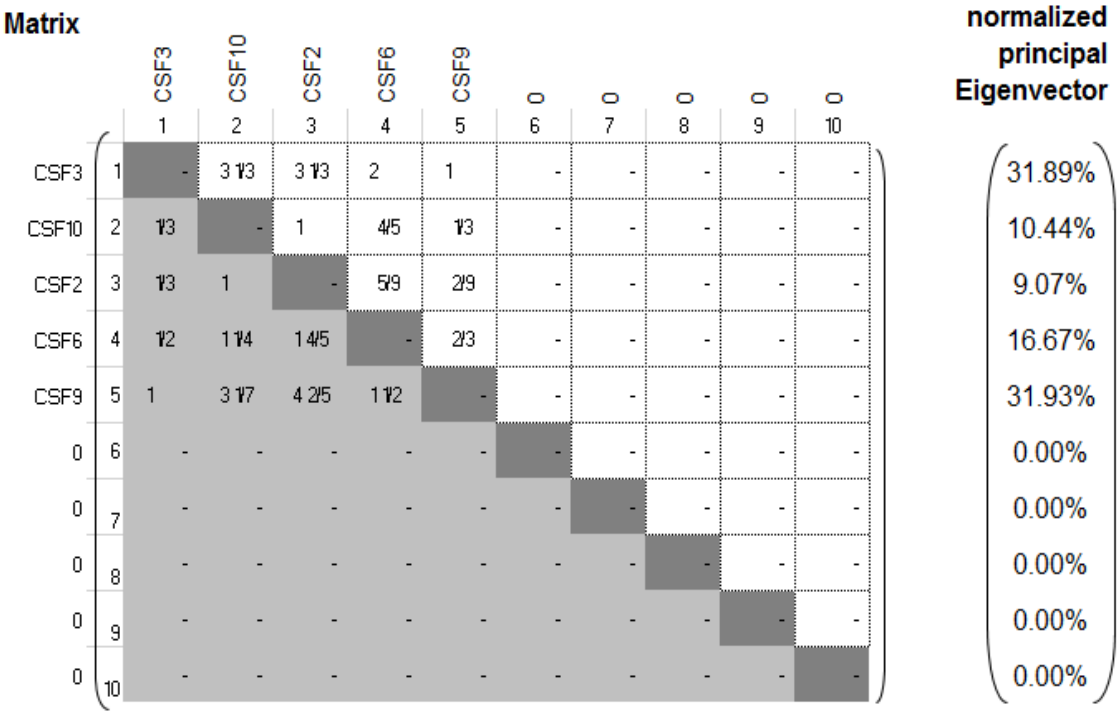

Figure 10: Comparison matrix

As shown in the result Table 23 with regard to calculated weights and rank using the EVM, the third round survey had concluded that CSF9 and CSF3 are almost equally important with a very tiny margin of calculated weights whereas CSF9 was ranked to be the first and CSF3 came to be the second in ranking. The third, fourth, and fifth

CSFs are CSF6, CSF10, and CSF2 respectively. The consensus indicator ranges from 0% (no consensus between decision makers) to 100% (full consensus between decision makers). The consensus indicator reached in the study was 67.6%. Principle Eigen Value Lambda of the analysis was 5.044. So the results show that a significant level of consensus has been achieved among the Delphi expert panel members.

Table 23: Ratings of CSFs in round three using AHP

Se. No	CSFs	Normalized Principle Eigenvector (%)	Rank
1	CSF3	31.89	2
2	CSF10	10.44	4
3	CSF2	9.07	5
4	CSF6	16.67	3
5	CSF9	31.93	1

4.4.2 Comparison of CSFs with other developing countries

According to the study conducted by Chileshe & Kikwasi (2014), 'Awareness of risk management systems among stakeholders' was rated to the very top as the foremost CSF in implementing risk management systems in Tanzania. The study steered by Hosseini, Chileshe, Jepson, & Arashpour, (2016) had concluded that 'Support from managers for implementing risk management systems' is the most influencing CSF in implementing risk management systems in Iran. The both of the studies available in the literature, contextualized to developing countries, are not brought into line with the findings of this study whereas 'Including the costs within project's budgets for IRMS' is concluded to be the foremost prompting CSF for the successful implementation of risk management systems in Sri Lankan construction projects. Table 24 shows the further comparison between the findings of the current research and previous similar studies.

Table 24: Comparison of the research findings between the current study and previous studies

Studies	Top 5 Rating of CSFs				
	Rank 1	**Rank 2**	**Rank 3**	**Rank 4**	**Rank 5**
(Chileshe & & Kikwasi, 2014)	Awareness of Risk management Processes	Teamwork and cooperation	Management style	Effective use of methods and tools	Goals and strategic objectives of the organization
(Hosseini, Chileshe, Jepson, & Arashpour, 2016).	Support from managers	Inclusion of risk management systems in engineering education and training modules of construction practitioners.	Promoting team work and communication among the stakeholders	Attempting to deliver projects systematically on time and within project's budget.	Awareness of risk management systems among stakeholders
Present Study	Including the costs within project's budgets for IRMS.	Request for Implementation of Risk Management Systems (IRMS) on projects by clients and end users.	Attempting to deliver projects systematically on time and within project's budget.	Inclusion of risk management systems in engineering education and training modules of construction practitioners.	Awareness of risk management systems among stakeholders

Even though a precise alignment is not found among the findings of the studies, a slight unison has been observed with the finding of the studies conducted by Hosseini, Chileshe, Jepson, & Arashpour, (2016). and the present study whereas ‘Inclusion of risk management systems in engineering education and training modules of construction practitioners’, ‘Attempting to deliver projects systematically on time and within project’s budget’, and ‘Awareness of risk management systems among stakeholders’ are established within the top five CSFs to promote risk management systems in developing countries’ construction projects.

CHAPTER 5

CONCLUSION

As a summary of findings on the actual usage of risk management techniques, construction professionals in Sri Lanka mostly use only their experience and historical information to make major risk management decisions while the other classy techniques are ignored or not studied. The findings of the study eventually conclude that the usage level of risk management techniques in Sri Lankan construction projects is in poor status.

The study has established that the cost incurred for implementing risk management systems is the first most reason for not trying to focus on implementing risk management systems in Sri Lankan construction projects. After this barrier, poor awareness of risk management systems among construction professionals is the second most reason which doesn't push the Sri Lankan construction industry towards implementing risk management systems. It is also found that unavailability of risk management consultants or experts in the country is the third most barriers for implementing risk management systems. Lack of information and time constraints are the other barriers to the adoption, usage, and implementation of construction risk management systems in Sri Lanka.

The present study attempted to develop the CSFs for implementing risk management systems in construction projects with a special reference to Sri Lanka. After three rounds of the survey, this research concluded that 'Including the costs within project's budgets for IRMS' is the most important CSF to successfully deploy the risk management systems in Sri Lankan construction projects.

The study reveals the construction stakeholders are to be keener on allocating money resources for proper risk management systems since it is going to pay back through enhanced and fully accomplished project objectives. The investment in the compulsory implementation of risk management systems will certainly carry return on project performance in countries such as Sri Lanka where risk management is not significantly implemented.

The second most and almost equally important CSF to ranked one CSF found through the study is 'Request for Implementation of Risk Management Systems (IRMS) on projects by clients and end users'. This CSF is regarded as much important as the ranked one CSF does when the weighted values are concerned. The initiation of risk management systems within projects should originate from clients or end users of the projects so that the rest of the parties would join hands in the process of implementing risk management systems.

The study further explores that 'Attempting to deliver projects systematically on time and within project's budget', 'Inclusion of risk management systems in engineering education and training modules of construction practitioners', and 'Awareness of risk management systems among stakeholders' are regarded as important factors for IRMS. Construction practitioners in Sri Lanka should attempt to deliver projects systematically respecting major project constraints such as time and budget. Systematic delivery of projects demands an in-depth exposure to knowledge, skills and tools and techniques of project management body of knowledge. Therefore, it is reasonable to say that engineering education and training modules should include in-depth project management contents in teaching spectrum, in particular, risk management systems. The knowledge on systematic project management will certainly be a driving factor for construction professionals to be more attentive on IRMS.

Even though a precise alignment is not found among the findings of the studies, a slight unison has been observed with the available past studies. 'Inclusion of risk management systems in engineering education and training modules of construction practitioners', 'Attempting to deliver projects systematically on time and within project's budget', and 'Awareness of risk management systems among stakeholders' are established within the top five CSFs to promote risk management systems in developing countries' construction projects.

This study brings some additions to the risk management body of knowledge as past studies were not attentive on exploring the critical success factors for executing risk management systems in developing nations such as Sri Lanka. This study has

endeavored to apply the existing theories, drawn from previous researches, to a different context and validated the CSFs for IRMS in Sri Lanka which is one of the developing countries in the world. Hence this has expanded the body of knowledge of construction risk management for the developing world. This extension of the body of knowledge has drawn a new perspective for addressing the difficulties related to the execution of risk management systems in the developing world. Though, the available literature is not sufficient enough in order to reach a common consensus on the knowledge of CSFs for IRMS in construction projects of developing world. So this study has taken a step forward to assist in finding generalizability of CSFs for IRMS in developing world.

In real sense, the findings of this study will be more beneficial to up bring the construction professionals' consciousness towards CSFs prompting the IRMS in developing world like Sri Lanka. This research will set routes for top level managers to endorse training programmes and educational reforms towards construction risk management.

It is also very factual that a solid conclusion towards CSFs in developing world context should be carefully reached only if these CSFs are tested and validated in some more similar countries. CSFs for IRMS should be separately studied in different types of projects. In this background, this research has shown paths to go for future researches in this study area.

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APPENDIXES

Annex-A

M.Sc. in Construction Project Management

Department of Civil Engineering

University of Moratuwa

Dear Sir / Madam,

I am a Post Graduate student at Department of Civil Engineering, Faculty of Engineering, University of Moratuwa. As a partial fulfillment of the M.Sc. degree programme, I need to carry out a research project in the study area. The study details are as follows:

Title:

INVESTIGATION OF CRITICAL SUCCESS FACTORS (CSFs) FOR THE DEPLOYMENT OF CONSTRUCTION RISK MANAGEMENT PRACTICES IN SRI LANKA

Aim:

This research is aimed to answer the question "how the risk management practices could be promoted and enhanced in Sri Lankan construction industry?"

Objectives:

- To study what risk management techniques are actually used at the project level or organization level.
- To identify the barriers to the adoption, usage, and implementation of risk management systems in Sri Lankan construction projects.
- To develop the Critical Success Factors (CSFs) for implementing risk management systems in Sri Lankan construction projects.

This study is designed to be carried out using **DELPHI TECHNIQUE**. The Delphi technique is a method which is used to collect data from a panel of experts in several rounds in order to achieve a consensus on the decision. The participants of the survey

are not supposed to interrelate with each other and their views are kept secret while the summarized result from the previous round is provided for them to reconsider their opinions.

I am pleased to inform you that you have been selected to take part in this survey and kindly request your fullest participation and cooperation throughout the survey with two rounds. For the first round, it would be grateful if you could spend your valuable time to answer all the questions in this questionnaire, as it is directed. This questionnaire will be used for academic purpose only. It is designed as a tool for collecting primary data for the research.

I assure that this information will be kept confidential and only the summarized results will be provided in the report and therefore no specific reference will be made to experts who take part in this survey.

Thank you.

Yours Faithfully,

ALM. Risath
M.Sc. Candidate
Mobile : 077-254-6898

Research Supervisor:
Dr. Chandana Siriwardana
Senior Lecturer
Department of Civil Engineering
Faculty of Engineering
University of Moratuwa
Mobile: 077-755-5655

This survey is designed to be carried out in three Delphi rounds.

DELPHI ROUND # 01

QUESTIONNAIRE – PART 1

General Information

Name of the respondent :

Name of the organization :

Designation :

Working experience :

1 - 5 Years ☐

10 - 15 Years ☐

16 - 20 Years ☐

21 - 25 Years ☐

26 - 30 Years ☐

Above 30 Years ☐

Email :

Telephone / Mobile :

QUESTIONNAIRE – PART 2

This part of the questionnaire will examine the current risk management practices used in Sri Lankan construction projects. Various risk management techniques identified from previous studies are listed below and the respondents are requested to put their view on **To What Extent** these techniques are used in Sri Lankan construction projects. Please use 1-5 Likert-scale for indicating your opinion on the extent of use.

1= Very low use

2= low use

3= Neutral

4= High use

5= Very high use

a) Risk Identification Techniques:	**1**	**2**	**3**	**4**	**5**
1. Brainstorming					
2. Check list					
3. Review of historical information					
4. Judgment based on experience					
5. Root cause identification					
6. Delphi technique					
7. SWOT analysis					
Specify any other techniques:					

b) Risk Analysis Techniques:	1	2	3	4	5
1. Probability and Impact model					
2. Analytical Hierarchy process					
3. Monte Carlo Simulation					
4. Judgment based on experience					
Specify any other techniques:					

c) Risk Response Techniques:	1	2	3	4	5
1. Risk avoidance					
2. Risk reduction					
3. Risk transfer					
4. Risk retention					
Specify any other techniques:					

d) Risk Monitoring techniques:	1	2	3	4	5
1. Risk Reassessment					
2. Milestone Tracking					
3. Corrective Actions					
4. Top 10 Tracking					
5. Status Meetings					
Specify any other techniques:					

QUESTIONNAIRE – PART 3

This section of the questionnaire is to identify the barriers to the adoption, usage, and implementation of risk management systems in Sri Lankan construction projects. The barriers were identified from past studies of similar nature in various countries. The respondents are requested to rate their opinions on these identified barriers using five points Likert- scale as follows:

1= Strongly disagree

2= Disagree

3= Neutral

4= Agree

5= Strongly agree

Barriers	1	2	3	4	5
1. Poor-awareness of risk management systems					
2. Lack of experience					
3. Lack of coordination between stakeholders					
4. Lack of information					
5. Unavailability of risk management consultants					
6. Implementation cost					
7. Time constraints					
Specify any other barriers:					

QUESTIONNAIRE – PART 4

This section of the questionnaire is to identify the Critical Success Factors (CSFs) for implementing risk management systems in Sri Lankan construction projects. The CSFs were identified from past studies of similar nature in the various part of the

world. The respondents are requested to rate their opinions on these identified CSFs using a five points Likert- scale as follows:

1= Strongly disagree

2= Disagree

3= Neutral

4= Agree

5= Strongly agree

Critical Success Factor (CSF)	**1**	**2**	**3**	**4**	**5**
CSF1: Support from managers for implementing risk management systems.					
CSF2: Awareness of risk management systems among stakeholders.					
CSF3: Request for **Implementation of Risk Management Systems** (**IRMS**) on projects by clients and end users.					
CSF4: Incorporating **IRMS** among the strategic objectives of organizations involved in projects.					
CSF5: Taking into account the effects of the business environment surrounding projects.					
CSF6: Attempting to deliver projects systematically on time and within project's budget.					
CSF7: Promoting teamwork and communication among the stakeholders.					
CSF8: Availability of specialist risk management consultants.					

CSF9: Including the costs within project's budgets for **IRMS**.					
CSF10: Inclusion of risk management systems in engineering education and training modules of construction practitioners.					
Specify any other CSFs:					

Annex-B

INVESTIGATION OF CRITICAL SUCCESS FACTORS (CSFs) FOR THE DEPLOYMENT OF CONSTRUCTION RISK MANAGEMENT PRACTICES IN SRI LANKA

M.Sc. in Construction Project Management

Department of Civil Engineering

University of Moratuwa

Dear Sir / Madam,

I take this juncture to thank you for your speedy response to the Questionnaire One of this study. You have stretched your hands to help this research by spending your valuable time from your tight schedules.

As it was informed in the Questionnaire One, I have prepared the Questionnaire Two with the same set of questions to be presented to the same panel of experts while providing the panel feedback from the questionnaire one. This questionnaire will be used for academic purpose only. It is designed as a tool for collecting primary data for the research. I assure that this information will be kept confidential and only the summarized results will be provided in the report and therefore no specific reference will be made to experts who take part in this survey.

It will be highly appreciated if you could spend a few minutes to complete this questionnaire and return it to me at your earliest.

Thank you.

Yours Faithfully,

A.L.M. Risath
M.Sc. Candidate
Mobile : 077-254-6898

Supervisor:

Dr. ChandanaSiriwardana
Senior Lecturer
Department of Civil Engineering
Faculty of Engineering
University of Moratuwa

QUESTIONNAIRE TWO

Name of the Respondent:

Instructions:

- The panel feedback from the **Questionnaire One** is provided below as the number of responses in the percentage of the total responses. The answer provided by you in the Questionnaire One has been shown by the grey colour box.
- You are kindly requested to let the box as it is if you still stand with the same answer or else please coulor a different box if you decide to change the previous answer.

PART 1: RISK MANAGEMENT PRACTICES

1= Very low use

2= low use

3= Neutral

4= High use

5= Very high use

Risk Identification Techniques:	**Number of response as a percentage of total responses**				
	1	**2**	**3**	**4**	**5**
1. Brainstorming	47%	13%	13%	20%	7%
2. Check list	7%	13%	60%	13%	7%
3. Review of historical information	13%	0%	20%	47%	20%
4. Judgment based on experience	0%	7%	27%	60%	7%
5. Root cause identification	0%	27%	60%	7%	7%
6. Delphi technique	73%	20%	0%	0%	7%
7. SWOT analysis	40%	33%	7%	20%	0%

Risk Analysis Techniques:	Number of response as a percentage of total responses				
	1	2	3	4	5
1. Probability and Impact model	60%	13%	13%	7%	7%
2. Analytical Hierarchy process	67%	20%	7%	0%	7%
3. Monte Carlo Simulation	67%	27%	0%	7%	0%
4. Judgment based on experience	20%	0%	13%	20%	47%

Risk Response Techniques:	Number of response as a percentage of total responses				
	1	2	3	4	5
1. Risk avoidance	0%	13%	20%	67%	0%
2. Risk reduction	20%	13%	20%	40%	7%
3. Risk transfer	7%	13%	20%	53%	7%
4. Risk retention	67%	13%	13%	7%	0%

Risk Monitoring techniques:	Number of response as a percentage of total responses				
	1	2	3	4	5
1. Risk Reassessment	53%	13%	20%	7%	7%
2. Milestone Tracking	47%	13%	13%	20%	7%
3. Corrective Actions	0%	27%	20%	53%	0%
4. Top 10 Tracking	27%	13%	47%	0%	13%
5. Status Meetings	0%	20%	7%	27%	47%

PART 2: BARRIERS TO THE ADOPTION, USAGE, AND IMPLEMENTATION OF RISK MANAGEMENT SYSTEMS

1= Strongly disagree

2= Disagree

3= Neutral

4= Agree

5= Strongly agree

Barriers	Number of response as a percentage of total responses				
	1	**2**	**3**	**4**	**5**
1. Poor-awareness of risk management systems	0%	7%	13%	20%	60%
2. Lack of experience	0%	13%	13%	60%	13%
3. Lack of coordination between stakeholders	0%	13%	7%	73%	7%
4. Lack of information	7%	7%	13%	27%	47%
5. Unavailability of risk management consultants	0%	7%	20%	20%	53%
6. Implementation cost	0%	0%	7%	33%	60%
7. Time constraints	0%	7%	13%	53%	27%

PART 3: CRITICAL SUCCESS FACTORS (CSFS) FOR IMPLEMENTING RISK MANAGEMENT SYSTEMS

1= Strongly disagree

2= Disagree

3= Neutral

4= Agree

5= Strongly agree

Critical Success Factor (CSF)	Number of response as the percentage of total responses				
	1	**2**	**3**	**4**	**5**
CSF1: Support from managers for implementing risk management systems.	0%	13%	7%	60%	20%
CSF2: Awareness of risk management systems among stakeholders.	0%	13%	13%	13%	60%
CSF3: Request for **Implementation of Risk Management Systems** (**IRMS**) on projects by clients and end users.	0%	7%	27%	13%	53%
CSF4: Incorporating **IRMS** among the strategic objectives of organizations involved in projects.	0%	20%	20%	47%	13%
CSF5: Taking into account the effects of the business environment surrounding projects.	7%	13%	47%	20%	13%
CSF6: Attempting to deliver projects systematically on time and within project's budget.	7%	7%	20%	20%	47%
CSF7: Promoting team work and communication among the stakeholders.	0%	13%	20%	53%	13%
CSF8: Availability of specialist risk management consultants.	7%	13%	47%	13%	20%
CSF9: Including the costs within project's budgets for **IRMS**.	7%	0%	13%	67%	13%
CSF10: Inclusion of risk management systems in engineering education and training modules of construction practitioners.	13%	0%	7%	27%	53%

Annex-C

INVESTIGATION OF CRITICAL SUCCESS FACTORS (CSFs) FOR THE DEPLOYMENT OF CONSTRUCTION RISK MANAGEMENT PRACTICES IN SRI LANKA

M.Sc. in Construction Project Management

Department of Civil Engineering

University of Moratuwa

Dear Sir / Madam,

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It will be highly appreciated if you could spend a few minutes to complete this questionnaire and return it to me at your earliest.

Thank you.

Yours Faithfully,

ALM. Risath

M.Sc. Candidate

Mobile : 077-254-6898

Supervisor:

Dr. ChandanaSiriwardana

Senior Lecturer

Department of Civil Engineering

Faculty of Engineering

University of Moratuwa

QUESTIONNAIRE THREE

Name of the Respondent:

Instructions:

- The following top five **Critical Success Factors (CSF1-CSF5)** for implementing risk management systems in Sri Lankan construction projects were identified from the results obtained in the previous round using Relative Important Index (RII).

  CSF1*: Request for Implementation of Risk Management Systems (IRMS) on projects by clients and end users.*

  CSF2*: Inclusion of risk management systems in engineering education and training modules of construction practitioners.*

  CSF3*: Awareness of risk management systems among stakeholders.*

  CSF4*: Attempting to deliver projects systematically on time and within project's budget.*

  CSF5*: Including the costs within project's budgets for IRMS.*

- **The Analytical Hierarchy Process (AHP)** will be used in this round of the survey to provide the ranking for the identified CSFs. The CSFs will be compared as a pair. The following numeric rating method will be used to rank the pairs.

AHP Scale of Importance for pair comparison (a_{ij})	Numeric Rating
Extreme Importance	9
Very strong to Extreme	8
Very Strong Importance	7
Strongly to Very Strong	6
Strong Importance	5
Moderately to Strong	4
Moderate Importance	3
Equally to Moderate	2
Equal Importance	1

(Item i) 9-8-7-6-5-4-3-2-1-2-3-4-5-6-7-8-9 (Item j)

- You are kindly requested to underline your answers in the following tables.

CSF1 Vs. CSF2, CSF3, CSF4 and CSF5

CSF1	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**CSF2**
CSF1	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**CSF3**
CSF1	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**CSF4**
CSF1	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**CSF5**

CSF2 Vs. CSF3, CSF4 and CSF5

CSF2	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**CSF3**
CSF2	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**CSF4**
CSF2	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**CSF5**

CSF3 Vs. CSF4 and CSF5

CSF3	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**CSF4**
CSF3	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**CSF5**

CSF4 Vs. CSF5

CSF4	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**CSF5**

Annex-D

AHP Calculations

AHP Analytic Hierarchy Process

bpmsg.com Multiple Input Summary Sheet

15 = k number of participants

5 = n number of criteria

Consolidated = Weighted geometric mean off participants

C **Consolidated**

	1	2	3	4	5	6	7	8	9	10
1		3.33	3.33	1.94	0.99	0	0	0	0	0
2	0.3		0.99	0.81	0.32	0	0	0	0	0
3	0.3	1.01		0.56	0.23	0	0	0	0	0
4	0.52	1.24	1.79		0.68	0	0	0	0	0
5	1.01	3.14	4.39	1.46		0	0	0	0	0
6	0	0	0	0	0		0	0	0	0
7	0	0	0	0	0	0		0	0	0
8	0	0	0	0	0	0	0		0	0
9	0	0	0	0	0	0	0	0		0
10	0	0	0	0	0	0	0	0	0	

1 Participant 1 1 1/0/1900

	1	2	3	4	5	6	7	8	9	10
1	1	8	3	1/4	1	0	0	0	0	0
2	1/8	1	1/8	1/9	1/7	0	0	0	0	0
3	1/3	8	1	1/9	1	0	0	0	0	0
4	4	9	9	1	6	0	0	0	0	0
5	1	7	1	1/6	1	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0
7	0	0	0	0	0	0	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

2 Participant 2 1 1/0/1900

	1	2	3	4	5	6	7	8	9	10
1	1	5	8	8	1	0	0	0	0	0
2	1/5	1	2	1	1/5	0	0	0	0	0
3	1/8	1/2	1	2	1/7	0	0	0	0	0
4	1/8	1	1/2	1	1/5	0	0	0	0	0
5	1	5	7	5	1	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0
7	0	0	0	0	0	0	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

3 Participant 3 1 1/0/1900

	1	2	3	4	5	6	7	8	9	10
1	1	4	9	8	2	0	0	0	0	0
2	1/4	1	2	4	1/4	0	0	0	0	0
3	1/9	1/2	1	4	1/9	0	0	0	0	0
4	1/8	1/4	1/4	1	1/6	0	0	0	0	0
5	1/2	4	9	6	1	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0
7	0	0	0	0	0	0	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

4	Participant 4						1			1/0/1900
	1	2	3	4	5	6	7	8	9	10
1	1	4	4	3	3	0	0	0	0	0
2	1/4	1	3	2	1/2	0	0	0	0	0
3	1/4	1/3	1	1/2	1/4	0	0	0	0	0
4	1/3	1/2	2	1	2	0	0	0	0	0
5	1/3	2	4	1/2	1	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0
7	0	0	0	0	0	0	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

5	Participant 5						1			1/0/1900
	1	2	3	4	5	6	7	8	9	10
1	1	4	1	1/2	1/2	0	0	0	0	0
2	1/4	1	1/6	1/6	1/9	0	0	0	0	0
3	1	6	1	1/5	1/9	0	0	0	0	0
4	2	6	5	1	1	0	0	0	0	0
5	2	9	9	1	1	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0
7	0	0	0	0	0	0	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

6	Participant 6						1			1/0/1900
	1	2	3	4	5	6	7	8	9	10
1	1	7	6	1	1/2	0	0	0	0	0
2	1/7	1	1/4	1/5	1/5	0	0	0	0	0
3	1/6	4	1	1/4	1/2	0	0	0	0	0
4	1	5	4	1	2	0	0	0	0	0
5	2	5	2	1/2	1	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0
7	0	0	0	0	0	0	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

7	Participant 7						1			1/0/1900
	1	2	3	4	5	6	7	8	9	10
1	1	8	2	3	1/2	0	0	0	0	0
2	1/8	1	1/3	1/7	1/8	0	0	0	0	0
3	1/2	3	1	1/6	1/6	0	0	0	0	0
4	1/3	7	6	1	1	0	0	0	0	0
5	2	8	6	1	1	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0
7	0	0	0	0	0	0	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

8	Participant 8						1			1/0/1900
	1	2	3	4	5	6	7	8	9	10
1	1	8	7	7	6	0	0	0	0	0
2	1/8	1	2	2	1	0	0	0	0	0
3	1/7	1/2	1	1/5	1/5	0	0	0	0	0
4	1/7	1/2	5	1	1	0	0	0	0	0
5	1/6	1	5	1	1	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0
7	0	0	0	0	0	0	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

9	Participant 9						1			1/0/1900
	1	2	3	4	5	6	7	8	9	10
1	1	3	8	4	3	0	0	0	0	0
2	1/3	1	3	2	3	0	0	0	0	0
3	1/8	1/3	1	1/7	1/7	0	0	0	0	0
4	1/4	1/2	7	1	2	0	0	0	0	0
5	1/3	1/3	7	1/2	1	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0
7	0	0	0	0	0	0	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

10	Participant 10						1			1/0/1900
	1	2	3	4	5	6	7	8	9	10
1	1	4	2	1/3	1/3	0	0	0	0	0
2	1/4	1	1/5	1/5	1/8	0	0	0	0	0
3	1/2	5	1	1/6	1/9	0	0	0	0	0
4	3	5	6	1	1/3	0	0	0	0	0
5	3	8	9	3	1	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0
7	0	0	0	0	0	0	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

11	Participant 11						1			1/0/1900
	1	2	3	4	5	6	7	8	9	10
1	1	1	2	1/4	1/5	0	0	0	0	0
2	1	1	1	1/4	1/9	0	0	0	0	0
3	1/2	1	1	1/8	1/8	0	0	0	0	0
4	4	4	8	1	2	0	0	0	0	0
5	5	9	8	1/2	1	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0
7	0	0	0	0	0	0	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

12	Participant 12						1		1/0/1900	
	1	2	3	4	5	6	7	8	9	10
1	1	5	7	7	2	0	0	0	0	0
2	1/5	1	3	3	1	0	0	0	0	0
3	1/7	1/3	1	3	1/7	0	0	0	0	0
4	1/7	1/3	1/3	1	1/9	0	0	0	0	0
5	1/2	1	7	9	1	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0
7	0	0	0	0	0	0	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

13	Participant 13						1		1/0/1900	
	1	2	3	4	5	6	7	8	9	10
1	1	1	3	1/2	1/2	0	0	0	0	0
2	1	1	4	1	1/2	0	0	0	0	0
3	1/3	1/4	1	1	1/6	0	0	0	0	0
4	2	1	1	1	1/6	0	0	0	0	0
5	2	2	6	6	1	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0
7	0	0	0	0	0	0	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

14	Participant 14						1		1/0/1900	
	1	2	3	4	5	6	7	8	9	10
1	1	1/5	1/5	5	1	0	0	0	0	0
2	5	1	1	8	1	0	0	0	0	0
3	5	1	1	8	6	0	0	0	0	0
4	1/5	1/8	1/8	1	1	0	0	0	0	0
5	1	1	1/6	1	1	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0
7	0	0	0	0	0	0	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

15	Participant 15						1		1/0/1900	
	1	2	3	4	5	6	7	8	9	10
1	1	5	7	7	1	0	0	0	0	0
2	1/5	1	3	2	1/6	0	0	0	0	0
3	1/7	1/3	1	3	1/9	0	0	0	0	0
4	1/7	1/2	1/3	1	1/6	0	0	0	0	0
5	1	6	9	6	1	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0
7	0	0	0	0	0	0	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1