EVALUATION OF ASSESSMENT OF INFRASTRUCTURE CONSTRUCTION PROJECT PERFORMANCE IN AUSTRALIA USING A MODIFIED CONCEPT OF EARNED VALUE MANAGEMENT

A Thesis submitted by

Maan Nihad Ibrahim

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Abstract

Australian infrastructure projects help promote national development and contribute significantly to the national economy. Assessing project performance is an important component of construction project management. Although there are many studies on the development of Australian infrastructure project assessment methods, factors influencing the performance of Australian infrastructure projects have not been explored. As a result of rapid developments in infrastructure projects and global economic trends towards environmental sustainability, there is an urgent need to study and assess the impact of risk-related factors on the performance of Australian infrastructure projects.

The method commonly used to assess performance during project execution is Earned Value Management (EVM). A weakness of this approach is its inability to specifically measure the impact of a number of factors on project performance. Due to the complexity of infrastructure construction projects, the current EVM approach is not sufficient to accurately predict project performance in the Australian infrastructure construction environment. This complexity is particularly associated with risk-related factors. Therefore, the gap is the need to develop an integrated approach to EVM that provides a modified EVM concept considering risk-related factors affecting the performance of the infrastructure project in Australia.

A set of risk-related factors was identified from the literature review and structured interviews with 15 interviewees. The set of risk-related factors was then tested with a questionnaire that was examined by a pilot study by using RII. The results of the questionnaire were analysed using SPSS and AMOS by using structural equation modelling (SEM) to extract the Risk Performance Index (RPI). The RPI was incorporated into the Estimate at Completion (EAC) equation to modify the concept. The performance of the revised concept was validated using historical data from previous Australian infrastructure projects.

The result was a modified concept of EVM possessing greater precision and realism, and more able to assess the performance of infrastructure construction projects in Australia by taking into account the impact of emerging and other factors in the evaluation process. The risk-related factors identified are sustainability (SS), stakeholder requirements (SR), communication (CM), procurement strategies, weather (WE), experience of staff (SE), site condition (SC), design issues (DI), financial risk (FR), subcontractor/s (CO), government requirements authority (GR) and material (MR). These factors have a clear impact on the performance of infrastructure projects in Australia by affecting the project duration and cost. The modified concept of EVM will assist project managers to evaluate and monitor project performance in a better way. In addition, the outputs of this research can be used in future research by examining the impact of these factors on the performance of projects in countries other than Australia.

Certification of Thesis

This Thesis is entirely the work of **Maan Nihad Ibrahim** except where otherwise acknowledged. The work is original and has not previously been submitted for any other award, except where acknowledged.

Maan Nihad Ibrahim

Signature of Candidature: ____________________ / / 2020

Associate Professor David Thorpe

Principal Supervisor: ____________________ / / 2020

Dr. Nateque Mahmood

Associate Supervisor: ____________________ / / 2020

Dr. Enamul Kabir

Associate Supervisor: ____________________ / / 2020

Student and supervisors signatures of endorsement are held at the University.

List of Publications

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Abbreviations

AC	Actual Cost
ACWP	Actual Cost of Work Performed
AGFI	Adjusted goodness of fit
AMOS	Analysis of a Moment Structures
AT	Actual Time
BAC	Budget at Completion
BCWP	Budgeted Cost of Work Performed
BCWS	Budgeted Cost of Work Scheduled
CFI	Comparative Fit Index
CM	Communications
CO	Subcontractors
CPI	Cost Performance Index
CV	Cost Variance
DI	Design Issues
EAC	Estimate at Completion
ETC	Estimate to Complete
EV	Earned Value
EVA	Earned Value Analysis
EVM	Earned Value Management
FR	Financial Risk

GFI	Goodness of Fit Index
GR	Government Requirements authority
IFI	Incremental Fit Index
KMO	Kaiser-Meyer-Olkin
MR	Materials
NFI	Normed Fit Index
NVivo	Qualitative data analysis computer software package
PS	Procurement Strategy
PV	Planned Value
RMSEA	Root Mean Square of Error Approximation
RPI	Risk Performance Index
SC	Site Conditions
SE	Experience of Staff
SEM	Structural Equation Modelling
SH	Stakeholders' requirements
SPI	Schedule Performance Index
SPSS	Statistical Package for the Social Sciences
SS	Sustainability
SV	Schedule Variance
TLI	Tuckler-Lewis Index
WE	Weather

1 CHAPTER ONE: - INTRODUCTION

1.1 Overview

This chapter introduced the dissertation. First, it outlines the assessment techniques for construction project performance and the importance of infrastructure projects in general, and in Australia in particular. A brief description of external and internal critical success factors and risk management is also provided. Second, it presents the aim and purpose of the research. Third, it discusses the research objectives created from the literature review, and the research questions arising from these objectives. Fourth, it explains the significant contribution of the results and outcomes. Finally, it outlines the structure of the dissertation and a summary of each chapter.

1.2 Research Background

The assessment of project performance is a vital and basic requirement of project management, and the accurate evaluation of the construction infrastructure project's performance helps project engineers, project managers and stakeholders control projects. The accurate and rapid assessment of the as-built status on any construction site allows current project performance to be assessed efficiently and quickly (Golparvar-Fard et al. 2011). This enables the achievement of project objectives within the required time limit, thus aiding the success of the construction project.

Infrastructure projects are a significant contributor to the national economy. Engineers Australia (2010) reported that in Australian infrastructure is used to strengthen national and regional development. It also reported that infrastructure contributes to employment creation and improved living standards for all Australians. Goh and Yang (2013) mention that the infrastructure sector faces significant challenges due to the high levels of funding required throughout the project life cycle. Many problems or factors lead to cost overruns in construction projects, and these can lead to the collapse of the performance of projects (Goh et al. 2015). Oberlender (1993) argues that using an appropriate concept for evaluating the performance of the project has an essential role in assessing and monitoring the performance of the project, and is vital to obtain the required goals.

Titarenko et al. (2015) state that many researchers emphasis the importance of evaluating and measuring the performance of the projects and the need to assess project performance with a comprehensive, multi-dimensional approach.

Many concepts are used to evaluate the performance of construction projects. EVM is one of these concepts. Lukas (2008) argues that Earned Value Analysis (EVA) seems a logical tool to obtain a better understanding of managing performance. EVM is used to evaluate the performance of a project by forecasting the final cost of the project and the time required for its delivery. It is used to compare the cost and duration with the planned cost and duration, and calculate the value of the variance between them. Many researchers have defined the concept of EVM. Acebes et al. (2013) and Lukas (2008) explained EVM is the most efficient technique for assessing the performance of projects. Furthermore, it is used in large scale projects all over the world to compare the actual costs and actual time with the budgeted costs and planned time and then predict the cost and time required to actually deliver the project. Najafi and Azimi (2016) mention that it combines the scope, cost and the time of the project, and allows stakeholders to monitor the progress of the project across its life circle. Furthermore, it corrects deviations in a timely manner.

There are many external and internal critical success factors impacting directly and indirectly on earned value management. These factors affect the traditional concept of project management which is presented by cost, time, quality, and scope of the project. Reducing the negative impact of these factors, thereby increasing their positive impact is considered a key requirement for improving the efficiency of project management.

One of these factors is Risk Management (RM). Risk management plays a vital role performance of project management through its close relationship with other factors affecting project delivery, such as sustainability, communication, stakeholder requirements, procurement strategies, and other factors. This relationship, in turn, affects the cost and duration of the project. Thus, risk management is a major issue in project delivery. According to Visser and Joubert (2008), risk in construction projects can make the main objectives (cost, time, and quality) of a project significantly restricted. Therefore, it will affect the process of calculating EVM correctly. Serpella et al. (2014) state that risk management in construction projects addresses the imbalance, flaws, shortcomings, and disability, which affect the efficiency of the function of project management and project performance. Consequently, risk management is likely to have an impact on infrastructure project performance management.

1.3 Problem Statement

Infrastructure projects are considered to be one of the most significant types of construction projects. CEIID (2010) mentions that proper management, proper planning, and good investment in infrastructure projects play an essential supporting role in the economic growth of countries. They also provide the ability to support the growing demands on public services that accompany population development (Engineers Australia 2010). Tsoukas (2005) argues that construction management generally suffers from the lack of a comprehensive technique for evaluating performance. Langston (2012) identifies the difficulty of measuring the performance of construction projects. Project evaluation using EVM focuses on cost and time, without considering other important factors such as sustainability, stakeholder requirements, communication, procurement strategies and other factors when measuring the project performance. These factors will make the measurement of Australian infrastructure project performance during the implementation phase, more accurate and reliable. Therefore, this research aims to fill the gap by developing an integrated approach to EVM which provides a modified EVM concept taking into consideration the risk-related factors influencing infrastructure project performance in Australia.

1.4 Purpose of the Study

The purpose of this research is to develop a performance evaluation system by developing a modified EVM concept for assessment of EVM as a technique in the risk environment, including the demands of risk-related factors such as sustainability, stakeholder requirements, communication, procurement strategies and other factors. This study is mainly concerned with infrastructure projects in Australia.

1.5 Research Objectives

The literature review discusses EVM and a range of issues relating to its successful use. The research objectives arising from this review are as follows:

Objective 1: Investigate the influence of risk management approaches on the technique for assessment of construction project performance (infrastructure projects in Australia), including contributing a set of risk-related factors such as the sustainability, requirements of stakeholders, communication, procurement strategies and other factors. In addition, identify the measurement items of these factors.

Objective 2: Inspect the influence of the set of risk-related factors such as sustainability, requirements of stakeholders, communication, procurement strategies and other factors on the performance of infrastructure projects in Australia. In addition, identify the relationships between these factors.

Objective 3: Account for the Risk Performance Index (RPI) resulting from the impact of the set of risk-related factors such as sustainability, stakeholder requirements, communication, procurement strategies and other factors on the performance of infrastructure projects in Australia.

Objective 4: Develop a new performance evaluation system using a modified concept of EVM that enhances the forecasting accuracy of the project estimate, and accomplished by considering risk-related factors such as sustainability, stakeholder requirements, communication, procurement strategies and other factors.

1.6 Research Questions

The research questions were developed in response the research objectives. The following are the main research questions for this study:

RQ1: What are the risk-related factors that impact infrastructure project performance in Australia?

RQ2: What are the significant measuring items for these risk-related factors?

RQ3: Are these risk-related factors likely to have significant impacts on the performance of infrastructure projects in Australia?

RQ4: What are the significant relationships between these risk-related factors?

RQ5: What is the Risk Performance Index value resulting from the effect of the risk-related factors on the performance of infrastructure projects in Australia?

RQ6: How can EVM be modified to enhance the forecasting accuracy of the project estimate through the consideration of risk-related factors such as sustainability, stakeholder requirements, communication, procurement strategies and other factors?

Table 1.1 shows the link between each research objective and the corresponding questions

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Objectives	**Corresponding questions**
Objective 1: Investigate the influence of risk management approaches on the technique for assessment of construction project performance (infrastructure projects in Australia), including contributing a set of risk-related factors such as the sustainability, requirements of stakeholders, communication, procurement strategies and other factors. In addition, identify the measurement items of these factors.	**RQ1**: What are the risk-related factors that impact infrastructure project performance in Australia?
	RQ2: What are the significant measuring items for these risk-related factors?
Objective 2: Inspect the influence of the set of risk-related factors such as sustainability, requirements of stakeholders, communication, procurement strategies and other factors on the performance of infrastructure projects in Australia. In addition, identify the relationships between these factors.	**RQ3:** Are these risk-related factors likely to have significant impacts on the performance of infrastructure projects in Australia?
	RQ4: What are the significant relationships between these risk-related factors?
Objective 3: Account for the Risk Performance Index (RPI) resulting from the impact of the set of risk-related factors such as sustainability, stakeholder requirements, communication, procurement strategies and other factors on the performance of infrastructure projects in Australia.	**RQ5:** What is the Risk Performance Index value resulting from the effect of the risk-related factors on the performance of infrastructure projects in Australia?
Objective 4: Develop a new performance evaluation system using a modified concept of EVM that enhances the forecasting accuracy of the project estimate, and accomplished by considering risk-related factors such as sustainability, stakeholder requirements, communication, procurement strategies and other factors.	**RQ6:** How can EVM be modified to enhance the forecasting accuracy of the project estimate through the consideration of risk-related factors such as sustainability, stakeholder requirements, communication, procurement strategies and other factor?

1.7 Research Hypotheses

From Objective 2 and the answer to Research Question 3, the research Hypotheses were created. These hypotheses were developed from factors obtained in the literature review and interviews presented in chapter 2 and 4, respectively. The following are the hypotheses of this research:
H1: Sustainability is likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

H2: Stakeholders' requirements are likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

H3: Communications are likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

H4: Procurement strategy is likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

H5: Weather is likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

H6: Experience of staff is likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

H7: Site conditions are likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

H8: Design issues are likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

H9: Financial risk is likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

H10: Subcontractors are likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

H11: Government requirements are likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

H12: Materials are likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

1.8 Significance and Outcomes

The success of construction projects reflects the economic progress of countries. Predicting the final project outputs in terms of time and cost is a substantial aspect of successful project management (Batselier & Vanhoucke 2017). The uniqueness of contruction projects means that the risks experienced by the projects are different and it is important to correctly identify risk factors in order to manage projects effectively (Omran et al. 2015). Although the concept of EVM has been studied by many researchers, there is still a lack of incorporation of the impact of risk into this concept (Khesal et al. 2019). The significance of this study is, therefore, reflected in the need for a more accurate assessment of infrastructure construction project performance; to achieve project delivery within the planned time and budget. The concept of earned value management in its current form focuses on the cost performance index (CPI) and schedule performance index (SPI) and does not address the impact of other important factors (Babar et al. 2016). The study makes a significant contribution to the review and use of EVM considering how and why risk management, sustainability, stakeholders, communication and procurement strategies impact it, and by investigating new concepts to evaluate infrastructure construction project performance in the discipline of Construction Management.

The outcome of this study will be a modified concept of EVM that provides a more accurate evaluation technique of the performance of the implementation of infrastructure projects. It will also consider the impact of emerging factors in the process of evaluating the performance of infrastructure projects in Australia, such as risk, sustainability, stakeholder requirements, communication, procurement strategies and other factors.

1.9 The Thesis Organization

This dissertation is composed of seven chapters which illustrate all the research stages, including data collection, data analysis, as well as the results of the research. A short description and details of each chapter are provided below:

Chapter One: This chapter introduces the research. It contains a brief background, problem statement and research purpose. It then outlines research objectives and research questions. Finally, it presents the research importance and outcomes.

Chapter Two: This chapter reviews the literature related to the research topic and identifies the weakness in project performance assessment techniques. This chapter presents the previous studies and discusses the major issue in infrastructure project performance assessment in Australia. It also explains some factors that affect infrastructure performance assessment.

Chapter Three: This chapter reviews the research methodology adopted for the study (mixed method). It explains all stages of data collection (literature review, interviews, pilot study, questionnaire survey) and explains the analysis approaches used (NVivo, SPSS, and AMOS).

Chapter Four: This chapter reviews the qualitative data collection and analysis, including the preparation of interviews from the interview protocol, interview questions, ethics approval, and invitation letters. In addition, this chapter includes the qualitative data analysis process using NVivo software to confirm the final set of risk-related factors which are used in the following stages.

Chapter Five: This chapter reviews the quantitative data collection and analysis, including the preparation of the questionnaire survey from the survey protocol, survey questions, ethics approval, invitation letters, and pilot study. This chapter includes the amendment of the questionnaire based on the results of the pilot study. In addition, the chapter explains the quantitative data collection process using the University of Southern Queensland (USQ) online survey (Lime Survey) and the quantitative data analysis process using SPSS and AMOS. The outcomes of the analysis are also discussed in this chapter.

Chapter Six: This chapter reviews the project performance assessment technique, which is represented by Earned Value Management concept. It discusses the results of the questionnaire on the prevalence of the use of the Earned Value Management in Australia, and the reasons for the use. This chapter also discusses the process of modifying the concept of Earned Value Management using the value obtained from the previous stage's results (quantitative analysis by AMOS). It also reviews the process of verifying the validity of the modified concept through the application of a revised concept with historical data.

Chapter Seven: This chapter provides a summary of the research in terms of the main results which answer the research questions, and the contributions of the research in evaluating the performance of infrastructure projects in Australia. It also discusses and explains the conclusions drawn from the analysis. Furthermore, it explains the recommendations from the research findings and suggests future research.

1.10 Chapter Summary

This chapter presents a summary of this thesis. It also provides a brief background on the evaluation of construction projects in general and infrastructure projects in particular. A brief background on the evaluation of construction projects during the implementation phase in general and infrastructure projects, in particular, was also provided. It explained the importance of the concept of EVM to evaluate construction projects. It offered a simple narrative of the impact of some risk-related factors on the performance of infrastructure projects in Australia. The problem statement was explained, through which the purpose and objectives were formulated, and research questions created. Finally, the structure was addressed.

2 CHAPTER TWO: - LITERATURE REVIEW

2.1 Introduction

This chapter examines the literature related to evaluating the performance of construction projects and the techniques used in assessing project performance, including EVM. It reviews the basic principles of EVM, the elements of EVM equations used to predict the output.

This chapter also conducts a comprehensive assessment of the literature related to the weaknesses of EVM. The impact of some risk-related factors on the performance of infrastructure projects in Australia is also addressed. The purpose of the literature review is to help determine the scope of the research and research problem in addition to setting up research objectives and research questions.

2.2 Project Performance

In the last decade, evaluating performance during the project life cycle has become one of the significant issues for the success of a project. Furthermore, performance evaluation influences the success of companies operating in competitive, complex and changing environments. Chancellor and Abbott (2015) noted that the shadow economy in the construction industry in Australia is growing over time. Moreover, in Australian, the construction sector is considered to be the most significant contributor to the economy, actively influencing economic growth (Hughes & Thorpe 2014). The contribution of construction projects to economic growth demands new concepts or the development of previous concepts in line with the changing environment and the pace of development in the field of project management.

In the 1960s and 1970s, evaluating the performance of projects depended on traditional methods. Traditional methods relied on the three basic elements of project performance (cost, time, quality) without taking into consideration the factors affecting these elements that change with the changing environment of the project.; for example, risk management, sustainability, stakeholders, communications and procurement strategies. The state of the global economy has stimulated contractors and construction companies to diagnose, in detail, the factors affecting the performance of their projects to obtain better outputs (Yun et al. 2016). Moreover, the state of the global economy has also stimulated engineering companies to seek new frameworks and approaches to evaluate their projects (Titov et al. 2016). Dainty et al. (2003) explain that traditional criteria for the success of construction projects are no longer sufficient or convenient, with success now requiring performance measurement according to a project's environment and conditions. Thus, there is a strong need to study the impact of these factors on the basic elements of project management on the one hand, and the relationships between these factors and the effects of each on the others. This requires a thorough understanding of the process of evaluating the performance of the projects and the relationships between performance. Besides measuring their impact to develop new parameters for the evaluation process to make it more accurate, more realistic and more successful in measuring the achievement of the project objectives.

So, at the beginning of the research, the definition of performance measurement or the process of controlling and monitoring the project work is critical. The process of controlling and monitoring the project work is the process of reaching the specific project objectives by tracking, evaluating, and determining the progress of the project (PMI 2017). According to Neely et al. (2005), performance measurement is the process of measuring the work done and the process of estimating the act or the work that leads to performance. Trnka and Taspinar (1995) mention that performance measurement is essential in project management for the planning and preparation of reports, as well as the analysis and assessment of the actual progress of the project compared with the planned progress. Trnka and Taspinar (1995) and Titarenko et al. (2015) explain that performance measurement is used to measure performance in construction projects to determine the proportion of the project's progress. It is also used to measure the success of the project regarding desired goals, such as completing the project within the specified period, within the allocated budget, within the required quality and customer satisfaction with the outcome of the project specifications. Schwalbe (2015) defined performance evaluation of a project as the process of measuring the progress of a project to reach the desired goals, identify failure positions in the plan, and take the necessary measures to ensure the performance of the project in conformity with what is planned.

Based on the definition provided above, it can be said that performance measurement is a measure of the completion of the project activities and a comparison of these with the planned completion to determine the defects or weaknesses in the areas of performance, as well as measuring the success in reaching the goals of the project process. Furthermore, depending on the requirements of economic development and technological development in the field of construction, the process of assessing the performance of projects should be more sophisticated than focusing on the traditional elements (time, cost) of performance evaluation only, and take into account the impact of many factors that change the performance of construction projects.

2.3 Project Performance Assessment Techniques

According to PMI (2013), several techniques, such as regression analysis, grouping methods, causal analysis, root cause analysis, forecasting method, failure mode and effect analysis (FMEA), fault tree analysis (FTA), reserve analysis, trend analysis, earned value management and variance analysis are used in monitoring and controlling projects to predict the performance of the project through the analysis of the project variables and project environment and the study of their relationships with each other.

Earned Value Management is considered the most commonly used and widely accepted way to manage the performance of projects across the project life cycle and to predict the total cost and time to complete the project. Furthermore, many of the sources, refer to the features and the importance of the use of EVM for evaluating the performance of projects which adopts a methodology which provides the best indication of the future performance of the project (Mohammed et al. 2015). Lipke (2003) argues that EVM is a magnificent management system that combines, in a very interesting way, cost and schedule and technical performance. Chen et al. (2016) mention that EVM is an effective instrument and system for project performance management. Most researchers in the field of project performance agree that EVM is an excellent tool to assess and calculate the performance of a project (Corovic 2006).

Koppelman and Fleming (2003), Acebes et al. (2013) , Batselier and Vanhoucke (2015) and De Marco and Narbaev (2013) mention that EVM was developed and utilised by the United States Department of Defence in the 1960s as a technique to evaluate the performance of a project and predict its total cost and the time required to complete the project.

Based on previous literature, Fleming (2010) and PMI (2017) assert that EVM is predicated on three basic elements: Planned Value (PV) or budgeted cost of work scheduled (BCWS), Earned Value (EV) or the budgeted cost of the work performed (BCWP), Actual Cost (AC) or the actual cost of work performed (ACWP).

Fleming (2010) and PMI (2017) define the Planned Value (PV), or budgeted cost of work scheduled (BCWS) as a budget for the implementation of project activities. The budgeted costs reflect the value of physical labour, equipment and materials to be used to complete the project activities. Moreover, the total value of the PV for accomplishing the project equals the budget at completion (BAC).

Fleming (2010) and PMI (2017) make clear that Earned Value (EV) or the budgeted cost of the work performed (BCWP) is the financial value of the work performed. Further, the earned value reflects the accomplishment of physical or intellectual work, together with the management of the allocated budget to complete the project.

Fleming (2010) and Chen et al. (2016) clarify that Actual Cost (AC) or the actual cost of work performed (ACWP) is a cumulative amount of money or costs actually disbursed for the work done within a specified period of time.

These three elements change during the project life cycle. They are the main elements of EVM. Acebes et al. (2013) explained that through these three basic elements, variance analysis (SV and CV) and performance indicators (SPI and CPI) can be measured.

- Schedule Variance (SV) is the amount, at a given time, that reflects the progress or delay of the project planned delivery date. It can be calculated by the difference between the Earned Value (EV) and the Planned Value (PV) as shown in Equation 2.1(PMI 2017):

$$SV = EV - PV \qquad (2.1)$$

- Cost Variance (CV) is the amount at a given time that reflects the shortfall or leftover in the planned budget of the project. It can be calculated by the difference between the Earned Value (EV) and the Actual Cost (AC) as shown in Equation 2.2 (PMI 2017):

$$CV = EV - AC \qquad (2.2)$$

- Schedule Performance Index (SPI) is an indicator used to measure schedule effectiveness and efficiency. It can be calculated by dividing the Earned Value (EV) and the Planned Value (PV) as shown in Equation 2.3 (PMI 2017):

$$SPI = \frac{EV}{PV} \qquad (2.3)$$

- Cost Performance Index (CPI) is an indicator used to predict final project completion estimates and to measure the effectiveness and efficiency of cost. It can be calculated by dividing the Earned Value (EV) and the Actual Cost (AC) as shown in Equation 2.4 (PMI 2017):

$$CPI = \frac{EV}{AC} \qquad (2.4)$$

Figure 2.1 shows the main elements (EV, PV, and AC) and variance analysis (Cost Variance CV, and Schedule Variance SV), and performance indicators (Cost Performance Index CPI and Schedule Performance Index SPI) of the EVM (Lipke 2004).

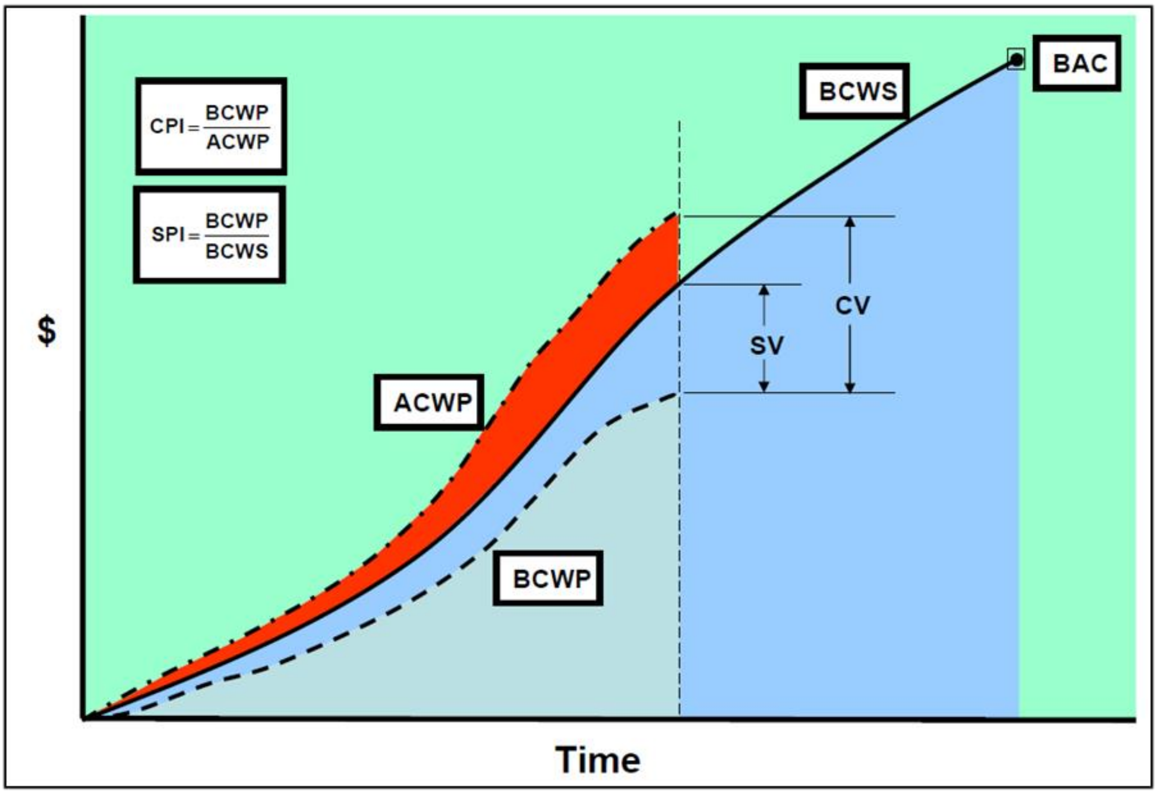


Figure 2-1: Main elements and four indicators of EVM (Lipke 2004)

Kim et al. (2003) point out that EVM is largely accepted by project managers. They compared the importance of EVM in different types of institutions (public and private). The results of a survey questionnaire showed that EVM is commonly used, especially to estimate cost and time to complete. It is also used to identify cost and schedule impacts of known problems, and accurately portrays the cost status of a project. Moreover, Kim et al. (2003) recognize the most important problems associated with the use of EVM are in variance kinds of the framework (private, public) and the sources of these problems. The results of a survey questionnaire showed that EVM problems are not major or extreme and that most of the minor problems are created by users of this concept.

According to Valle and Soares (2006) the benefits of EVM are as follows: integration of costs and time, better visibility of the scope of the project and procurement, early warning of problems, determines the direction of the deviations in the project, shortens time taken to understand problems and devise solutions, supports the decision-making process and motivates employees responsible for project management and the application of the control system. Many researchers have investigated the benefits of EVM to evaluate the performance of the projects. Chin Keng and Shahdan (2015) summarized the benefits of the use of EVM as:

- Providing a suitable environment for process planning through the promotion of understanding and communication between the various components of the project, and thus helps those in charge of project management plan appropriately for work riskiness
- Taking appropriate decisions in critical situations and achieve the project objectives
- Providing a clear vision for the scope of the project and the progress of work on the project
- Providing an early warning of any potential defects
- Controlling costs and time, to predict the final cost and the final period of the project
- The use of information and historical data in future projects

Fleming and Koppelman (2000) and Lipke (2004) mention that EVM cannot provide a reliable formula to predict the final duration of the project as it assesses along the lines of the financial situation of the project. Lipke (2004) discusses the shortcomings of the concept of EVM to predict the final duration of the project. He introduced an additional measurement requirement using the earned schedule (ES) approach. Lipke (2003) argued that EVM is not effective in the last third of the project because the schedule indicators do not provide sufficient and perfect information for this stage of the project. Moreover, a new concept called Earned Schedule (ES) was introduced to overcome this limitation. (Lipke 2003, 2004) developed EVM to solve the problem of prediction in the last stages of the project where it was proposed to use the Earned Schedule (ES) and re-identify the specific time variables Schedule Variance SV(t) and SPI(t) as explained in Equations 2.5 and 2.6 respectively. Figure 2.2 shows the ES (Lipke 2004):

$$SV(t) = ES - AT \quad (2.5)$$

$$SPI(t) = \frac{ES}{AT} \quad (2.6)$$

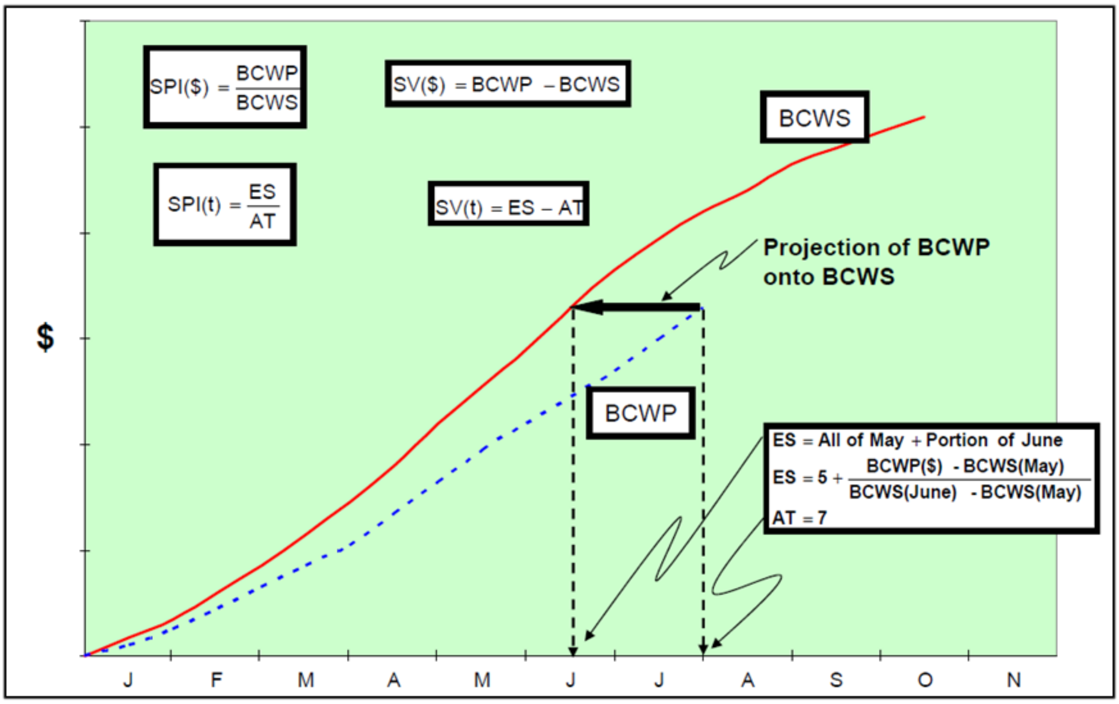


Figure 2-2: Earned Schedule (ES) (Lipke 2004)

During the past two decades, considerable research has been conducted on the use of EVM. Lipke (2012) compares the use of ES on different serial tracks for the project to find the best use for the ES, and the result was that the Longest Path (LP) gives the best and most accurate results.

Naderpour and Mofid (2011) explored the dimensions of EVM and compared its use and the use of the traditional concept. They concluded first, that the EVM provides an early warning of the decay of a project's progress. Second, it is an accurate predictor, helping in decision making. Third, it provides a clear vision of the progress of a project. Finally, it reduces the risks associated with decisions in the critical conditions of a project.

De Marco and Narbaev (2013) identified three factors related to the academic and cultural environment affecting the widespread use of EVM in Europe: a lack of studies relevant to EVM applications, a lack of recording of best practices and a lack of case studies in the global literature.

Acebes et al. (2014) proposed a new methodology for monitoring and evaluating the performance of projects through a combination of EVM and risk management. This methodology helps project operators determine whether the deviations are within planned limits. Chin Keng and Shahdan (2015) note that, when the level of awareness of those in charge of construction projects for the use and application of the concept of EVM is low, it is better to identify and understand the foundations and principles of the concept of EVM before expanding into new dimensions. Naeni et al. (2011) introduced a new fuzzy model with features of expansion and analysis under uncertainty for earned value uncertainty, time, cost, to assess the progress of a project.

The S curve can be used to view elements of EVM as well as variances and indicators to examine project performance and determine whether performance is deteriorating or improving. This analysis is called trend analysis by charts (PMI 2017).

The other type of trend analysis is known as forecasting, where the project management team predicts the Estimate at Completion (EAC), which may be different from the total planned value at completion (Budget at Completion BAC). The Estimate at Completion (EAC) is calculated by adding the Actual Cost (AC) expended on the work performed to the value of the Estimate to Complete (ETC) of the residual work (PMI 2017).

PMI (2017) suggested three methods that are most commonly used to calculate the EAC.

The first method is to calculate the EAC of the AC of the work done, whether negative or positive plus the value of the estimate for completion as in the budget as explained in Equation 2.7:

$$EAC = AC + (BAC - EV) \qquad (2.7)$$

The second method is to calculate the EAC based on the Cost Performance Index (CPI). The work is expected to continue on the same cumulative cost performance index, as shown in Equation 2.8:

$$EAC = \frac{BAC}{CPI} \qquad (2.8)$$

The third method is to calculate the EAC by including the effect of both the Cost Performance Index (CPI) and the Schedule Performance Index (SPI). In this method, weights can be given to each indicator as estimated by the project manager, as shown in Equation 2.9 and 2.10 respectively:

$$\mathrm{EAC} = \mathrm{AC} + \frac{\mathrm{BAC} - \mathrm{EV}}{\mathrm{CPI} * \mathrm{SPI}} \qquad (2.9)$$

$$\mathrm{EAC} = \mathrm{AC} + \frac{\mathrm{BAC} - \mathrm{EV}}{(\mathrm{W1CPI} + \mathrm{W2SPI})} \qquad (2.10)$$

Much research has been done to explore the problems of EAC and provide insight into the appropriate formula of EAC (Christensen et al. 1992). Christensen et al. (1992) classifies the equation for calculating the EAC to a regression formula and index-based formula. Moreover, the index-based formula is classified into four groups and one of these groups is based on the composite index (W1*SPI+W2*CPI); the value of W1and W2 range from 0 to 1 and these values depending on average or cumulative data.

Narbaev and De Marco (2011) mention that during project performance monitoring and evaluation, project managers face the challenge of selecting the perfect and most reliable method of EAC. Furthermore, despite the extensive use of the method of Estimating at Completion EAC, it suffers from some weaknesses in the treatment of the risk effect.

The formula for calculating the EAC provided by Christensen et al. (1992), Narbaev and De Marco (2011), PMI (2017) and others before them, assisted in introducing the effect of factors other than time and cost; such as the effect of risk.

Babar et al. (2016) calculated performance indicators for quality, safety, and stakeholder satisfaction as a Risk Performance Index (RPI). The formula for calculating the EAC is adjusted by integrating the RPI into the equation, as shown in Equation 2.11.

$$\mathrm{EAC} = \mathrm{AC} + \frac{\mathrm{BAC} - \mathrm{BCWP}}{\mathrm{W1CPI} + \mathrm{W2SPI} + \mathrm{W3RPI}} \qquad (2.11)$$

Where, W1, W2, and W3 are the complementary weight for CPI, SPI and RPI respectively. Equation 2.11 helps introduce the influence of many risk-related factors that affect project performance. Despite the importance of this research in the development of EVM, the relevant factors vary from country to country according to the project environment. Babar et al's questionnaire was distributed to 12 countries and the validity of the revised concept was verified through its application in Qatar and Pakistan only.

Khesal et al. (2019) developed EVM by incorporating the quality control indicator and proposed two methods to determine the quality control indicator: the first is linear and the second depends on the Taguchi loss function.

It is clear from the above, that EVM is widespread. In previous years, there has been much research on the performance of EVM, and this research has taken many directions. Some of this research illustrates the importance of this concept in project management and the factors that influence or limit its spread. Some research seeks to improve the accuracy of EVM in predicting project outputs and giving project managers high accuracy in determining any defect in terms of time and cost by modifying concept equations. Other research attempts to identify the problems of EVM in terms of the organizational environment or the project environment. However, there is an urgent need to adjust this concept for the impact of many factors that affect the performance of projects. Risk-related factors should be incorporated into EVM calculations. These factors vary from country to country depending on the project environment. Therefore, there is an urgent need to identify and study risk-related factors based on the country of the project, and to integrate the influence of these factors into the EVM formulas.

2.4 Factors Impacting Project Performance

Numerous factors (e.g., safety, environment, economic and political conditions) influence the assessment of project performance (Baloi & Price 2003; Sun & Meng 2009; Akanni et al. 2015). These factors are called critical success factors (CSFs). To obtain the best assessment or evaluation for project performance, the study of the impact of these factors on the performance of the projects and the components of performance evaluation of projects in terms of cost, time and scope of the project is required. Furthermore, considering these factors during the assessment will reduce their impact and lead to a more comprehensive performance measurement. Therefore, the results of the assessment will be more realistic.

Rockart (1982) was the first author to use the term critical success factors in project management, and described them as some elements of action in which appropriate outcomes are fully required for the manager of a project to achieve the specific project objective.

Many factors affect the performance of infrastructure projects. Risk Management (RM) is one of the important factors that affect the performance of infrastructure construction projects. Standards Australia and Standards New Zealand (2009) describe risk as the internal and external factors that create uncertainties or ambiguity about the extent of desired objectives or when desired objectives will be achieved.

Why focus on risk management? The answer to this question has been addressed in various literature. These literature suggest that risk is an important issue for infrastructure construction projects, particularly with respect to achieving the project objectives. Shen et al. (2006) argue that construction activities are subject to risks more than other businesses because of the complexity of construction projects, especially in the area of coordination between groups with different skills and activities. Aritua et al. (2011) mention that risk management is an integral part of investment decisions in infrastructure projects.

Furthermore, as a result of the changing nature of construction projects, continuous research and development are required to increase the effectiveness of risk management and reduce the adverse impact of risk. Smith et al. (2014) point out that many projects cannot meet deadlines and the budgets, causing a poor reputation for construction projects dealing with the negative consequences of change. They also note that this problem can be eliminated through the implementation of effective risk management.

Another important factor is sustainability in infrastructure projects. Sustainability is one of the emerging factors. Garren and Brinkmann (2018) mentioned Sustainability and frameworks of sustainability emerging as a result of accelerated climate change, which has led to significant social and economic challenges. Sustainability needs to be expanded and a comprehensive study needs to be undertaken as sustainability (based on the three pillars: economy, society, and environment) is one of the important issues related to international standards. Upadhyaya et al. (2014) explain that the Canadian Society for Civil Engineering (CSCE) refers to sustainability as an essential element for infrastructure projects. The relationship between international standards and risk is considered through the influence of types of risk on the basic elements of the economy, society, and the environment. Most previous research has focused on the relationship between risk and its impact on the sustainability of infrastructure projects during the operations phase only. For example, Padgett and Tapia (2013) argue that the impact of natural hazards on infrastructure has a significant influence on infrastructure sustainability. They also argue that sustainability can be discerned through the environmental, economic and social indicators for infrastructure performance. Thus, the relationship between international standards and risk in the construction phase needs more in-depth understanding and research.

Furthermore, stakeholder requirements and communication are two factors that affect the goals of a project. Stoney and Winstanley (2001) mention that many references define stakeholders to include any group or persons that could influence or is influenced by, the achievement of an organization’s goals. Thekdi and Lambert (2013) explain that the views, experiences and interests of stakeholders can be used in the development of the priorities of infrastructure systems to address the risk of emergency conditions. Li et al. (2013) point out that stakeholder interests vary, and that this represents one of the risks which affect (both negatively and positively) infrastructure projects. For example, Abednego and Ogunlana (2006) link different viewpoints of stakeholders involved in infrastructure projects and risks within different procurement strategies such as the public-private partnership (PPP) procurement strategy. They also argue that these disagreements reduce the chances of project success.

Communication between stakeholders in the construction industry is a major challenge due to the different natures of stakeholders who meet for short periods of time (Dainty et al. 2007). Chan and Kumaraswamy (1997) pointed out that communication between project stakeholders is one of the risks that affect the duration and performance of a project. The performance of any construction project depends on the quality of supervision in terms of the ability of the supervisors to communicate appropriately with the project staff (Yeboah 2017). Construction project managers in Australia are at risk of losing the quality of communications. Therefore, there is an urgent need to maintain the quality of communications in construction projects (Hosseini et al. 2017). Thus, stakeholder requirements and communication are key risk factors that need to be highlighted and studied in depth.

Another factor is procurement strategies. Loosemore and Cheung (2015) point out that risks can arise due to the complex nature of procurement strategies. Lu et al. (2015) argue that the selection of appropriate contractual regulations is essential to achieve improved project performance. Hwang et al. (2013) identified 23 risk factors have a significant influence on the Public-Private Partnership (PPP) procurement strategies in Singapore. They also rank the top five risk factors which are “lack of support from the government”, “availability of finance”, “construction time delay”, “inadequate experience in PPP”, and “unstable government”. Shen et al. (2006) identified the types of risk that affect PPP procurement strategies in Hong Kong. They found that some types of risk affect the public sector more, while other types of risk affect the private sector more. They also pointed to the participation of public and private sector in some types of risk.

Hwang et al. (2015) identified the major risks facing various parties involved in international construction joint ventures (ICJVs) in Singapore. They also argued that partner disagreement over conditions in contracts is the most important risk for parties involved in ICJVs. Morledge and Smith (2013) mentioned that there are risks to the performance of a project when using the traditional contracting strategy as a result of changes in design after the contract has been signed. Several risk factors affect the cost and performance of infrastructure projects when using Alliance contracting. These include reliability, reputation and accountability (Love et al. 2010). In Private Finance Initiative (PFI) contracts, conflicting requirements and restrictions on project managers are one of the risks that affect the performance of project implementation, and therefore affect access to project objectives (Badi & Pryke 2016). It is clear from previous research conducted in different countries, that construction projects are at risk due to choice of procurement strategy. Therefore, there is a need to focus on procurement strategies in order to understand and explore associated risks for infrastructure projects in Australia.

Previous literature have shown that CSFs in Australian infrastructure projects are different from other countries, as they depend on the nature of the project and the project environment. Furthermore, the risk is influenced by variables such as sustainability, stakeholder requirements, communication, and procurement strategies. Table 2.1 shows the variables that impact project performance as risk-related factors.

Table 2-1:Risk-related factors impact project performance

Factors impacting project performance		
No	**Factors**	**Sources**
1	Sustainability	(Garren & Brinkmann 2018), (Upadhyaya et al. 2014), (Padgett & Tapia 2013), (Lubin & Esty 2010), (Khatib 2016), (Ugwu & Haupt 2007), (Häkkinen & Kiviniemi 2008), (Thorpe & Ryan 2007), (Lam et al. 2011), (Berardi 2012), (Martens & Carvalho 2016), (Fernández-Sánchez & Rodríguez-López 2010), (Bocchini et al. 2013), (Padgett & Tapia 2013), (Florez et al. 2013), (Kamali & Hewage 2017), and (Cheng et al. 2018)
2	Stakeholder Requirements	(Stoney & Winstanley 2001), (Thekdi & Lambert 2013), (Li et al. 2013), (Abednego & Ogunlana 2006), (Díaz et al. 2017), (Zhang 2011), (Wang et al. 2017), (Ogunlana 2010), (Doloi 2011), (Yang et al. 2009), (Doloi 2012), (Yang et al. 2011), (Lindhard & Larsen 2016), (Zhao et al. 2016), (Xia et al. 2018), (Sambasivan et al. 2017),and (Yeung et al. 2017)
3	Communication	(Dainty et al. 2007), (Chan & Kumaraswamy 1997), (Yeboah 2017), (Hosseini et al. 2017), (PMI 2004), (PMI 2017), (Lindhard & Larsen 2016), (Nipa et al. 2019), (Harstad et al. 2015), (Hassan et al. 2018), and (Ejohwomu et al. 2017).
4	Procurement Strategies	(Loosemore & Cheung 2015), (Lu et al. 2015), (Hwang et al. 2013), (Shen et al. 2006), (PMI 2017), (Dhanushkodi 2012), (Naoum & Egbu 2016), (Naoum & Egbu 2015), Eriksson (2017), (Ruparathna & Hewage 2015), (Dhanushkodi 2012), (Australian Government - Department of Infrastructure and Regional Development 2016), (Jentsch & Gulsett 2018), (Bower 2003), and (Du et al. 2016).

Below are more details about each variable.

2.4.1 Risk Management

Risk Management plays a vital role in influencing the delivery of the project within the planned time and planned cost. The effect of risk management on project time and cost is influenced by factors such as sustainability, stakeholder requirements, communication, and procurement strategies. Standards Australia and Standards New Zealand (2009) mention the contribution of risk management to many management activities. For example, helping to increase the probability of achieving objectives, assisting in the efficiency of financial reporting, helping to increase trust among stakeholders, increasing communication and participation between the organizations, helping lay the foundation for reliable decision-making, planning and monitoring, and helping in the management of the environment and resources. Furthermore, they define risk management as the procedure for managing risk by imagining or expecting that something will happen, understanding it and resolving to modify it. Tohidi (2011) defines risk management as the procedure of evaluation and identification of potential risk or maximisation of opportunity and then applies the appropriate approach to reduce the impact of these risks. Standards Australia and Standards New Zealand (2009) define risk management as "coordinated activities to direct and control an organization with regard to risk". Baloi and Price (2003) and Hwang et al. (2014) mention that the risk management procedure consists of the following steps: planning and designing of risk management, evaluation of risk management, quantitative and qualitative analysis of risk, risk response planning, and risk monitoring and reporting.

Categorising the types of risks is necessary for any risk management procedure. Ng and Loosemore (2007) categorise the types of risk in infrastructure projects as: site risks, which include site conditions, site preparation and land use; construction risks, which include cost overrun, delay in completion and failure to meet performance criteria; operation risk, which includes operation cost overrun, delays or interruptions to the operation and a shortfall in service quality; revenue risks, which include an increase in input prices, change in taxes, tariffs and demand of output; financial risks, which include the interest rate and inflation; force majeure risk; regulatory political risks, which include changes in law and political interference; project default risks; and asset risks. Furthermore, Tan (2007) classifies risk type depending on project stages such as completion risk, counter-party risk (the inability of other parties to pay or perform), political risk, force majeure risk, financial risk, input risk, market risk; insurance risk, environmental risk, operational risk, regulatory risk, residual value risk and technological risk. Some of these risk types directly affect the cost and duration of the project, and others affect projects indirectly. As can be seen from previous literature, risk type relates to the different phases of infrastructure projects. This research focuses only on risks associated with phases of Australian infrastructure construction projects.

Several studies have been conducted to consider risk management and its impact on the time and duration of projects. For example, Serpella et al. (2014) argue that the ineffectiveness of risk management in construction projects is due to a lack of knowledge in risk management. Therefore, a knowledge-based approach will be suggested to assist stakeholders in applying a more systematic approach to risk management and using acquired knowledge and experience and past practices in risk management. Hwang et al. (2014) conclude that the level of risk management in small projects is low due to time constraints and the lack of an adequate budget to manage. They also conclude that there is a strong positive relationship between risk management and project performance in terms of time and cost. Visser and Joubert (2008) found that construction companies suffer from a lack of culture, practices, and systems for risk management in spite of their awareness of problems associated with running a project at relatively high risk.

Thus, there is a need to study the effect of risk management on the time and cost of the project and the performance of the project because the impact of risk management varies from one country to another and from one project to another depending on the project environment.

2.4.2 Sustainability

Sustainability is a major and unprecedented challenge for organizations and projects managers, and will affect the competitiveness of their organizations and projects (Lubin & Esty 2010). Sustainable development refers to meeting the requirements of the present while maintaining the needs of future generations (Khatib 2016). Ugwu and Haupt (2007) mention that sustainability is an international issue which demands a global solution. They argue that there is an urgent need to increase the use of international standards (related to economy, society, and environment) designed to evaluate the sustainability of infrastructure projects. The construction industry can achieve a global standard of sustainability by reducing environmental impact and taking into account the economic and social aspects of projects (Häkkinen & Kiviniemi 2008). Thorpe and Ryan (2007) indicate that, all over the world governments are moving towards achieving the parallelism between proper economic management and social requirements with the growing need for natural resources.

Lam et al. (2011) mentioned that there is no uniform specification system for sustainable construction in both the public and private sectors. Therefore, additional efforts should be made in the area of specifications, with a study of their impact on the performance of the project (time and cost). Measuring sustainability in the construction industry needs a lot of attention as a result of global awareness and direction to more sustainable buildings (Berardi 2012). Martens and Carvalho (2016) pointed to a lack of research linking sustainability. In addition, Martens and Carvalho (2016) identified the basic variables of sustainability in terms of the economic, social, and environmental dimensions and their impact on the success of a project. Berardi (2012) reviewed the state of sustainability assessment methods in the construction industry and the need to develop these systems to become more comprehensive in terms of the economy, society and the environment.

Fernández-Sánchez and Rodríguez-López (2010) developed a method to distinguish and prioritize sustainability indicators in infrastructure projects in Spain. Bocchini et al. (2013) compared the effect of the resilience and sustainability of infrastructure projects and concluded that sustainability is more closely associated with environmental orientation and reduced impacts on the environment, while resilience is more closely associated with catastrophic events and the administration of disasters. Padgett and Tapia (2013) assessed the sustainability of infrastructure projects (bridges) by reviewing the relationship between natural risk management and sustainability during the project operation phase by employing risk-based indicators.

Florez et al. (2013) mentioned that the construction industry is heading for a significant change as a result of growing interest in using sustainable materials to achieve economic, social, and environmental benefits. Furthermore, although the sources of sustainable materials are increasing, no clear definition of this term has been developed. Three factors have been used to identify and measure sustainable materials; namely user attractiveness, function and resourcefulness. Kamali and Hewage (2017) mentioned that the process of selecting a sustainable construction method is based on evaluating the sustainability of the building style, sustainability evaluation criteria (SEC) including the elements of the triple bottom line (TBL) (economic, social and environmental) and each component containing a number of sustainability performance indicators (SPI) for each stage of construction. Cheng et al. (2018) pointed to the lack of a system for evaluating the implementation of sustainable construction projects. They proposed the project sustainability assessment system in Taiwan by using the Level of Project Sustainability (LPS) which provides a mechanism for, and guidance to, help project managers and project engineers monitor the overall sustainability of projects.

Sustainability and sustainable environments are emerging and significant global issues that have attracted increasing amounts of research in a variety of areas. Most research represents the foundation for the subsequent research to access sustainability assessment methods, the using of sustainability, and the development of criteria and indicators for sustainability. This process varies from one country to another as a result of different environments and economic and social situation and requirements. Therefore, the application and development of sustainability principles should be considered an important risk-related factor for the performance of Australian infrastructure projects. The concept of sustainability requires a comprehensive study to cover all aspects that affect the performance of projects under the influence of risk.

2.4.3 Stakeholder Requirements

Most literature sources divide stakeholders into three main groups; clients, consultants, and contractors. Stakeholder perceptions and understandings of the risks surrounding construction projects vary depending on their opinions, ideas and interests (Díaz et al. 2017). Construction projects' Risk Management (RM) and

Stakeholder Management (SM) are connected (Zhang 2011; Wang et al. 2017). Ogunlana (2010) argues that some performance indicators such as safety and stakeholder satisfaction and reduced conflicts and disputes have become of greater significance, and this leads to the transformation of performance management from a quantitative measurement process (cost, time and quality) to a combination of quantitative and qualitative measurements. They also mention that construction projects commonly suffer from significant problems in time and cost if the relationships between stakeholders are not satisfactory. Doloi (2011) established a conceptual model to distinguish the fundamental problems related to the views of the stakeholders during the life of the project. Yang et al. (2009) identified 15 critical success factors in construction projects in Hong Kong and found that the factors influencing stakeholder management are “managing stakeholders with social responsibilities”, “assessing the stakeholders' needs and constraints to the project”, and “communicating with stakeholders properly and frequently”. Doloi (2012) identified 73 stakeholder-related factors in construction projects, which affect the cost of projects and found: a lack of competence of stakeholders and technology needed to implement projects leading to claims and delays in the project implementation period, a lack of understanding of the plans and specifications leading to weak productivity and increased differences among stakeholders which leads to increased project cost and good communication between stakeholders reduces the time and cost of the project. Yang et al. (2011) identified four gaps with regard to stakeholder management: there is no complete list of factors influencing successful stakeholder management, a stakeholder management approach needs to be developed, there are no standardized approaches to stakeholder management, and few stakeholder relationship studies analyze the impact of stakeholder relationships on projects. This study was validated with Australian projects and has provided a small but essential step to understanding the management of stakeholders.

Lindhard and Larsen (2016) pointed out that the emphasis on knowledge sharing and information among stakeholders (clients, consultants, and contractors) leads to the good performance of the project implementation in terms of cost and time, and also reduces the risks that affect the success of project performance. Zhao et al. (2016) presented an empirical study on stakeholders' awareness and understanding of risks in construction projects, and found that awareness and understanding reduce the risk effect. In addition, risk assessment among stakeholders (clients, consultants, and contractors) varies depending on social circumstances. Xia et al. (2018) suggested the possibility of combining Risk Management (RM) and Stakeholder Management (SM) to enhance the comprehensive management and improvement of project performance. They also identified four patterns in the relationship between risk management (RM) and stakeholder management (SM): "(1) management of risk based on stakeholder identification, (2) internal stakeholders' responsibility and ability in the RM process, (3) management of stakeholder differences concerning risk, and (4) interrelatedness between RM and SM and effect on project performance". These patterns help to strengthen the relationship between risk management (RM) and stakeholder management (SM). Sambasivan et al. (2017) mentioned that the process of understanding and analyzing stakeholder (clients, consultants, and contractors) relationhips helps reduce the risk of delays in construction projects. In addition, disputes, litigation and arbitration among stakeholders are risk-related factors that lead to cost overruns. Yeung et al. (2017) explained that disputes between contractors and subcontractors due to a lack of coordination between them, and the inability of the main contractor to meet the requirements of the subcontractor, affect the performance and time of the subcontractor.

Based on the above, there is a significant difference between stakeholders' perceptions of the risks surrounding the project and there is overlap between Risk Management (RM) and Stakeholder Management (SM). On the other hand, stakeholders are the main factor in project management. Therefore, the relationships between stakeholders have a positive or negative impact on the cost and duration of the project, and meeting the requirements of stakeholders (clients, consultants, and contractors) is a major risk issue.

2.4.4 Communication

Project Communication Management is the critical relationship between the stakeholders of a project and the information necessary for successful communication. It is also the process of managing and using procedures required for the establishment, gathering, distribution, sharing, delivery, and storage of project information (PMI 2004). Project Communications Management consists of a set of operations necessary to meet project's information needs and meet the requirements of stakeholders by designing an effective communication and information exchange strategy and implementing the activities necessary for successful communication, as shown in Figure 2.3 (PMI 2017).

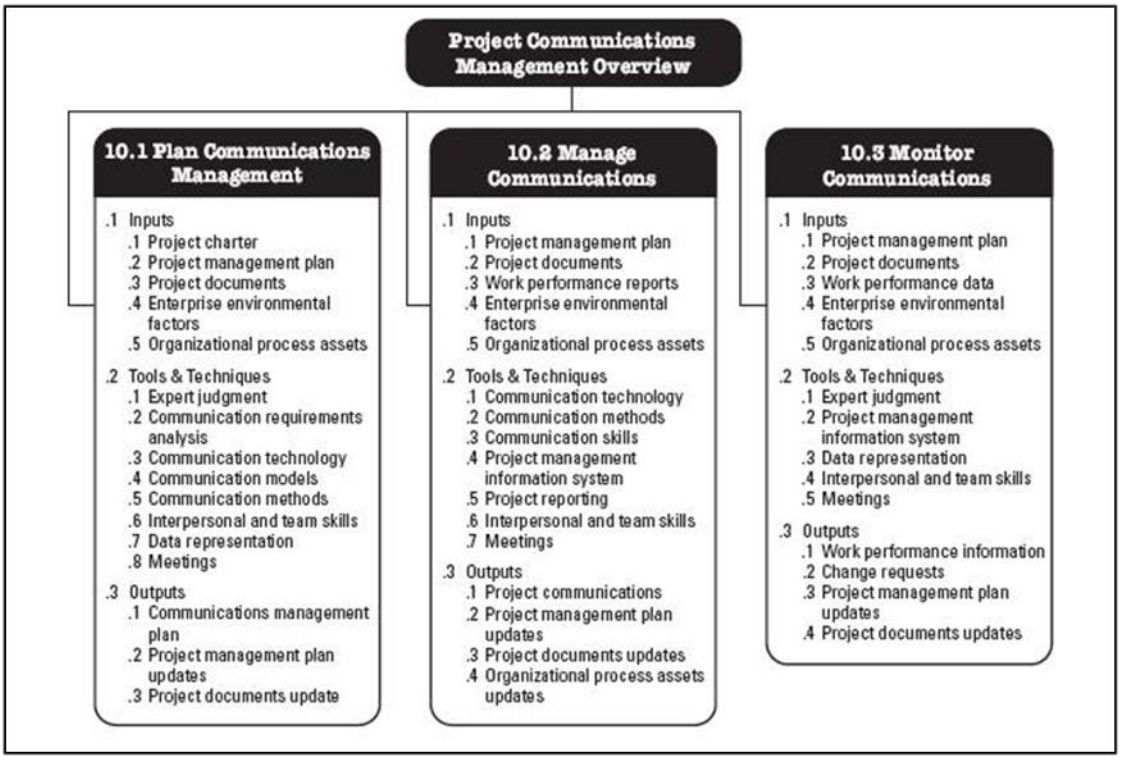


Figure 2-3: Overview of the Project Communications Management process (PMI 2017)

According to Lindhard and Larsen (2016), communication that works well is one of the significant factors affecting project performance in terms of cost and time, and also reduces the risks that affect the success of a project. Nipa et al. (2019) found that incompetent communication among stakeholders leads to: challenges as a result of internal misunderstandings, time delays and budget excesses due to the inaccurate transfer of information.

Enormous amounts of time can be spent on communication between stakeholders (PMI 2004). Harstad et al. (2015) pointed out that the use of appropriate and modern communication tools such as tablets helps to save information in the construction industry. They identified that despite the cost of tablets, the cost of training and use, and the cost of the Internet connection, They help to reduce the transfer of unnecessary information and reduce errors. Hassan et al. (2018) explained that the increasing use of virtual design and construction (VDC) leads to increased efficiency, speed and accuracy of work during the bidding phase. This is because the use of new methods of communication between stakeholders increases the role of the stakeholders associated with the bidding process. Ejohwomu et al. (2017) specified that the most significant barriers to stakeholder communication in Nigeria are "unclear objectives", "ineffective reporting system" and "poor leadership". Nipa et al. (2019) identified that "design and technology, scope clarity, technical and financial support, facility, experience issues, and decision-making issues" are the key communication indicators during the design phase.

Based on the above, communication between the components of the project is necessary and directly affects the duration of the project and the cost of the project. Many factors affect the efficiency of communication, which in turn affects the performance of the project. Most of the research seeks to develop a system of Project Communication Management and a means of communication between stakeholders through the use of modern information communication technologies as well as identifying barriers to communication and identifying key indicators of communication. Therefore, communication between stakeholders (clients, consultants, and contractors) in projects is a major risk factor that has a positive or negative impact on the cost and duration of projects. The impact of communication as a risk-related factor affecting the performance of infrastructure projects in Australia must be studied and calculated.

2.4.5 Procurement Strategies

The procurement strategy is the management processes necessary to obtain or purchase services or products from a group other than the project team. It includes the preparation of purchase or service conventions and monitoring of the management of these conventions (PMI 2017). Procurement is the essential and necessary process to obtain services and products from outside the project team (Dhanushkodi 2012). Over the past three decades, there has been a great deal of interest in the procurement strategies used in construction projects. The decision-making process associated with procurement is complex (Naoum & Egbu 2016). Naoum and Egbu (2015) mention that there is a lack of research exploring the relationship between procurement methods and a number of issues, such as innovation, technology and sustainability, and the management of value. However, choosing an appropriate method or strategy for procurement in infrastructure projects has a significant impact on the cost and duration of project delivery.

Eriksson (2017) mentioned the need to use a suitable procurement strategy according to the characteristics, nature, and size of the project. Ruparathna and Hewage (2015) pointed to procurement strategies as an essential process in managing construction projects and showed that sustainable procurement strategies are seldom used in Canadian construction projects. Dhanushkodi (2012) explained that there are seven types of procurement methods and points out that only two types are preferred for infrastructure projects: the traditional method and the public-private partnership method. Partnership alliances and early contractor involvement are being used for large projects.

Australian governments provided national guidelines for the delivery approach of infrastructure projects to enhance the use of efficient practices. These guidelines cover the main procurement strategies used in infrastructure project delivery and include traditional contracting, alliance contracting and public-private partnerships (Australian Government - Department of Infrastructure and Regional Development 2016).

The procurement strategy affects the performance of the project due to conflicts, low productivity, exceeding the project budget and the time needed to complete the project. Solutions to these problems can be found by changing the procurement strategy approaches for efficient cooperation between the main contractors and subcontractors (Jentsch & Gulsett 2018). Bower (2003) argues that procurement strategies are likely to have a significant influence on the schedule and the cost of accomplishment of the project. He also argues that there is a negative impact on the outcomes of the project if unsuitable procurement strategies are used. Du et al. (2016) pointed to the risks of procurement strategies on the performance and delivery of the project in terms of the relationship between contractors and stakeholders needed to obtain the necessary project resources and successful completion of the project.

Based on the above, the procurement strategy is an important process to provide services and resources for construction projects and its success leads to the successful delivery of the project at the specified time and cost. As a result, the procurement strategy is a significant risk issue. Dispute arising from the contracting process directly affect the performance of a project. Research suggests that a purchasing strategy should be considered in relation to many factors such as sustainability. In addition, the development of procurement strategies affect performance. Thus, selecting appropriate procurement strategies positively affects the cost and duration of a project. The impact of purchasing strategies as a risk-related factor affecting the performance of infrastructure projects in Australia should be studied and calculated.

2.5 Research Gap

The concept of earned value management focuses on time and cost in the process of evaluating project performance without taking into account many of the factors that represent as risk factors for the project. To obtain high accuracy and reliability in measuring the performance of infrastructure projects must be calculated the impact of these factors. There are many risk-related factors that affect the measurement and evaluation of the performance of infrastructure projects in Australia. Therefore, there is a need to study the impact of risk management on the performance of infrastructure projects in Australia. The impact of risk management varies from country to country and from project to project depending on the project environment. It is also the study of related-risk factors, and their measurement items and calculate the impact of these risk-related factors as an RPI and incorporate this effect into the EVM formulas to modify the concept of EVM. These factors are sustainability, requirements of stakeholders, communication, procurement strategies and other factors.

In order to bridge the research gap, the aim of this research is to develop an integrated approach to the concept of EVM; this modified concept takes into account the impact of risk-related factors that affect the performance of infrastructure projects in Australia.

2.6 Chapter Summary

This chapter provides a literature review on risk-related factors that affect the performance of projects in the construction industry. It explores the current literature on Earned Value Management (EVM) and the gaps and shortcomings of this associated with this concept, and how to address them. It also identified the limitation of EVM and its use, which have been adopted as the research gaps to be addressed by this research. The current failure to consider the impact of factors other than time and cost in EVM calculation and prediction of outputs will be explored in this research study.

This chapter sets out the basic structure and the starting point for identifying the associated risk factors by reviewing the literature. The literature identified the impact of some factors on the performance of projects in countries other than Australia. In previous studies, the influence of a number of factors has been identified and proved, without calculating the value of this effect on the project performance. Some emerging factors have not been extensively studied. Based on this, four key factors were identified: sustainability, stakeholder requirements, communication, and procurement strategies.

Figure 2.4 explains the conceptual framework of this research. It emphasises the development and modification of EVM concept enhanced by considering risk-related factors such as sustainability, stakeholder requirements, communication, procurement strategies and other factors.

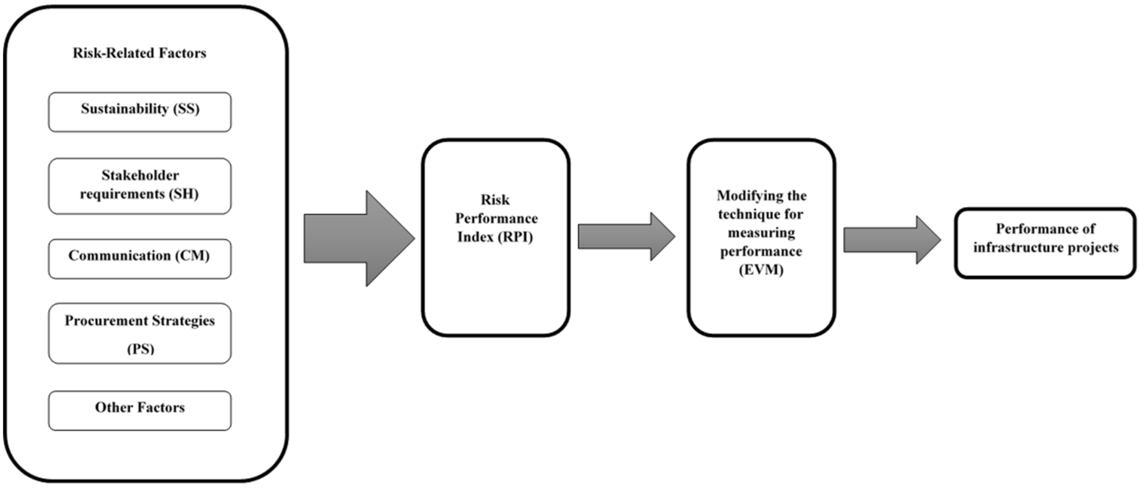


Figure 2-4:The conceptual framework for the modified EVM

3 CHAPTER THREE: - RESEARCH METHODOLOGY

3.1 Introduction

In the previous chapter, the literature review mentioned the importance of infrastructure projects to a country's development and national income. In addition, the literature review has demonstrated the need to develop and modify the concepts currently used to monitor and evaluate the performance of infrastructure projects, and to predict the cost and duration of projects. Australian infrastructure projects suffer from a low level of control over the performance of projects despite efforts and research to address the problem. By monitoring and evaluating cost and time factors, risk management plays an important role in infrastructure project performance.

This chapter addresses the methods or procedures adopted to achieve the research objectives. A mixed method was followed to gather data and analyse the results. The qualitative data were obtained from the literature review and face to face interviews. This data was analyzed with manual methods and verified with NVivo qualitative analysis software. The quantitative data was gather through the use of a questionnaire survey which was tested by a pilot study. The quantitative data were analyzed with SPSS and AMOS. The results of the analysis were used to modify the concept of Earned Value Management. The validity of the modified concept was tested by applying it to historical data from previously implemented infrastructure projects.

3.2 Research Paradigms

The research paradigm is a guide that assists the researcher in the conducting research according to assumptions and philosophies (Collis 2009). The selection of appropriate research paradigms helps the researcher decide which research strategy and research methodology are precise and accurate (Saunders 2012).

This research aims to identify factors related to the risks that affect the performance of infrastructure projects in Australia. The conclusions of the literature review in the previous chapter pointed to a number of risk-related factors that affect the performance of projects but, there is a lack of research about some of these factors as they are emerging factors or they have been studied in places other than Australia. So, there is an urgent need to identify these factors in greater detail depending on the experience of those involved in the management and implementation of infrastructure projects in Australia.

The researcher chose to interview experts with experience in this field to identify a set of risk-related factors (qualitative data) and then use the questionnaire (employing the Likert scale) to allow the participants to assess the effects of these factors based on their experience in the field of infrastructure projects (quantitative data).

In mixed research, the researcher looks at numerous methods, approaches and techniques for the collection and analysis of data rather than relying on one method. This approach is compatible with pragmatist philosophy (Creswell 2018). Pragmatism supplies the philosophy that drives the procedures, techniques and ways of research to achieve the aim of the research (Creswell 2014). Furthermore, The pragmatism philosophical approach broadly trends through their characteristics by systematic pluralism (Shah et al. 2018). The pragmatism philosophy provides an adaptive research approach with a modern demeanour in management research (Emison 2010). So, pragmatism was adopted in this research as the research paradigm.

3.3 The Research Design

The research design is a comprehensive outline that deals with procedures employed to achieve answers to the research question (Saunders 2012). The research design is the general plan used to organize and conduct the research (Velde 2004). The research design is the idea about how to answer research questions and designate approaches for collecting data (Gibson 2009). The research design is a strategy of inquiry (in a qualitative approach, quantitative approach, and mixed methods approach) that supplies particular orientation for the execution of the research study (Creswell 2018).

This research aims to develop a performance assessment system for Australian infrastructure projects during their implementation phase by modifying the concept of EVM. The modified concept takes into account the impact of risk-related factors on the performance assessment of infrastructure projects in Australia. To achieve this target, four research objectives were identified. Six research questions were created based on these objectives. The mixed methods approach was selected to answer these questions. The qualitative method used in the first and third stages of data collection and analysis. The quantitative was method used in fourth stage of data collection and analysis. Each stage will be explained and discussed in detail in the next paragraphs of this chapter.

3.4 Mixed Methods Approach

Choosing the appropriate research method to achieve research objectives is a significant factor for successful research. Creswell (2018) argues that the selection of the research method is one of the main elements in the research framework, and covers data gathering, data analysis and data interpretation. Many research designs in management research are likely to use qualitative and quantitative approach (Saunders 2012).

Based on the above and based on the objectives and purpose of the research, a mixed methods approach will be used. According to Johnson et al. (2007) and Venkatesh et al. (2013), in mixed methods, both qualitative data and quantitative data are used to provide a more detailed understanding of the phenomenon or concept, as well as provide a high level of confidence in the results of the study. So, the mixed methods approach will provide deep understanding and accurate results. According to Johnson and Onwuegbuzie (2004), the advantage of a mixed method is that the researcher can maximise the strengths and minimize the weaknesses of each method of analysis (quantitative and qualitative). Mixed methods also provide more credibility to researchers who are interested in understanding the specific description of the methodology or the evolution of technology so as to be closer to practice. Venkatesh et al. (2013) argue that using the mixed method in research serves or covered the seven different research purposes. Two of these purposes are complementarity and developmental:

- Complementarity, “different methods are used in order to obtain views on the same complementary phenomena or relations” (Venkatesh et al. 2013)
- Developmental: “using varying methods of designs to ensure a complete picture of the phenomenon is obtained” (Venkatesh et al. 2013)

A mixed method approach has been selected to serve the objective of the study. For the first objective, four potential risk- related factors have been identified from the literature review (first stage). However, there may be other risk-related factors that have not been identified. These other risk-related factors were identified from interviews (third stage). The qualitative study using interviews (third stage) will be used to explore the set of the risk-related factors affecting performance of infrastructure in Australia. Furthermore, a quantitative study using the questionnaire survey (fourth stage) will be used to test the relationships between these risk-related factors and measurement the effect of sets of the risk-related factors on infrastructure performances (time and cost) as risk performance index. The research stages are explain and discussed in next paragraph. Table 3.1 illustrates the selected research methods to answer the research questions to achieve the research objectives. Each method was discussed in specifics in the following paragraphs.

Table 3-1: Research methods for each research objective

Research methods for each research objective			
Research objectives	**Research questions**	**Selection methods**	**Data gathering methods**
Objective 1: Investigate the influence of risk management approaches on the technique for assessment of construction project performance	**RQ1**: What are the risk-related factors that impact infrastructure project performance in Australia?	Qualitative	Literature review and Interviews

(infrastructure projects in Australia), including contributing a set of risk-related factors such as the sustainability, requirements of stakeholders, communication, procurement strategies and other factors. In addition, identify the measurement items of these factors.	**RQ2:** What are the significant measuring items for these risk-related factors?	Qualitative	Literature review and Interviews
Objective 2: Inspect the influence of the set of risk-related factors such as sustainability, requirements of stakeholders, communication, procurement strategies and other factors on the performance of infrastructure projects in Australia. In addition, identify the relationships between these factors.	**RQ3:** Are these risk-related factors likely to have significant impacts on the performance of infrastructure projects in Australia?	Quantitative	Questionnaire Survey
	RQ4: What are the significant relationships between these risk-related factors?	Quantitative	Questionnaire Survey

Objective 3: Account for the Risk Performance Index (RPI) resulting from the impact of the set of risk-related factors such as sustainability, stakeholder requirements, communication, procurement strategies and other factors on the performance of infrastructure projects in Australia.	**RQ5:** What is the Risk Performance Index value resulting from the effect of the risk-related factors on the performance of infrastructure projects in Australia?	Quantitative	Questionnaire Survey
Objective 4: Develop a new performance evaluation system using a modified concept of EVM that enhances the forecasting accuracy of the project estimate, and accomplished by considering risk-related factors such as sustainability, stakeholder requirements, communication, procurement strategies and other factors.	**RQ6:** How can EVM be modified to enhance the forecasting accuracy of the project estimate through the consideration of risk-related factors such as sustainability, stakeholder requirements, communication, procurement strategies and other factors?	Quantitative	Case study

3.5 Sample

Data collection from a member of the population is not possible because it takes too long and is costly in economic terms (Levy & Lemeshow 2013). So, The process of selecting a sample of the population involves a small number of people representing all the population which can be generalized from the sample to include the entire population (Rea & Parker 2014). The objective of this research is to identify and a broad and comprehensive understanding of the risk-related factors that affect the performance assessment of the implementation of infrastructure projects in Australia. Individuals involved in the implementation of infrastructure projects in Australia are considered the most appropriate sources of data collection required.

The initial plan was to conduct 20 interviews. However, the number of interviews is dependent on the content of the interviewee responses. If similar themes and concepts are received after undertaking a number of interviews, then the data has reached its saturation stage (Saunders et al. 2018). This means, there is no further requirement for undertaking interviews.

As SEM will be developed based on the data from a questionnaire survey, the number of samples is dependent on the number of the latent variables, number of the observed variables, desired statistical power level, and probability level. As shown in Figure 5.12. For more details see section 4.3.2, 5.4.1 and 6.2.1.

3.6 Research Stages

The research stages used to conduct any research, show the sequence of procedures, processes and methods used to collect and analyse the data used to achieve the research objectives. Data quality reflects the methods and approaches used in data collection and analysis (Ali 2016). Figure 3.1 illustrates the research stages followed in this study. These stages will be explained in detail in the following paragraphs.

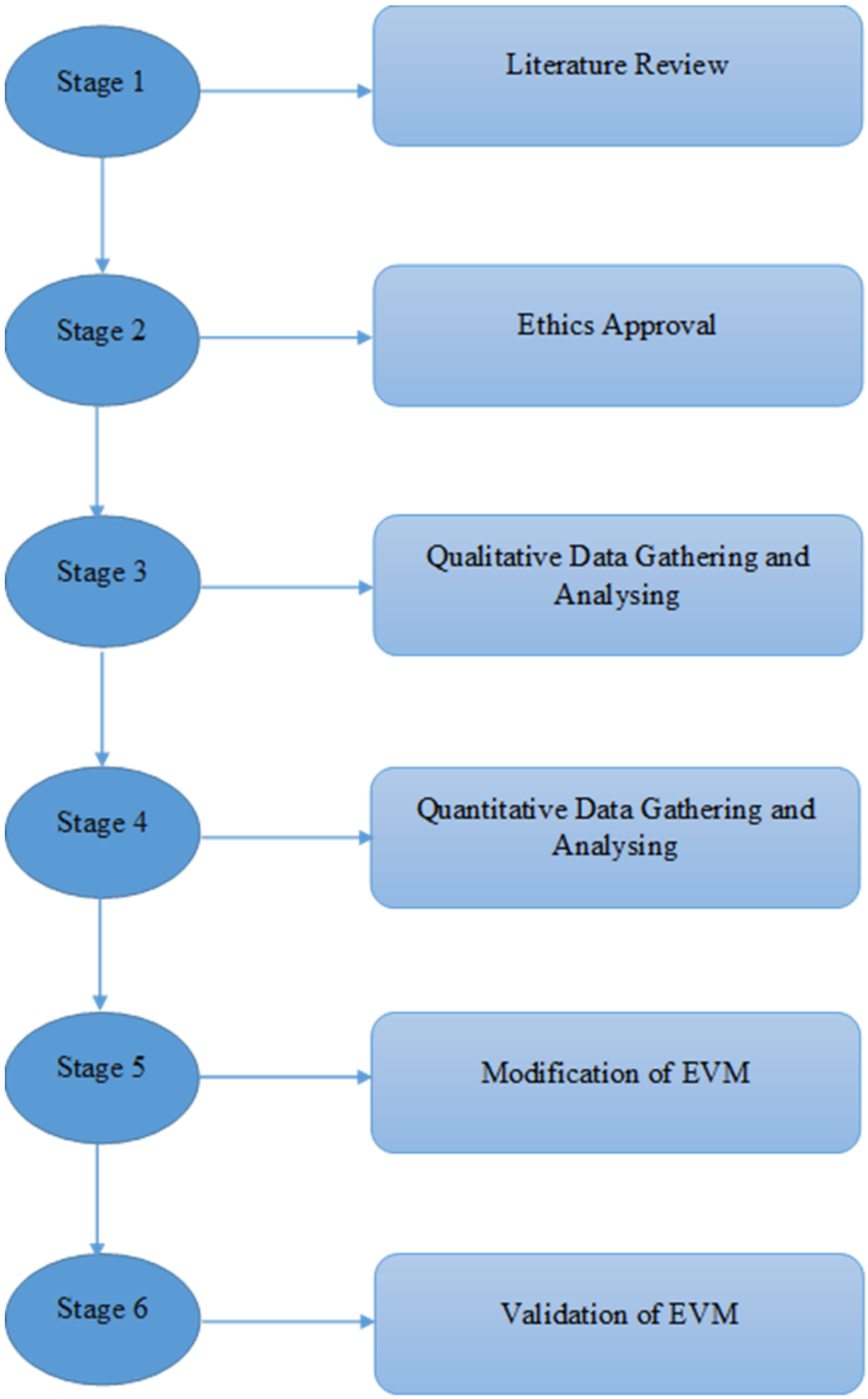


Figure 3-1: The research stages for this research

3.6.1 Literature review

The documents that are admitted by organizations as a reliable exporter of information and data called the academic literature (Evans 2011). Searching and connecting with previously published research in the initial stages of the research is obviously important (Gibson 2009). The literature review through research in libraries and internet is one of avenue for gathering initial data and is a significant step in determining the research issue (Cavana 2001).

In the early stages of research, it is important to identify the research problem of research and the objectives and hypotheses of research. The literature review was used to investigate these. The initial review of the literature helps to promote and develop the researcher's knowledge and provide the researcher with a framework for the research gap, research issue, research objectives and research questions (Collis 2009). The review of the academic literature related to the performance of infrastructure projects in terms of weaknesses in the methods of evaluation and factors affecting the performance of infrastructure projects was of great importance.

In this research, the USQ library and Google Scholar were used to review books, articles, conference papers and Australia Government reports about construction performance and risk management. The literature review is also used to explain the principle of EVM and to identify the benefits of using this concept. Moreover, it is used to identify the weaknesses and strengths of EVM, and to investigate the factors that affect the accuracy of EVM under the effect of risk management (risk-related factors). The literature review identified four risk-related factors: sustainability, stakeholder requirement, communication and procurement strategies. Furthermore, the literature review helped to develop the framework for the interview questions.

3.6.2 Ethics approval

Ethical considerations are a significant and necessary part of conducting any research related to the opinions and perspectives of people and data or information for institutions, organizations and public and private companies. Therefore, researchers must adhere to ethical considerations to protect participants from any misconduct in the name of their institutions and organizations (Israel & Hay 2006). The researcher is required to meet the standards and guidelines of the Human Research Ethics Committee (HREC) at USQ, to ensure that the confidentiality of information is maintained. Moreover, interviewees and survey respondents will be free to choose whether or not they answer questions, and care will be taken to ensure that answers do not have legal consequences.

The researcher applied for the ethical approval from USQ to conduct this research. Approval was given with number H16REA261 (see Appendix A2). The documents necessary for conducting the research, such as information sheet for particpants and consent form for interview and survey, were also considered in the approval prosess (see Appendix A3). Therefore, the confidentiality of all the information provided as well as the names of the persons involved in the research has been kept confidential. Participants' names and the names of their institutions are not mentioned in this research.

3.6.3 Qualitative data gathering and analyzing

3.6.3.1 Interviews

Qualitative data collection, such as interviews, includes field work to gather data and the analysis of data in a way that explains the participants' views. The researcher must then report the results in an expressive and convincing manner (Creswell 1998). Interviews are selected as a method or technique for collecting data for a number of reasons. Interviews are one of the most widely used research tools in the various fields of science. They are used in surveys and conducted officially by telephone or face-to-face (Brinkmann 2014). Interviews are very useful to understand what is happening and to provide background research-related materials. In addition it will be used to explore the subjects and detect the results (Saunders 2012). The interviews are used to assert past data add to discover and get new (Creswell 2009). They are used in exploratory research to obtain a clear and deep understanding of a complicated problem (Velde 2004).

In this research, the interview serves four purposes. First, it helps the researcher ascertain the impacts of the key risk-related factors obtained from the literature review on the performance (cost and duration) of Australian infrastructure projects.

Second, it allows the researcher to investigate, identify and obtain a list of new risk-related factors affecting the performance of infrastructure projects in Australia. Third, they let the researcher obtain relevant sub-risk factors (measurement items) influencing the key factors. Fourth, they enable the establishment of a comprehensive idea of the quality and nature of the questions in the questionnaire survey.

Interviews were conducted with different members of infrastructure construction project management community in Australia. The face-to-face interview was conducted with 15 people working on infrastructure projects in Australia. The manual analysis was conducted continuously during interviews. After the interview number15, the manual analysis was conducted. The saturation state was reached (noted) at interview number12, where nothing new was added during the interview 13-15, but confirmed what was mentioned in the previous 12 interviews. Table 3.2 lists the details of the interviews conducted.

Table 3-2: Interview details

Interviews details			
NO.	**Interview code**	**Date of Interview**	**Duration of interview**
1	Interviewee # 1	25/04/2017	27.3
2	Interviewee # 2	2/05/2017	40.46
3	Interviewee # 3	17/05/2017	15.8
4	Interviewee # 4	2/06/2017	44.59
5	Interviewee # 5	5/06/2017	34.8
6	Interviewee # 6	10/06/2017	43.59
7	Interviewee # 7	27/06/2017	48.15
8	Interviewee # 8	5/07/2017	53.11
9	Interviewee # 9	6/07/2017	21.18
10	Interviewee # 10	6/07/2017	17.07
11	Interviewee # 11	6/07/2017	30.05
12	Interviewee # 12	6/07/2017	22.46
13	Interviewee # 13	6/07/2017	23.16
14	Interviewee # 14	6/07/2017	17.11
15	Interviewee # 15	6/07/2017	28.14

The use of interviews in this research with project team members with good experience in infrastructure projects in Australia such as project managers, construction engineers, estimating engineers, management engineers, planning engineers and design engineers will assist to monitor and evaluate the performance of infrastructure projects during implementation. Interviews were conducted with experienced managers of Australian infrastructure projects. Responses were sought from these people because they are particularly able to consider the first and second research questions:

RQ1: What are the risk-related factors that impact infrastructure project performance in Australia?

RQ2: What are the significant measuring items for these risk-related factors?

The interview data also seek to achieve the first research objective, which RQ1 and RQ2 seek to address.

Objective 1: Investigate the influence of risk management approaches on the technique for assessment of construction project performance (infrastructure projects in Australia), including contributing a set of risk-related factors such as the sustainability, requirements of stakeholders, communication, procurement strategies and other factors. In addition, identify the measurement items of these factors.

This stage of the research prepares for the next stages of research, which include the preparation and testing of questionnaire questions. Interviews can be used to prepare the questionnaire survey by exploring the survey themes and survey structure (Saunders 2012). In this research, more than one method was used to collect and verify the data, ensuring a more comprehensive final framework.

The process of qualitative data analysis contains a number of steps beginning with the use of coding to distinguish between interview participants. In the second step, the voice recordings of interviews are converted into texts. The third step is to start the manual analysis by scanning data. Manual analysis is in stages during the conduct of the interviews until making sure of access to the saturation state. During this step, the themes are identified. The qualitative data needs to be transcribed, scanned, sorted, organized and stored (Leavy 2017). Then it is verified for and validity and credibility through a manual analysis using NVivo and the quantitative data analysis using Relative Important Index RII are conducted. In the last 20 years, there have been important developments in the process of qualitative data analysis through the use of computer programs that help researchers with the analysis process (Bryman 2007). Finally, each factor and its measurement item are classified according to the percentage of frequency obtained through the interview. This step prepares for the next stage. More details about qualitative data analysis and computer software analysis are clarified in Chapter 4 Section 4.4.1 and 4.4.2.

3.6.4 Quantitative data gathering and analyzing

The process of quantitative data collection and analysis is a significant stage in reaching a successful theoretical test. Creswell (2018) mentions that testing quantitative data, inspecting the impact and relationships between variables, is essential to testing hypotheses by answering research questions. The term “quantitative” is usually used to refer to numerical data collection methods such as a questionnaire or numerical data analysis processes such as statistics or graphs (Saunders 2012). This stage includes the process of preparing questionnaire questions based on the results obtained from reviewing the literature and the required information, testing the structure, quality, content and length of the questionnaire by the pilot study, collecting the data by conducting the questionnaire survey, and finally analyzing the questionnaire survey results.

3.6.4.1 The questionnaire survey preparation and design

The first step in the survey is preparing and designing the questionnaire survey questions. The questionnaire was prepared and designed based on the outputs of the literature review and interviews. To achieve research objectives through the answering of questions, the questionnaire should be clear and easy to use. More details about the questionnaire preparation and design are provided in Section 3.5.4.3 and Chapter 5 Section 5.2.

3.6.4.2 Pilot study

The purpose of this pilot study was to check the questionnaire survey. Van Teijlingen and Hundley (2001) mention that the pilot study is a critical factor in the design and preparation of a good study, and helps researchers get a clear view by providing a range of significant functions. The online survey (Lime Survey) and email were used to distribute and submit the pilot study. The use of the online survey is much less costly and takes less time than administering the questionnaire through traditional methods such as mail (Schleyer & Forrest 2000). Twenty-four managers of Australian infrastructure projects and academic staff were invited, through an invitation letter to evaluate the initial version of the questionnaire survey (see Appendix B1). The pilot study included questionnaire questions serving the objectives of the research and questions to evaluate the questionnaire in terms of the clarity of the questionnaire questions, the structure of the questionnaire, and the time required to answer the questionnaire (see Appendix B2). The pilot study answers were analysed and used to modify the questionnaire survey questions, making them more clear, convenient and easy to answer. The final version of the questionnaire survey was then ready to send to the survey participants.

3.6.4.3 The questionnaire survey

A questionnaire survey provides the researcher with an active, comparatively accurate and fast way to gather data (Zikmund et al. 2013). For the purpose of this study, the questionnaire was divided into four parts (see Appendix B4). The first part contained demographic questions: background questions about the respondents such as years of experience, the highest education qualification level (Certificate, Diploma, Bachelor's degree, Master's degree and Doctorate), the state or territory in which worked (Western Australia, Northern Territory, South Australia, Queensland, New South Wales, Australian Capital Territory, Victoria and Tasmania), the roles played by the participants during their work in infrastructure projects (site engineer, senior project manager, project manager, design engineer, senior engineer, operation manager, construction engineer, planning engineer, estimating engineer, management engineer and others), types of projects where participants have experience (roads, tunnels, bridges, airports, railroads, dams, infrastructure maintenance, harbours, pipeline construction, water supply, wastewater, and others), sectors that participants worked in (public sector, private sector and mixed sector (quasi-government sectors.)), as well as the category of the organization that the participants worked in (client representative, consultant, contractor, and others).

The other parts will contained questions related to the research objectives. The second part of the questionnaire survey contained two questions related to extent of

EVM use in Australia and the reasons for that use. The third part of the questionnaire survey contained 49 questions related to the significant impact of risk-related factors on the performance of infrastructure projects in Australia. These questions were created based on the results of the literature review and interviews. These questions were used to measure and evaluate the impact of each risk-related factor. Each risk-related factor had a measurement item used to evaluate the performance of infrastructure projects in Australia. Measurement items were used for factors that cannot be measured directly, and this method was used to best explain the theoretical concepts and reduce error in measurement, and to obtain a better statistical estimation (Hair et al. 2010a). To answer these questions, a five-point Likert scale was used, ranging from (1) strongly disagree to (5) strongly agree

This part served to achieve the second and third research objectives,

Objective 2: Inspect the influence of the set of risk-related factors such as sustainability, requirements of stakeholders, communication, procurement strategies and other factors on the performance of infrastructure projects in Australia. In addition, identify the relationships between these factors.

Objective 3: Account for the Risk Performance Index (RPI) resulting from the impact of the set of risk-related factors such as sustainability, stakeholder requirements, communication, procurement strategies and other factors on the performance of infrastructure projects in Australia.

The fourth part of the questionnaire survey contained one question related to estimating the complementary weight of CPI, SPI, and RPI for different periods of the infrastructure project life. This part served to achieve the fourth research objective:

Objective 4: Develop a new performance evaluation system using a modified concept of EVM that enhances the forecasting accuracy of the project estimate, and accomplished by considering risk-related factors such as sustainability, stakeholder requirements, communication, procurement strategies and other factors.

The target sample or the target population in the questionnaire are infrastructure workers in Australia. This target population was divided into three categories. The first category included clients from the public sector, the mixed sector and the private sector. The second category included consultants: supervisors, managers, construction engineers, architects and estimating engineers. The third category, contractors, which included the main contractors, subcontractors and suppliers (tier one contractors, and all contractors involved in or under tier one contractors).

The questionnaire consists of four sections. Some respondents only answered the first and second sections. Some respondents answered only the first, second and third sections. Others answered all sections of the questionnaire. Sections were analyzed separately, in other words, the first and second sections of the questionnaire were analyzed separately, which relates to the widespread use of the concept of earned value management in infrastructure projects in Australia. In the same way, the first and third sections were analyzed separately and the first and fourth sections were analyzed separately. Thus, there is a significant difference in the number of results used in different chapters.

After conducting the pilot study and amending the questionnaire questions, the invitation letter to participate in the survey and answer the questionnaire questions was prepared (see Appendix B3). The invitation letter and questionnaire survey were sent by e-mail to the selected sample.

Analyse the results of a questionnaire survey, using different response scale by Likert scale of five points to measure the impact of the set of risk-related factors on the performance of infrastructure projects. The results from the questionnaire survey were statistically analysed using the popular statistical analysis software, the Statistical Package for Social Science (SPSS). SPSS includes a variety of techniques for statistical analysis. For example, Factor analysis (FA) and Structural Equation Modelling (SEM).

Over the past decade, there has been an increase in the use of Factor Analysis (FA) as a multivariate statistical technique (Hair et al. 2010a). The Factor Analysis (FA) process involves a number of stages to reach a research objective. This approach consists of two steps, the first step is Exploratory Factor Analysis (EFA), followed by the Confirmatory Factor Analysis (CFA).

Data is entered into SSPS. The first step before starting any process of factors' analysis using SSPS is to examine the data. The data checking process involves the deletion of data with regard to missing values and unengaged illogical responses (Hair 2006). After the deletion process, the sample is ready for the Factor Analysis (FA) process.

Exploratory Factor Analysis (EFA) involves reducing the number of variables per factor. Each of the 12 risk-related factors contains a number of measurement items that are used to measure factors that can not be measured directly.

First, for the sets of variables, check the Correlation Matrix. The Correlation Matrix reflects the value of a. Determinant. This value test tests for any problem with very highly correlated variables (multicollinearity). The value of a. Determinant greater than 0.00001 is acceptable (Field 2013).

Then, running SPSS to calculate Kaiser-Meyer-Olkin (KMO) tests for measuring sampling adequacy. "The KMO can be calculated for individual and multiple variables and represents the ratio of the squared correlation between variables to the squared partial correlation" (Field 2009). Hair et al. (2010a) state that statistical values of KMO range from 0 to 1. When the value of KMO is 0, the sum of the partial correlations is significant relative to the total of the correlations, indicating that there is a spread in the correlation pattern and that the process of factor analysis is not appropriate. On the other hand, Hair et al. (2010a) mention that when the value of KMO is close to 1, the correlation patterns are almost integrated and the process of factor analysis will result in independent and reliable factors. So, a value of KMO greater than 0.05 is acceptable (Hair et al. 2010a; Field et al. 2012).

Another test result appears with KMO results when running SPSS, Bartlett's Test of Sphericity. "Bartlett's test tell us whether our correlation matrix is significantly different from an identity matrix" (Field 2009). The value is significant when they are less than 0.05 ($p<0.05$) (Field et al. 2012). This reflects a large sample size.

Another output of SPSS is Eigenvalue. The eigenvalue is a step in the process of extracting the factor in terms of identifying non-important variables, by finding linear components within the data set (Field 2009). The eigenvalue provides the percentage of variance and the percentage of cumulative variance which attempts to demonstrate approximately 50-75% of variance using the minimum number of factors.

For extracting factors, the exploratory factor analysis is run more than once, and the pattern matrix demonstrates the outputs as a basic set of items of each factor: "pattern coefficients are the weights applied to the measured variables to obtain scores on the factor analysis latent variables" (Thompson 2004). More details about Exploratory Factor Analysis are provided in Chapter 5, Section 5.4.3.1.

Depending on the final number of items,12 new factors will be ready to use in the second step of Factor Analysis (FA), which is called Confirmatory Factor Analysis (CFA).

The theoretical model was created to examine the relationships between latent variables. Measurement items were used as observable variables (obtained from qualitative data collection and analysis) to measure the latent variables.

Structural Equation Modelling (SEM) by AMOS was used to test the theoretical model. Structural Equation Modelling (SEM) is one of the statistical models which provides an attractive method for examining theory by illustrating and plotting the relationships between multiple variables (Hair et al. 2010a). Furthermore, Hair et al. (2010a) demonstrates the stages of the SEM as explained in Figure 3.2.

The significant fit measurement limits are used to achieve the best fit model. The fit model reflects the assessment of the measurement model's validity. Table 5.21 explains the significant fit measurement limits. The fit measures consist of Chisq (Chi-square), Chisq/df (Normall Chi-square), RMSEA (Root Mean Square of Error Approximation), GFI (Goodness of Fit Index), AGFI (Adjusted Goodness of Fit), CFI (Comparative Fit Index), TLI (Tuckler-Lewis Index), NFI (Normed Fit Index), and IFI (Incremental Fit Index). More details about Confirmatory Factor Analysis

(CFA) and Structural Equation Modelling are clarified provided in Chapter 5 Section 5.4.3.2.

Depending on the initial outcomes of the fit measurement model, the model is re-assessed until the fit measurement limits are achieved. This process is done by adding arrows which indicate a new relationship between the factors until fit measurement limits are reached.

The results of the final Structural Equation Model are used to calculate the Risk Performance Index RPI resulting from the effect of the 12 risk-related factors (sustainability (SS), stakeholders' requirements (SH), communication (CM) and procurement strategy (PS) which were obtained from the literature review, and weather (WE), experience of staff (SE), site condition (SC), design issues (DI), financial risk (FR), subcontractor (CO), government requirements authority (GR) and materials (MR) which were obtained from interviews) on the performance of Australian infrastructure projects, as well as to test research hypotheses and identify relationships between the risk-related factors. The Risk Performance Index RPI reflects the impact of the set of risk-related factors on the performance of infrastructure projects in Australia. The Risk Performance Index ranges between 0 and 1(Babar et al. 2016). When the Risk Performance Index RPI is close to, or equal to 1, the performance is ideal. When the Risk Performance Index RPI is close to 0, the performance is bad. The value of the Risk Performance Index will be used in the next stage to modify the Earned Value Management.

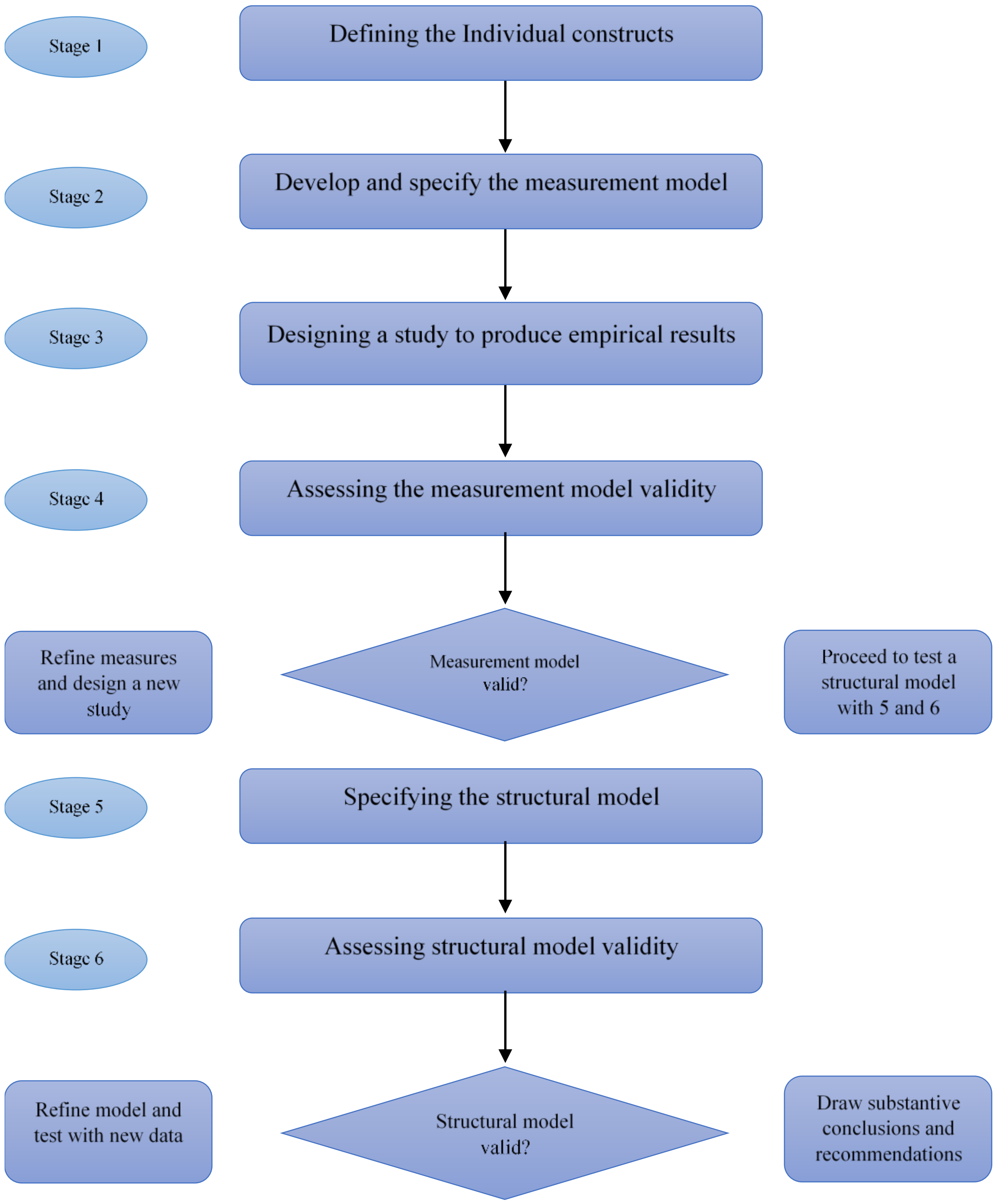


Figure 3-2: Stage process for Structural Equation Modelling (Hair et al. 2010)

3.6.5 Modify the concept of EVM

This stage is done through the use of the value of Risk Performance Index RPI obtained from the analysis of the quantitative data by SEM to modify the EVM. In the problem statement, the current approach of EVM has limited accuracy. This problem is due to the fact that EVM depends on the basic elements of performance (time and cost) without taking into account the impact of many risk-related factors.

This stage serves to achieve the fourth research objective:

Objective 4: Develop a new performance evaluation system using a modified concept of EVM that enhances the forecasting accuracy of the project estimate, and accomplished by considering risk-related factors such as sustainability, stakeholder requirements, communication, procurement strategies and other factors.

In the previous chapter, the literature review demonstrated the principle of EVM, and the major elements were explained. The elements are Planned Value (PV) or Budgeted Cost of Work Scheduled (BCWS), Earned Value (EV) or the Budgeted Cost of the Work Performed (BCWP), Actual Cost (AC) or the Actual Cost of Work Performed (ACWP). Most of these elements are obtained by drawing the relationship between the time and cost of the project. The result of this relationship is the curve of the cumulative cost (BAC) of the project. The elements of EVM were also used for the Estimate at Completion (EAC). PMI (2017) refers to the calculation of the traditional equation of the Estimate at Completion (EAC) in Equations (3.1) and (3.2):

$$\mathrm{EAC} = \mathrm{AC} + \frac{\mathrm{BAC} - \mathrm{BCWP(EV)}}{\mathrm{CPI} + \mathrm{SPI}} \qquad (3.1)$$

$$\mathrm{EAC} = \mathrm{AC} + \frac{\mathrm{BAC} - \mathrm{BCWP\ (EV)}}{\mathrm{CPI}} \qquad (3.2)$$

Babar et al. (2016) developed this equation to be more comprehensive, where the effect of the Risk Performance Index (RPI) is included in the calculation process of the estimate at completion EAC as shown in Equation (3.3):

$$\mathrm{EAC} = \mathrm{AC} + \frac{\mathrm{BAC} - \mathrm{BCWP}}{\mathrm{W1CPI} + \mathrm{W2SPI} + \mathrm{W3RPI}} \qquad (3.3)$$

Where W1, W2, and W3 are the complementary weights CPI, SPI, and RPI respectively. W1, W2, and W3 were obtained from the questionnaire survey. The life of the infrastructure project was divided into four periods (0% to 25%, 26% to 50%, 51% to 75%, and 76% to 100%). Respondents gave a weight or percentage of effect to each indicator in this period by answering this question "For each period of infrastructure project life, could you provide a simple proportional breakdown of the complementary weight (proportional weight or relative weight) of CPI, SPI, and RPI?". Depending on this equation, the impact of risk-related factors was inserted into the calculation process of the EAC. More details about the modified EVM in Australia are clarified in Section 6.2.4. The revised EVM becomes more accurate and realistic as a result of considering the impact of the set of risk-related factors on the performance of infrastructure projects in Australia during the implementation phase.

3.6.6 Validation of the modified concept of EVM

The modified EVM was checked for validity by applying it to real historical data from two Australian infrastructure projects. The financial statements of these two projects, which included the Planned Value (PV), the Actual Cost (AC) and the Earned Value (EV), were used for four different percentages achieved during the life of the project. These values will help evaluate the application of the modified EVM in terms of efficiency and accuracy. This process aims to evaluate accuracy and validity. Furthermore, it compares the variation between the modified concept and the traditional concept.

Based on ethical approvals and due to the importance of this information, respondents’ identifying information will be treated in a very private manner. Names of companies or organizations or work locations will not be mentioned.

3.7 Validity

To verify the validity and reliability of the data, a critical basis must be relied upon to ascertain the research results. The pilot study was adopted to measure the validity and accuracy of qualitative data obtained (Van Teijlingen & Hundley 2001). To obtain an effective pilot study, respondents from a sample similar to the research sample are tested.

To ensure the importance of qualitative data (a set of risk-related factors affecting the performance of infrastructure projects in Australia), the results of the pilot study were analysed using the Relative Importance Index (RII) by factors analysis with SPSS. For more details see section 4.6 and 5.4.4.3

3.8 Reliability

The reliability of the data is ascertained by ensuring the positions of the persons involved in the data collection process. In this research, this was confirmed through the submission of questions that close the demographics of the participants. These questions confirm that all participants have knowledge and information relevant to infrastructure projects in Australia.

The reliability of qualitative data has been verified by auditing sound recordings with texts as well as ensuring that the symbols used to reflect all subjects clearly (Creswell 2009). For more details see section 4.7

3.9 Summary

This chapter has explained the strategy and methodology adopted in this research to collect and analyze data. It outlines the sections, stages and steps of conducting this research as well as a clear description of each.

This chapter presented an introduction, the research paradigm which guided the researcher through the research process, the research design and the research approach (mixed methods approach). The research approach section included a description of the research method and the reasons for choosing it. The six research stages used to achieve the research objectives were described in depth. The use of the literature, ethics approvals, and the methods of qualitative and quantitative data collection and analysis were also discussed. Then, the procedure for modifying EVM was presented. Finally, the chapter has been summarized.

4 CHAPTER FOUR: - INITIAL DATA (Qualitative data gathering and analysis)

4.1 Introduction

This chapter addresses the results from the third stage of the research methodology and the first stage of data collection to answer RQ1 and RQ2 and to achieve Objective one of research. The chapter presents the initial collection and analysis of qualitative data. This process consists of three phases. The first phase is the literature review to identify the main risk-related factors for infrastructure project performance. The second phase is the face-to-face interviews to confirm the main risk-related factors and to identify other risk-related factors which affect the performance of infrastructure projects in Australia. The third phase is the data analysis to develop a set of risk-related factors affecting the performance of infrastructure projects and the attributes (measurement items) of these factors.

4.2 Factors Identified by the Literature Review

A comprehensive literature review shows that there is a lack of research investigating the risk-related factors affecting the performance of infrastructure projects in Australia. Accordingly, the risk-related factors affecting construction projects in general and throughout the world have been used and their impact tested on the performance of infrastructure projects in Australia.

The preliminary results obtained from the literature review showed four important risk-related factors: sustainability (SS), stakeholders’ requirements (SH), communication (CM) and procurement strategies (PS). Table 2.1 shows the factors obtained from literature review that impact project performance as risk-related factors.

The justifications for selecting these factors are: emerging factors such as sustainability that need to be studied more deeply and extensively and factors that have been studied in different parts of the world and on construction projects in general such as stakeholders’ requirements (SH), communication (CM) and procurement strategy (PS). Therefore, there is a need to study (more deeply and extensively) the impact of these factors on infrastructure projects in Australia specifically.

4.3 Interviews

4.3.1 Overview

Interviews depend on individual experiences and opinions to obtain perceptions about phenomena or concepts and influences. These perceptions are uncovered through the answering of open questions. Qualitative data collection, such as interviews, includes fieldwork to gather data which is then analysed in a way that explains the participants' view. After analysis, the results are written up in an expressive and convincing manner (Creswell 1998).

The purpose of the interviews was threefold. First, to ascertain the impact of the key risk-related factors obtained from the literature review on the performance of infrastructure projects in Australia. Second, to obtain relevant sub-risk factors (attributes or measurement items) influencing the key factors. Third, to investigate new risk-related factors and their attributes (measurement items) that impact the performance of the infrastructure projects in Australia. In the exploratory phase of research, face-to-face interviews are to explore and understand the effect of factors on a certain concept or phenomenon (Cavana 2001).

4.3.2 Sample

Since the goal of this researcher is to obtain a broad and comprehensive understanding of the risk-related factors affecting infrastructure performance in Australia, individuals were deemed to be the most appropriate sources of required data.

Objective One of this research was to investigate the influence of risk management approaches on the technique for assessment of construction project performance (infrastructure projects in Australia), including contributing a set of risk-related factors such as the sustainability, requirements of stakeholders, communication, procurement strategies, and other factors. In addition, to identify the measurement items of these factors.

Interview invitations (see Appendix A1) were sent to more than 58 people and companies by email, mail and hand delivery by visiting companies. The interview invitation letter outlines ethical approval for the project (see Appendix A2) such as approval number, ethics office contact number and email for more information in the case of any query. The invitation letter includes attachments such as Interview Consent Form for USQ Research Project (see Appendix A3). The response rate was 0.26. The face-to-face interview was conducted with 15 people working on infrastructure projects in Australia.

4.3.3 Participants' demographics

4.3.3.1 Participants' years of experience

The participants' experience is very important because it reflects the value of the information obtained during interviews. Figure 4.1 shows the years of participants' experience in Australian infrastructure projects. More than 90% of interviewees have more than 10 years' experience in infrastructure projects.

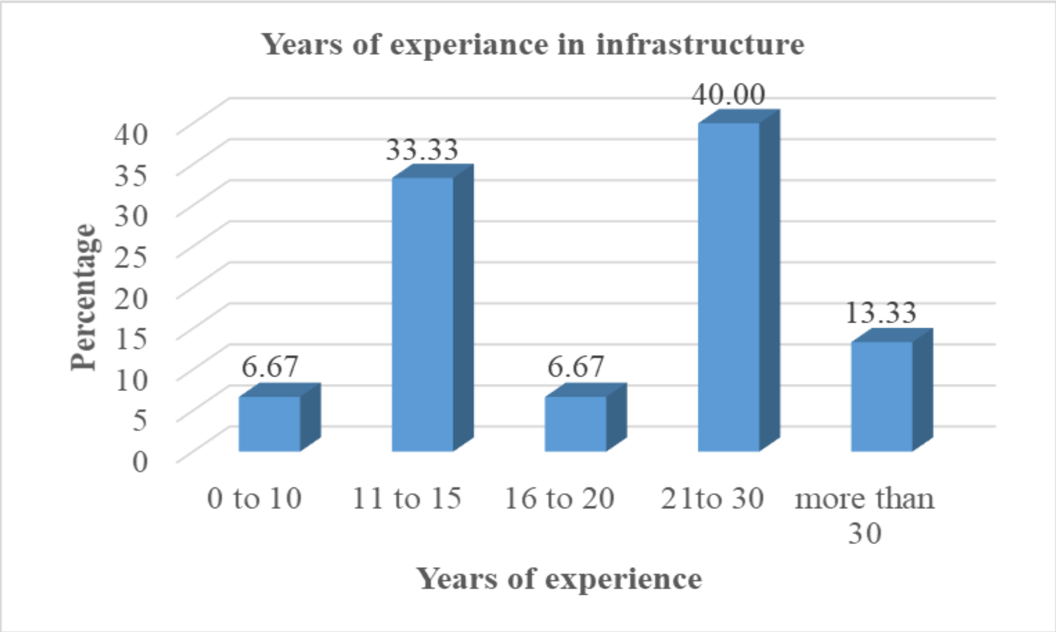


Figure 4-1: Participants' experience in infrastructure projects in Australia

4.3.3.2 Participants’ qualifications

All interviewees have a Bachelor degree in civil engineering, 33.33% of the participants have a Master degree and 13% of the participants have a Ph.D. degree, as shown in Figure 4.2.

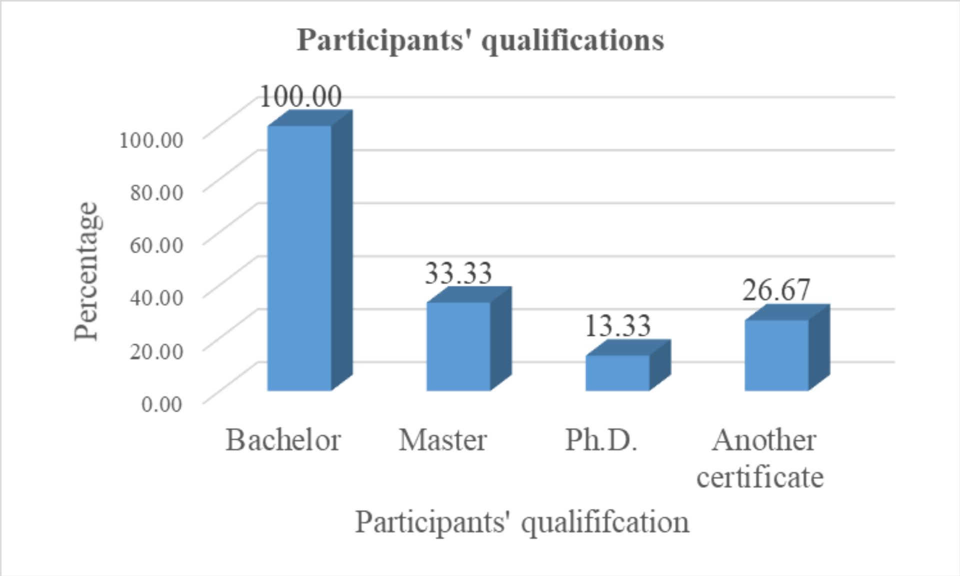


Figure 4-2: Participants’ qualifications

4.3.3.3 Participants’ roles in infrastructure projects

As shown in Figure 4.3, most of the participants had worked as site engineers (93.3%) during their career. 73.3% of participants had worked as construction engineers, and 60% had worked as project managers. In addition, the percentage of employees who had worked as estimating engineers and management engineers was 46.7% and 40%, respectively. The percentage of participants who had worked as planning engineers and design engineers were 33.3% and 20% respectively.

4.3.3.4 Types of infrastructure construction projects

The participants had worked on several infrastructure construction projects types (an indication of the size of the project) such as roads, tunnels, bridges, airports, railroads, dams, infrastructure maintenance and harbours. Figure 4.4 illustrates the percentage of each type of infrastructure project that the interviewees had worked on.

As shown in Figure 4.4, roads and bridges have the highest rate of 93.3% and 73.3% respectively.

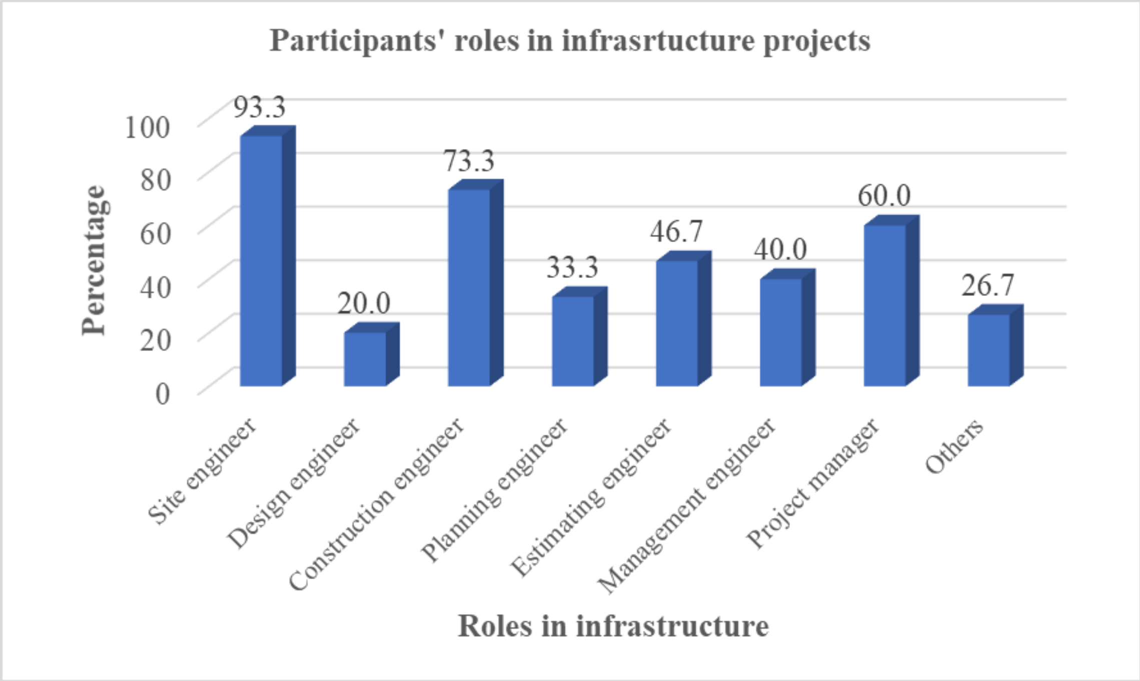


Figure 4-3: Participants' roles

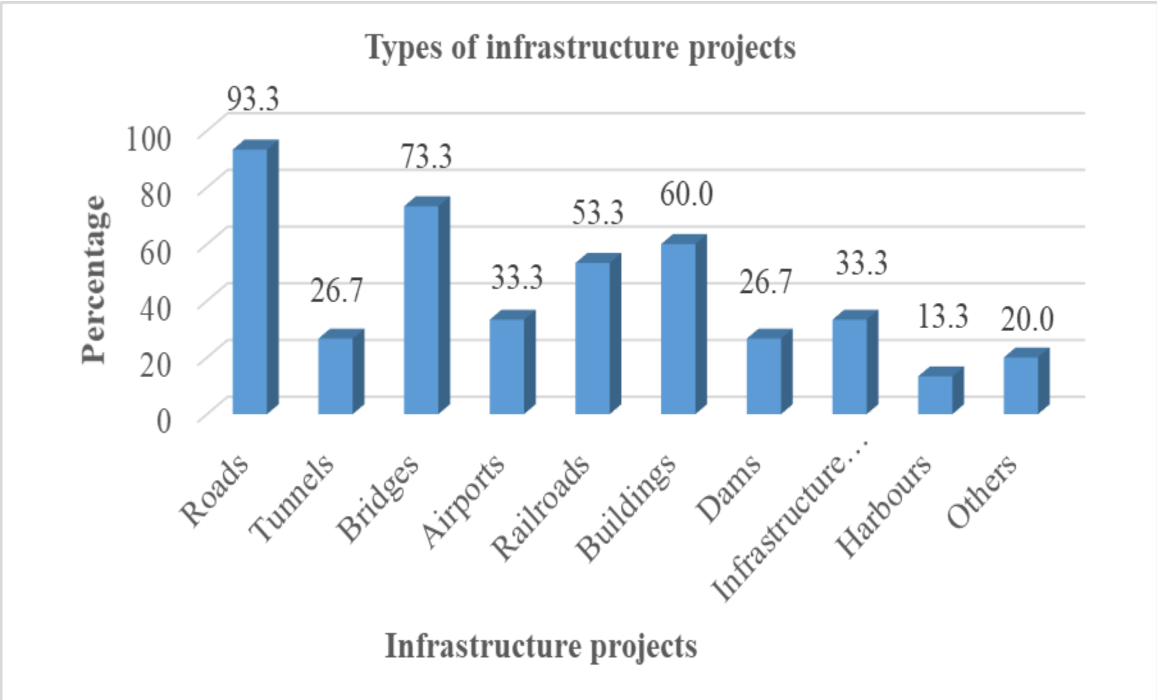


Figure 4-4: Types of infrastructure projects

4.4 Qualitative Data Analysis and Results

This section presents the analysis of data obtained from the face-to-face interviews. The interviews were recorded and then transcribed into text format. According to Creswell (2009), the procedure of conducting semi-structured interviews, recording them and transcribing them to text, is one of the approaches used for gathering qualitative data. Then the data was analysed manually. Finally, computer software was used to confirm the process of manual analysis.

4.4.1 Qualitative data analysis

First, using coding technology allows the researcher to clarify and concentrate on a set of features and helps the analyst to summarize the results (Richards 2007). The coding technique used consists of three parts, the first part is the word "Interviewee", the second part is the hash key (#), and the third part is the number indicating the sequence of the interview procedure. For example, (Interviewee #3) refers to a third interview conducted.

After transcribing the recording to text, the manual analysis starts to investigate the themes in the text. The manual analysis was conducted continuously during interviews. The manual analysis of the first three interviews was conducted to ensure that the questions were consistent with the research objectives. The manual analysis was then carried out after the eighth interview to obtain a clear view of the interview track. After interview number15, the manual analysis was conducted. The saturation state was reached (noted) at interview number12, where nothing new was added during the previous three interviews but confirmed what was mentioned in the previous 12 interviews.

Most of the participants confirmed the risk-related factors obtained from the literature review (sustainability (SS), stakeholders' requirements (SH), communication (CM) and procurement strategy (PS)). In addition, they referred to new risk-related factors. Tables 4.1, 4.2 and 4.3 illustrates all factors and their proportion as mentioned by interviewees. Some of the responses from the interviewees are discussed (according to factor) in the next paragraphs.

Table 4-1: Risk-related factors (Main factors)

Risk-related factors	Interviewee # 1	Interviewee # 2	Interviewee # 3	Interviewee # 4	Interviewee # 5	Interviewee # 6	Interviewee # 7	Interviewee # 8	Interviewee # 9	Interviewee # 10	Interviewee # 11	Interviewee # 12	Interviewee # 13	Interviewee # 14	Interviewee # 15	Frequency	Proportion %
Sustainability (SS)	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	15	100%
Stakeholders' requirements (SH)	●		●	●	●	●	●	●	●	●	●	●	●	●	●	14	93.3%
Communication (CM)	●		●	●	●	●	●	●	●	●	●	●	●	●	●	14	93.3%
Procurement strategy (PS)	●		●	●	●	●	●	●	●	●	●	●	●	●	●	14	93.3%

Table 4.1 shows the main factors associated with the risks obtained from the literature review and was confirmed by more than 93% by interviewees.

Table 4-2: Risk-related factors (Other factors acceptable)

Risk-related factors	Interviewee # 1	Interviewee # 2	Interviewee # 3	Interviewee # 4	Interviewee # 5	Interviewee # 6	Interviewee # 7	Interviewee # 8	Interviewee # 9	Interviewee # 10	Interviewee # 11	Interviewee # 12	Interviewee # 13	Interviewee # 14	Interviewee # 15	Frequency	Proportion %
Weather (WE)	●	●	●	●	●	●	●		●		●	●	●		●	12	80%
Experience of staff (SE)	●	●		●	●	●				●		●		●	●	9	60%
Site condition (SC)		●	●	●			●		●		●		●	●	●	9	60%
Design issues (DI)		●	●			●			●	●	●			●	●	8	53.3%
Financial Risk (FR)	●		●	●	●	●		●				●			●	8	53.3%
Subcontractor (CO)	●	●			●	●				●		●		●		7	46.7%
Government requirements authority (GR)	●			●		●	●	●							●	6	40%
Materials (MR)		●	●						●	●		●	●			6	40%

Table 4.2 illustrates other factors that were mentioned by the participants in the interviews, with a rate of more than 40%. The mentioned rate ranged from 40% to 80%. These factors were accepted in this paper.

Table 4-3: Risk-related factors (Other factors neglected)

Risk-related factors	Interviewee	Interviewee	Interviewee	Interviewee	Interviewee	Interviewee	Interviewee	Interviewee	Interviewee	Interviewee	Interviewee	Interviewee	Interviewee	Interviewee	Interviewee	Frequency	Proportion %
Health and Safety			●				●			●		●			●	5	33.3%
Planning of the project	●	●			●									●		4	26.7%
Unrealistic time frames				●	●							●			●	4	26.7%
Resources		●	●			●										3	20%
Local community (social unrest)				●		●						●				3	20%
Quality control			●							●						2	13.3%
Political risk				●				●								2	13.3%
Volume of work on that time					●	●										2	13.3%
Productivity			●													1	6.7%
Unrealistic costings				●												1	6.7%
Interaction with other groups									●							1	6.7%
Temporary works														●		1	6.7%
Methodology of build (construction methods)														●		1	6.7%
Change in industrial position						●										1	6.7%
Force majeure				●												1	6.7%

Table 4.3 illustrates other factors that were mentioned by the participants in the interviews, with a rate of less than 40%. The mentioned rate ranged from 6.7% to 33.3%. These factors have been neglected in this research.

4.4.1.1 Sustainability (SS)

All the participants confirmed sustainability as an important risk-related factor affecting the performance of infrastructure projects. As shown in Table 4.1 the reference to sustainability was made in 15 interviews. Furthermore, the interviewees explained the attributes (measurement items) of sustainability: such as design incorporating sustainability requirements, current market price, materials supply and resources, government legislation on sustainability, and understanding the principle of sustainability. The following are the observations of some of the interviewees, which illustrate the importance of sustainability and its attributes (measurement items).

- **Design incorporating sustainability**

Design incorporating sustainability requirements is mentioned in this comment: ‘I will go back to the risk associated with the design and sustainability. This design should be long enough. Let's suppose if you have a project which you have to maintain for the next 50 years, the design should be good enough that it has its design life for 50 years. That's the biggest risk. The design should address the maintenance to period.’ (Interviewee #6)

- **Current market price**

The current market price which is reinforced in this comment: ‘In our field, complying with all the requirements is so essential to proceed with the project and one of the requirements is the sustainability. Considering the current market prices, it is very difficult to implement the 100% sustainability requirements which will dramatically increase the project cost and then reflect badly on the decision to proceed with the entire development plan.’ (Interviewee #1)

- **Materials supply and resources**

Materials supply and resources are highlighted in this comment: ‘With sustainability obviously, your materials supply. For sustainability things like asphalt, if you're using recycled asphalt things like that. Like, say, for this job we've got road embankments. For the sustainability where is that material coming from? Is it coming from a quarry? Is it coming for you or is it potentially coming from another development that you're taking their material and putting it into your road?

As for risks of that, it's a hard one. Affect the sustainability. There's the procurement material and if you can incorporate those things into a design. It's designed as well.' (Interviewee #9)

- **Government legislation**

Government legislation is confirmed in this comment: 'A large one is possibly government legislation. We define sustainability as, typically, defined long-term through government legislation, and then obviously, there's a lot of more short-term items such as predominantly environmental sustainability and also sustainability in terms of impact to the end users.' (Interviewee #15)

- **Understanding the principle of sustainability**

Understanding the principle of sustainability, this issue was confirmed by (Interviewee #10) in this comment: 'Risks are so a person's understanding of the principle of sustainability. If they know what they are looking at and what they need to be looking for, they'll make better decisions in regarding of wasted material, or just making decisions that don't take sustainability into the court process. Policies, legislation, such as bio-hazards, will have an impact on sustainability. And then it falls back to material procurement once again and subcontractor management.'

4.4.1.2 Stakeholders' requirements (SH)

The other risk-related factor influencing the performance of infrastructure projects is stakeholder requirements, as confirmed by 93.3% of interviewees. As shown in Table 4.1, stakeholders' requirements was referenced in 14 of interviews. Furthermore, the interviewees explained the attributes (measurement items) of stakeholders' requirements as government requirements, the risk of diverse requirements of stakeholders and type of construction contract. Below are some comments from interviewees, which clarify the importance of stakeholders' requirements (SH) and its attributes (measurement items).

- **Government requirements**

Interviewee #7 declared that: ‘In terms of stakeholders, you'd have things like the approving authorities. To an extent, they could probably fall under that client category as well. It's the person who's paying for the project, but you've also got to meet the requirements of local authorities or state authorities or whatever the case may be. They become a stakeholder as well because ultimately, some of this stuff will be taken over by them as well. I think we need to make sure that we include groups like state and local authorities, federal authorities if it goes to that extent.’

- **The risk of different requirements**

The risk of different requirements is mentioned in this comment: ‘The risk of the stakeholders when they're looking at their requirements, they're really looking at the final job, the final outcome and getting it on time, getting it on cost, meeting the expectations and perceptions, those sorts of things.’ (Interviewee #2)

- **Type of contract**

This issue was raised in this comment: ‘Risk of choosing the appropriate contract type, for example, clients want a project that is fit for purpose, whatever that purpose is defined as. Reducing travel time and increasing convenience, changing travel mode, whatever it might be, that's what they want, the client, and it's important that they get it. The risks are that the consultant and contractor will not fully understand what the client is wanting and provide something that is not exactly what they need and there's a big communication gap, usually between the consultant and the contractor. It is not the most efficient way to work. Alliance projects, PPPs that kind of arrangement is usually not cheaper, but it has a better outcome because the communication between the parties is better.’ (Interviewee #4)

4.4.1.3 Communication (CM)

Communication is a significant risk for the performance of infrastructure projects in Australia. As shown in Table 4.1, communication was confirmed by 93.3% of participants and it was mentioned in 14 interviews. Furthermore, the participants explained the attributes (measurement items) of communication such as communication strategy, stakeholders' experiences, and the relationships between stakeholders. The following are the remarks of some of the interviewees, which explain the attributes (measurement items) of communication.

- **Communication strategy**

Interviewee #1 stated that: 'The communication strategy and the responsible parties should be identified from the beginning of the project. In addition to that, using advanced communication programs will improve the communication between all the parties. Good communication will educate all the team members about the timely requirement, cost requirement and will make sure that all parties get the required information within the proper time which will allow them to act according to the action required'

- **Stakeholders 'experiences**

Stakeholders 'experiences are mentioned in this comment: 'The people on the project and their experience that affects the communication of the project and it's a big risk' (Interviewee #2)

- **The relationship between stakeholders**

The relationship between stakeholders is emphasised in this comment: "Communication between stakeholders is very important. I guess the main risk in terms of communication between stakeholders is all about the relationship. It's very important to have a long-term relationship for the better of the project. You want to have a good relationship, good communication, for the project. Secondly, for a company having a good relationship and good communication is beneficial in terms of your reputation and delivering more work into the future. If you have a good relationship with the client, that will give you more work, you'll win more work in the future.” (Interviewee #14)

4.4.1.4 Procurement strategy (PS)

As shown in Table 4.1, 14 of participants (93.3%) agreed on procurement strategy as risk-related factor affecting infrastructure performance. Furthermore, the participants explained the attributes (measurement items) of procurement strategy as: design meets the contracting requirement, type of procurement strategy, and size of project. Here are the perceptions of some of interviewees, which demonstrate the importance of procurement strategy and its attributes (measurement items).

- **Design meets the contracting requirement**

Design meets the contracting requirement is strengthened in this response: ‘Depending on contracting requirements, if you don't define the performance of the design, with a performance-based specification adequately, you can get poorer quality and design outcomes. I've seen that happening, where for example, an air conditioning performance spec, doesn't have enough information in about quality and poor quality ordered the fan motors that only have a short, five-year lifespan, get used by the services contractor. Quality can potentially, be at risk there. That's probably the main one. You get the advantage, you get its time. Sometimes, if you don't have it well enough to find, the goals the client's looking for in his brief, you might get poorer quality building, potentially’ (Interviewee #5).

- **Type of procurement strategies**

The type of procurement strategy is confirmed by this comment: ‘Each contract type is going to have its own type of risk and this project is a design and construct. We've been given a budget of money, of funding and we have to deliver under that cost or else we don't make our company money. Same as traditional lines. As in the other two like for an alliance, there will be a share gain, we're all collaboratively trying to get the same project. It's hard to what are the different kinds of risks-- Each selection is-- Like a traditional contract is the drawing, go build that drawing, so it's clear cut but then, if there's any variation between having to build that drawing, then you didn't have to go and get a variation approved. That has its own risks. So choose the appropriate type of contract is a big issue have a risk in infrastructure projects' (Interviewee #10)

- **Size of the project**

Interviewee #8 answered the question about the types of risks affecting the procurement strategy with the following comment: 'What kind of risk affects the procurement strategy? It comes down to size. Nowadays, it comes down to two or three things. One is it is very much about the size of the project and who are the owners of those projects'

4.4.1.5 Weather (WE)

Weather is a new theme to the interview. It was derived from the interviews. The recurrence of mentions the weather during the interviews was (80%). The weather was referenced by 12 out of 15 participants as shown in Table 4.2. Furthermore, the participants clarified extreme weather attributes (measurement items) such as, heavy rain and flooding, low and high temperature, storms and cyclones. The following are the comments of some interviewees, which clarify the importance of weather and its attributes (measurement items).

- **Extreme weather such as heavy rain and flooding**

According to Interviewee #15: 'Weather is always an issue. But the thing is that you have one of the influencing factors. So, typically, you would make an allowance in your program for weather. There would be an allowance, but sometimes the weather is good, sometimes the weather is bad. I have been involved in projects where you shut the project for three months because you expect the rainy season. Typically, you have to manage the weather.'

- **Extreme weather such as low and high temperature**

Interviewee #2 stated that: 'Even things like fog, cold temperatures, and hot temperatures. When you're further at west, sometimes it gets too hot and the men actually struggled to work, and then some of them would get sick through heat stroke, and things like that. Conversely, cold temperatures, sometimes they can't hold the tools. The Fog. They had tires overworking and sleeping, and things like that because of the weather.'

- **Extreme weather such as storms and cyclones**

Interviewee #7 argued that: 'Again, weather -- It's just the very similar type of things really. If you get delays due to weather, that might mean that you have to go back and you don't think a major-- a storm event or something like that, causing a lot of damage, it's going to cost you a lot of money, particularly depending on the insurance coverage that you've got. You might recover them insurance-wise but some would go down the drain. That can have a major effect.'

4.4.1.6 Experience of staff (SE)

Another theme is the experience of staff. As shown in Table 4.2, the frequency of that experience of staff was mentioned during interviews was 60%, and it was referenced by nine participants. The interviewees mentioned the attributes (measurement items) of experience of staff such as staff commitment, staff skills, and staff management. Here are some views of some of the interviewees, which emphasize the importance of the experience of staff and its attributes (measurement items).

- **Staff commitment**

Staff commitment is mentioned in this comment: 'On the performance. You've got to look sometimes are the team all here for the right reason. Are they all working together? Do they get along? Sometimes they don't get along. You might have a contract where they say about the A-team and the B-team? The contractor has got two crews. They win two jobs. The A-team goes to the more important job. The B-team, which is the team which maybe isn't as good as the A-team comes to your job because that's the next job they won. You might not have the best team from the contractor on your job. There are things like that that can happen. The contractor may have over-stretched themselves and they are grabbing in resources from who knows where and they may not be their normal employees.

They may not even be used by the company. They may be new. They may be inexperienced. Definitely, things like the experience of the team, whether they are committed to your project, what are they there for and what are their motives? It's a big, big thing.' (Interviewee #2)

- **Staff skills**

Staff skills is mentioned in this comment: Interviewee #12 supposed that, 'Kind of risks made a few notes. I supposed the skilled workforce'

- **Staff management**

Staff management is mentioned in this comment from interviewee #15 found that, 'Getting sufficient resources. So, people are a huge issue. Also, this includes management. Staff management is a big issue. Having good project management. Team culture. Overall project delivery.'

4.4.1.7 Site condition (SC)

The site condition theme was found through manual analysis. Site condition was mentioned by nine interviewees (60%) during interviews, as shown in Table 4.2. Additionally, the participants pointed out the attributes (measurement items) of site condition such as sub-soil geotechnical work (geotechnical investigation), earthworks, ground condition (old building foundations, an archaeological find and water table level), and site access on time (possession in time). The following are perceptions of some of the interviewees, which emphasize the importance of site condition and its attributes (measurement items).

- **Sub-soil geotechnical work (geotechnical investigation)**

Interviewee #11 explained that: 'So just particularly for my job, I guess some of the risks can be like soft soils or not enough geotechnical information during design.'

- **Earthworks**

Interviewee #9 mentioned that: ‘the earthwork is a quite a big risk in the performance of infrastructure projects.’

- **Ground condition (old building foundations, an archaeological find, and water table level)**

Ground condition is mentioned in this comment: ‘If you're working through a site and you find something that's been buried that might be contamination that needs to be remediated or you might find some archaeological find that could stop your project and slow things down while that gets dealt with. That can have an effect on your cost as well.’ (Interviewee #7)

- **Site access on time (possession in time)**

Interviewee #3 specified that, ‘site possession in time is one of risk affecting infrastructure performance.’

4.4.1.8 Design issues (DI)

Eight interviewees (53.3%) pointed to that design issues is one of the important risk-related factors in Australian infrastructure projects, as shown in Table 4.2. Moreover, the interviewees defined the attributes (measurement items) of design issue such as poor and inefficient design (mistakes in design), inadequate and insufficient design (lack of details, information and specifications), and major design changes. Here are some the opinions of some of the interviewees, which reveal the importance of design issues and its attributes (measurement items).

- **Poor and inefficient design (mistakes in design)**

Poor and inefficient design (mistakes in design) is cited in this comment: ‘Mistakes in design, they cost lots when you come to implementation to be fixed.’ (Interviewee #2)

- **Inadequate and insufficient design (lack of details, information and specifications)**

Inadequate and insufficient design (lack of details, information and specifications) is quoted in this comment: ‘During implementation, I guess probably poor design, or inadequate design or insufficient design information have a big impact on the program. Getting designs checked and inquiries closed there.’ (Interviewee #11)

- **Major design changes**

Major design changes are mentioned in this comment: ‘There is a risk of a design change as well, which I have faced a lot in my career during the execution process once the design changes. You have to implement those design changes, which will have an impact on time, cost and, of course, scope as well, which will be manhandled during a change management process. These are the biggest risks, in my opinion, during the execution process.’ (Interviewee #6)

4.4.1.9 Financial Risk (FR)

As shown in Table 4.2, eight participants (53.3%) identified financial risk as risk-related factor affecting infrastructure performance. Furthermore, participants debated the attributes (measurement items) of financial risk such as inflation rate fluctuations, exchange rate fluctuations and, interest rate fluctuations. The following are response of some interviewees, which reveal the importance of financial risk and its attributes (measurement items).

- **Inflation rate fluctuations**

The fluctuating of inflation rate was reported in this comment: ‘Australia is a distorted economy. Depending on the phase and the economic cycle. Right now in WA, you can get things probably half the price and you can get them immediately because they are in a low economic activity period. That's a big one, and you can't predict it.’ (Interviewee #4)

- **Exchange rate fluctuations**

Exchange rate fluctuation is mentioned in this comment: 'Kind of risks made a few notes. I supposed the price of the Australian Dollar would affect that.' (Interviewee #12)

- **Interest rate fluctuations**

Interviewee #4 declared that, 'The global financial situation is beyond our control. The ability to borrow money at what cost? During the global financial crisis, nobody would lend you money. If they did it, it was at a very high rate.'

4.4.1.10 Subcontractor (CO)

Another risk-related factor influencing the performance of infrastructure projects is the use of subcontractors. This factor was derived from the interview data. As shown in Table 4.2, this factor was confirmed by 46.7% of interviewees. It was mentioned by seven interviewees. Furthermore, the interviewees noted the attributes (measurement items) of subcontractor: subcontractors' performance, and subcontractors' availability. Below are some responses from interviewees which illustrate the importance of subcontractor and its attributes (measurement items).

- **Subcontractors' performance**

Subcontractors' performance is presented in this response: 'Subcontractors. There's always a risk on subcontractors. Whether you've adequately assessed their capability, they might say they can do all sorts of thing, but when you get them out on site, they can't perform or function as well as they said they could.'(Interviewee #2)

- **Subcontractors' availability**

Subcontractors' availability is indicated in this comment: 'The volume of work at that time. If there is a lot of jobs, a lot of contracts happening, that will impact the project as well. If there are not many project happening, all the good contractor would come and work for you. If there is a lot of work happening in the industry, you will lose the good quality subcontractors. I mean, if a lot of work is happening, you will not find a good quality subcontractor. If less work happening, you will find a good price and a good contractor.’ (Interviewee #6)

4.4.1.11 Government requirements authority (GR)

The government requirements authority theme was constructed through manual analysis. Government requirements authority was specified by six interviewees (40%), as shown in Table 4.2. Additionally, the participants identified the attributes (measurement items) of government requirements authority as a change in government policy and sovereign government intervention. The following are the reports of some interviewees which demonstrate the importance of government requirements authority and its attributes (measurement items).

- **Change in government policy**

Change in government policy is confirmed in this comment: ‘Changes in government policy can affect. That's a big one. Can you identify risks affecting project time? Over in WA, the government is saying they want to have a special tax regime for the mining companies. They want to change it now. Pay in advance kind of thing because they're short of money. Mining companies could not predict that, so change in government policy and objectives.’ (Interviewee #4)

- **Sovereign government intervention**

Sovereign government intervention is referred to in this comment: ‘I would say out of that you already mentioned a couple of issues there. I think in Australia sovereign risk has increased. What I mean by sovereign government intervention. Changing your mind over projects. One example is the dam of Victoria of West Connect project was totally cancelled. It was awarded, the final package already did but the Victorian government decided not to go ahead with the project. That kind of sovereign risk it's becoming really important to consider in Australia."(Interviewee #8)

4.4.1.12 Materials (MR)

As shown in Table 4.2, six interviewees (40%) pointed to materials as a crucial risk-related factor for infrastructure projects in Australia. Moreover, the interviewees presented the attributes (measurement items) of materials: material procurement and availability of material. The following are the opinions of some of the interviewees which explain the importance of materials and its attributes (measurement items).

- **Material procurement**

Material procurement is highlighted in this response: ‘In terms of construction risks or any? First off, procurement risks around larger items among late time items. Now, I went to order them in time, something that could be six months late time. You've got to order really early otherwise you'll have problems with program.’ (Interviewee #13)

- **Availability of material**

Availability of material is evident in this comment: ‘Sometimes you just can't get the supplies. Like at this multiple contracts going all at one time, and there's only one gravel supplier in the area, if you don't get your order in, you might not be able to get gravel from that person, or it could just be the distance from the delivery.’(Interviewee #2)

Consequently, the interviewees focused on more than 12 themes which indicate the types of risks experienced during infrastructure project implementation in Australia. The discussions with the interviewees suggested sustainability, stakeholders’ requirements, communication, procurement strategy, weather, experience of staff, site condition, design issues, financial risk, subcontractor, government requirements authority and materials. These factors have gained consensus by more than 40% of participants. As shown in Table 4.4, other factors were identified by fewer than 40% of interviewees, and were not researched further.

Based on the above, Table 4.4 explains the risk-related factors and their attributes (measurement items).

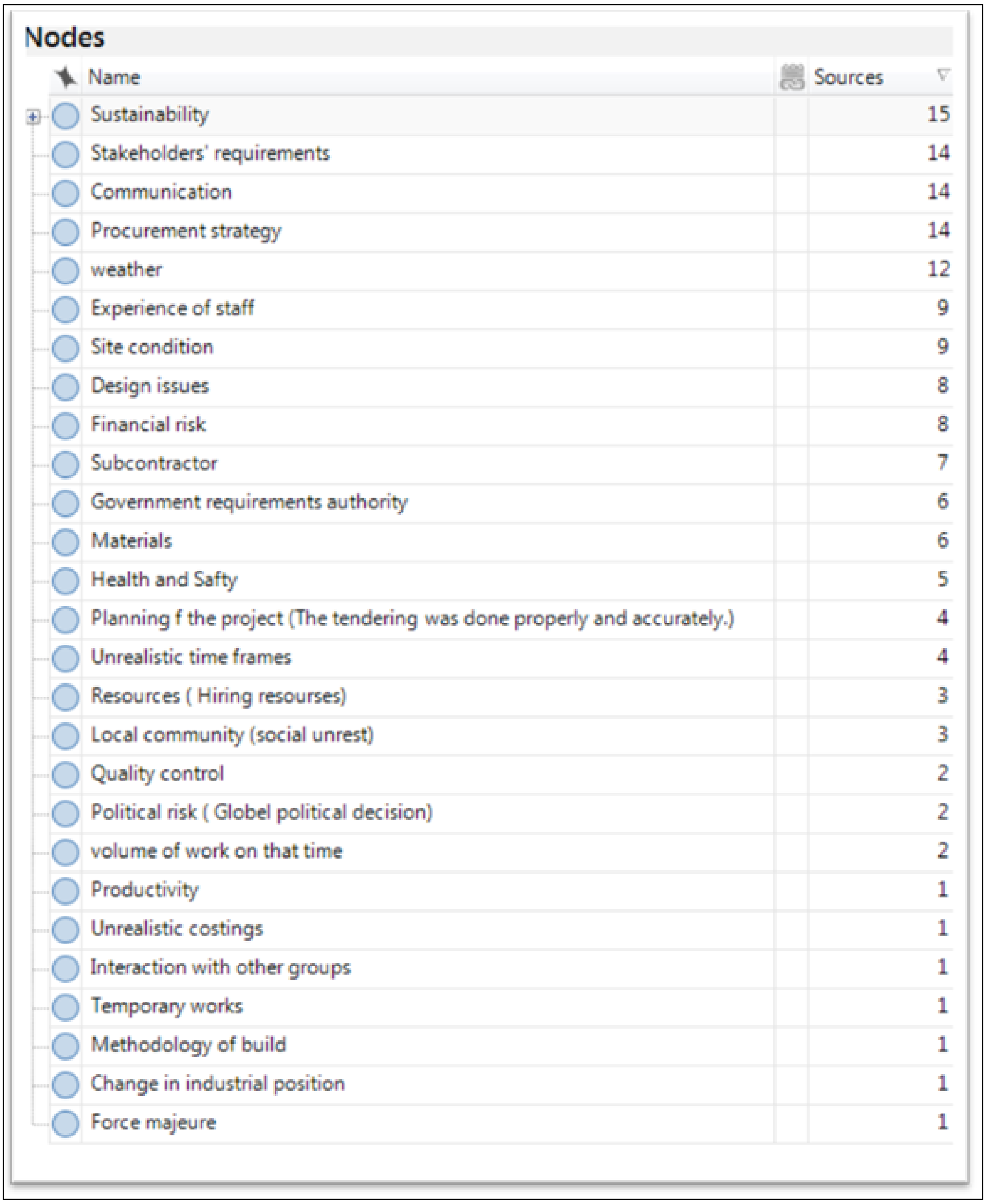
Table 4-4: Risk-related factors and attributes (measurement items)

	Factors	Attributes (measurement items)	Interviewees
1	Sustainability (SS)	Design incorporating sustainability requirements	Interviewee # 6
		Current market price	Interviewee # 1
		Materials supply and resources	Interviewee # 9
		Government legislation	Interviewee # 15
		Understanding the principle of sustainability	Interviewee # 10
2	Stakeholders' requirements (SH)	Government requirements	Interviewee # 7
		Risk of diverse requirements of stakeholders	Interviewee # 2
		Type of construction contract	Interviewee # 4
3	Communication (CM)	Communication strategy	Interviewee # 1
		Stakeholders' experiences	Interviewee # 2
		Relationship between stakeholders	Interviewee # 14
4	Procurement strategy (PS)	Design meets the contracting requirement	Interviewee # 5
		Type of procurement strategies	Interviewee # 10
		Size of the project	Interviewee # 8
5	Weather (WE)	Extreme weather such as heavy rain and flooding	Interviewee # 15
		Extreme weather such as low and high temperature	Interviewee # 2
		Extreme weather such as storms and cyclones	Interviewee # 7
6	Experience of staff (SE)	Staff commitment	Interviewee # 2
		Staff skills	Interviewee # 12
		Staff management	Interviewee # 15
7	Site condition (SC)	Sub-soil geotechnical	Interviewee # 11
		Earthworks	Interviewee # 9
		Ground condition (old building foundations, archaeological find and water table level)	Interviewee # 7
		Site access on time (possession in time)	Interviewee # 3
8	Design issues (DI)	Poor and inefficient design (mistakes in design)	Interviewee # 2
		Inadequate and insufficient design (lack of details, information and specifications)	Interviewee # 11
		Major design changes	Interviewee # 6
9	Financial Risk (FR)	Inflation rate fluctuations	Interviewee # 4
		Exchange rate fluctuations	Interviewee # 12
		Interest rate fluctuations	Interviewee # 4
10	Subcontractor (CO)	Subcontractors' performance	Interviewee # 2
		Subcontractors' availability	Interviewee # 6
11	Government requirements authority (GR)	Change in government policy	Interviewee # 4
		Sovereign government intervention	Interviewee # 8
12	Materials (MR)	Material procurement	Interviewee # 13
		Availability of material	Interviewee # 2

4.4.2 Computer software analysis

In the previous stage, the researcher manually identified different risk actor themes. In this next stage of the research, Nvivo was used to confirm the analytical procedure. NVivo software is used to buttress the researcher's decision making, and to grant the researcher the ability to process data and identify notes (Cavana 2001).

NVivo was used to investing and confirm the risk-related factors affecting infrastructure construction performance. Figure 4.5 provides a screenshot of NVivo's analysis of the interview data. The results showed all factors and their sources (frequency). Moreover, NVivo provides a visual tool for data analysis (Cavana 2001). By using this feature, the researcher was able to map the themes revealed through the interview process. Appendix A4 (Figures A4.1 to A4.12) shows the mapped frequencies for each theme. These figures confirmed the results of the manual analysis.



Nodes

Name	Sources
Sustainability	15
Stakeholders' requirements	14
Communication	14
Procurement strategy	14
weather	12
Experience of staff	9
Site condition	9
Design issues	8
Financial risk	8
Subcontractor	7
Government requirements authority	6
Materials	6
Health and Safty	5
Planning f the project (The tendering was done properly and accurately.)	4
Unrealistic time frames	4
Resources (Hiring resourses)	3
Local community (social unrest)	3
Quality control	2
Political risk (Globel political decision)	2
volume of work on that time	2
Productivity	1
Unrealistic costings	1
Interaction with other groups	1
Temporary works	1
Methodology of build	1
Change in industrial position	1
Force majeure	1

Figure 4-5: Screenshot view of NVivo

4.5 Qualitative Data Collection, Analysis and Conclusions

The results of the qualitative data collection and analysis identified several risk-related factors affecting the performance of infrastructure projects during the implementation phase. These risk-related factors were identified from the participants' comments. Table 4.5 summarizes the results of the interviews. As mentioned previously, factors not considered for the next stage were identified by fewer than 40% of respondents. For the purpose of collecting qualitative data in the least number of themes, the researcher fixes up, modernizes and reassembles the data (Creswell 2013). Accordingly, some of these factors will be included in the accepted indirect factors, through the attributes (measurement items) of the accepted factors. For example, despite the fact that the quality control factor was identified by only 13.33% of participants, the quality factor was addressed indirectly when attributes (measurement items) of design issues were mentioned. As well as with similarly resources (20%) fell within the availability of materials. Thus, such factors while not being nominated directly by questionnaire respondents, were considered indirectly in the 12 factors used for the next stage of analysis.

As can be seen in Table 4.5, the main factors' proportion (sustainability (SS), stakeholders' requirements (SH), communication (CM) and procurement strategy (PS)) was high (identified by 93.3% of participants in the survey), which underlines the significance of these factors for infrastructure project performance. At the same time, the factors that were accepted (weather (WE), experience of staff (SE), site condition (SC), design issues (DI), financial risk (FR), subcontractor (CO), government requirements authority (GR) and materials (MR)) received a good percentage, which confirms their inclusion in the research. The percentages obtained were between 40% and 80%. The impact of these factors (either negative or positive) on the performance of infrastructure projects is through the main elements of performance (duration and cost) measured in earned value analysis. This impact will be evaluated and calculated in the next chapter.

Table 4-5: Summary of qualitative stage

No.	Risk-related factors	Sources	References	Proportion	
1	Sustainability	15	47	100.00%	Main factors
2	Stakeholders' requirements	14	34	93.33%	
3	Communication	14	38	93.33%	
4	Procurement strategy	14	51	93.33%	
5	Weather	12	20	80.00%	Other acceptable factors
6	Experience of staff	9	12	60.00%	
7	Site condition	9	14	60.00%	
8	Design issues	8	14	53.33%	
9	Financial risk	8	11	53.33%	
10	Subcontractor	7	11	46.67%	
11	Government requirements authority	6	7	40.00%	
12	Materials	6	10	40.00%	
13	Health and Safety	5	10	33.33%	Other factors
14	Planning of the project	4	7	26.67%	
15	Unrealistic time frames	4	4	26.67%	
16	Resources	3	3	20.00%	
17	Local community (social unrest)	3	3	20.00%	
18	Quality control	2	2	13.33%	
19	Political risk	2	5	13.33%	
20	Volume of work on that time	2	3	13.33%	
21	Productivity	1	1	6.67%	
22	Unrealistic costings	1	1	6.67%	
23	Interaction with other groups	1	1	6.67%	
24	Temporary works	1	1	6.67%	
25	Methodology of build (construction methods)	1	1	6.67%	
26	Change in industrial position	1	1	6.67%	
27	Force majeure	1	1	6.67%	

4.6 Validity

To verify the accuracy of the data gathered at the qualitative data collection stage, the researcher prepared a pilot study. Van Teijlingen and Hundley (2001) mention that the pilot study is a critical factor in the design and preparation of a good study, and helps researchers obtain a clear view by providing a range of significant functions. The sample used in the pilot study was from a group similar to the main sample interviewed and the number of participants in the pilot study was 24. Details of the pilot study will be discussed in the next chapter. The questions used for the pilot study were similar to those used in the main questionnaire. The questions were “The following attributes (measurement items) are likely to have a significant risk that impacts on the performance of infrastructure projects in Australia”. A Likert scale ((1) Strongly Disagree, (2) Disagree, (3) Neutral, (4) Agree, (5) Strongly Agree) was used to ascertain the importance of these factors as risk-related factors affecting the performance of infrastructure projects. The results of the pilot study were analysed using the Relative Importance Index (RII) by factors analysis with SPSS. The RII was also used to obtain the level of effect of each attribute (measurement items) on the infrastructure project, and to rank these attributes (measurement items) using Equation (4.1).

$$\text{RII} = \frac{\Sigma W}{A \times N} \quad \text{--------------------} \ (4.1)$$

Where:

W = weight given to each factor by the respondents.

A = highest weight (5 in this case)

N = total number of respondents.

As shown in Table 4.6 all, attributes (measurement items) have gotten RII more than 0.55. That means all factors are likely to have a significant risk that impacts on the performance of infrastructure projects in Australia.

Table 4-6: Attributes (measurement items) and Relative Importance Index (RII)

NO.	Factors	Attributes (Measurement items)	RII
1	Sustainability (SS)	Design incorporating sustainability requirements	0.55
		Current market price	0.62
		Materials supply and resources	0.69
		Government legislation	0.64
		Understanding the principle of sustainability	0.85
2	Stakeholders' requirements (SH)	Government requirements	0.67
		Risk of different requirements	0.82
		Type of contract	0.76
3	Communication (CM)	Communication strategy	0.71
		Stakeholders' experiences	0.71
		Relationship between stakeholders	0.73
4	Procurement strategy (PS)	Design meets the contracting requirement	0.73
		Type of procurement strategies	0.82
		Size of the project	0.76
5	Weather (WE)	Extreme weather such as heavy rain and flooding	0.80
		Extreme weather such as low and high temperature	0.67
		Extreme weather such as storms and cyclones	0.82
6	Experience of staff (SE)	Staff commitment	0.82
		Staff skills	0.78
		Staff management	0.80
7	Site condition (SC)	Sub-soil geotechnical	0.78
		Earthworks	0.80
		Ground condition (old building foundations, archaeological find and water table level)	0.78
		Site access on time (possession in time)	0.76
8	Design issues (DI)	Poor and inefficient design (mistakes in design)	0.80
		Inadequate and insufficient design (lack of details, information and specifications)	0.84
		Major design changes	0.80
9	Financial Risk (FR)	Inflation rate fluctuations	0.60
		Exchange rate fluctuations	0.56
		Interest rate fluctuations	0.60
10	Subcontractor (CO)	Subcontractors' performance	0.82
		Subcontractors' availability	0.80
11	Government requirements authority (GR)	Change in government policy	0.69
		Sovereign government intervention	0.55
12	Materials (MR)	Material procurement	0.80
		Availability of material	0.80

4.7 Reliability

According to the procedures followed by Gibbs (2007) and Creswell (2009) to verify the reliability of the quantitative data obtained from interviews, the researcher must do the following:

1. Make sure that the texts are compatible with the sound recordings of the interviews to ensure that no text is lost or that there is a defect in the copying process.

2. Make sure that the symbols used clearly, reflect all the themes under them.

4.8 Developing Research Hypotheses

Based on the above, the factors obtained were used in constructing 12 research hypotheses. These hypotheses will be used to achieve Objective 2 by answering Research Question 3. The following are the hypotheses of this research:

H1: Sustainability is likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

H2: Stakeholders’ requirements are likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

H3: Communications are likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

H4: Procurement strategy is likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

H5: Weather is likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

H6: Experience of staff is likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

H7: Site conditions are likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

H8: Design issues are likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

H9: Financial risk is likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

H10: Subcontractors are likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

H11: Government requirements are likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

H12: Materials are likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

4.9 Summary

This chapter shows the results obtained from the third stage of the research. The main objective of this chapter was to analyse the interviews and explore the risk-related factors influencing the performance of infrastructure projects in Australia. The result of this stage was the creation of 12 risk-related factors significantly impacting the performance of infrastructure projects. Furthermore, the result of this stage was used for constructing 12 research hypotheses. This stage covers the first objective of the research.

5 CHAPTER FIVE: - QUANTITATIVE DATA GATHERING AND ANALYSIS

5.1 Introduction

This chapter addresses the procedures and results from the fourth stage of the research methodology and the second stage of data collection. It presents the quantitative data collection and data analysis. This process consists of four phases. The first phase is the preparation of the questionnaire survey questions to identify the main risk-related factors’ effects on infrastructure project performance. The second phase is the pilot study to check the framework, content and quality of questionnaire survey, and update the questionnaire survey according to the pilot study results. The third phase is the submission of the questionnaire survey to the target sample. The fourth phase is data analysis using Factor Analysis with SPSS to modify and prepare the set of risk-related factors affecting the performance of infrastructure projects for use in the Structural Equation Modelling SEM.

5.2 Preparing and Designing the Questionnaire Survey Questions

Figure 5.1 illustrates the questionnaire survey preparation steps. First, an outline of the initial version of the questionnaire survey was prepared. The initial version included dividing the questionnaire survey into parts and formulating questions for each part reflecting the purpose of the part. The main questionnaire survey consisted of four main parts, with a fifth part specific to the pilot study.

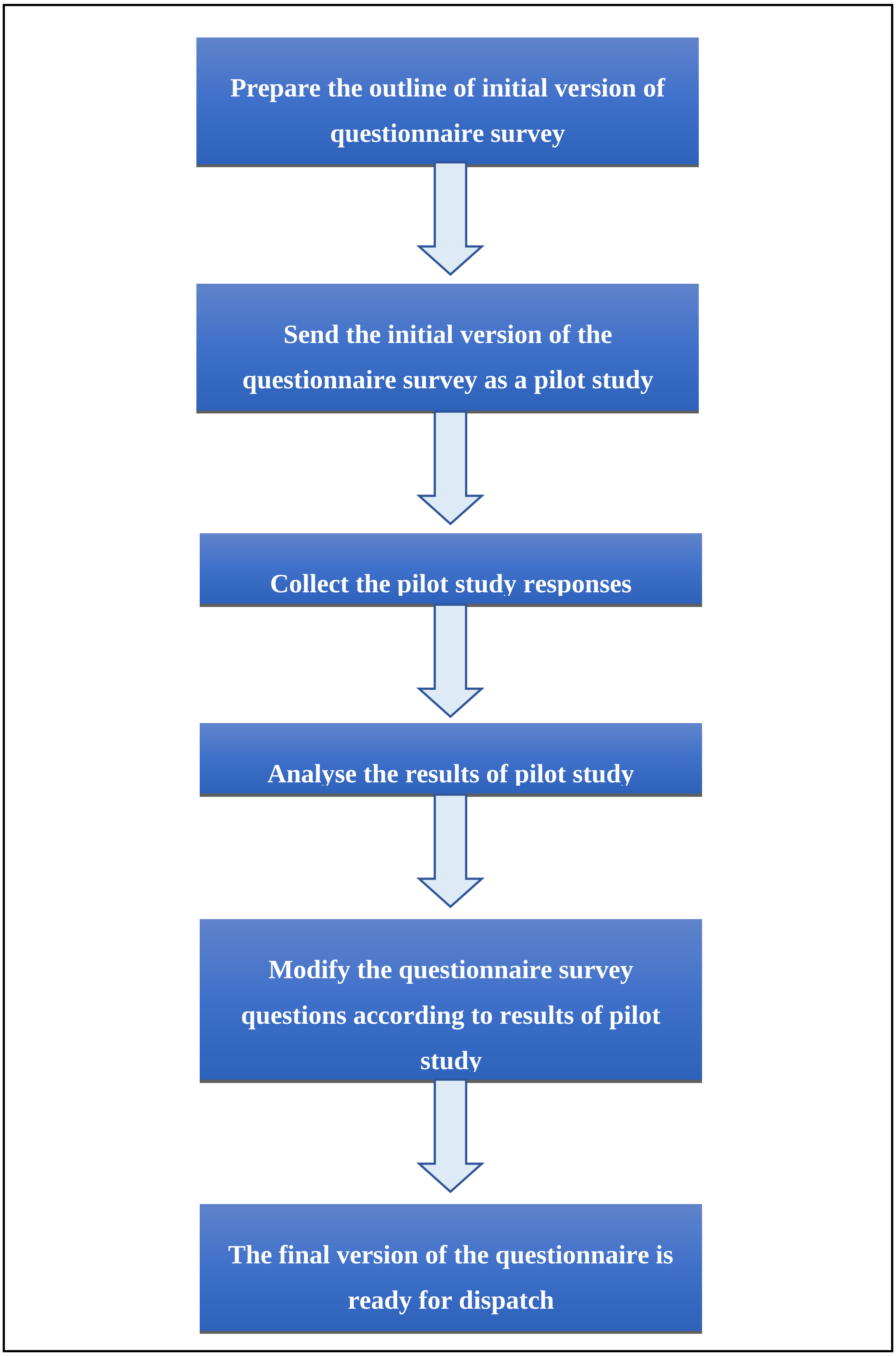


Figure 5-1: Questionnaire survey preparation steps

The first part of the questionnaire was designed to gather data about the demographics of the participants. This part contained seven questions: years of experience in infrastructure projects, the highest education degree completed, the state (territory) in which worked, the roles performed during the years of work in infrastructure projects, the types of infrastructure projects, sector and category of organization. These questions are important because they reflect respondents' participation in infrastructure projects and reflect their roles and years of experience in these projects.

The second part addressed EVM, and contained two questions. This part will be discussed extensively in the next chapter.

The third part contained questions about risk-related factors. These questions were prepared to reply to this research question:

RQ3: Are these risk-related factors likely to have significant impacts on the performance of infrastructure projects in Australia?

The questions reflect the measurement items for each factor. Measurement items were formulated based on results obtained from the interviews and the literature review. Measurement items can be obtained from multiple sources such as a review of the literature and suggestions obtained from interviewing people with experience in the field (MacKenzie et al. 2011). Furthermore, for SEM as used in this research, to achieve a constant equation, each latent factor required at least three measuring items (Kline 2015). According to the results obtained from the interviews and the literature review, 49 questions were drafted to investigate the level of impact of the risk-related factors on the performance of Australian infrastructure projects. A Likert scale with a range of five points starting from (1) Strongly disagree and ending with (5) Strongly agree was used. The measurement items (observed variables) for each factor (latent variable) are illustrated as follows.

5.2.1 Sustainability (SS)

As shown in Table 5.1, Design incorporating sustainability requirements (SS1), Fluctuating current market price in term of sustainability material (SS2), Unavailability of material supplies and resources (SS3), Government legislation of sustainability requirements (SS4), and Understanding the principle of sustainability (SS5) were derived from the interviews.

5.2.2 Stakeholders' requirements (SH)

Government requirements of stakeholder (SH1), Diverse requirements of stakeholders (SH2) and Type of contract (SH4) were also extracted from the interviews. Requested changes by clients (SH3). Cheung et al. (2004) identified client changes as one of seven categories which is used to measure the performance of construction projects. See the Table 5.1.

5.2.3 Communication (CM)

Three measurement items were created from interviews, Do not use the appropriate communications strategy (CM1), Stakeholder experience in terms of communications (CM2), and Relationship between stakeholders in terms of communications (CM4). Delay of change orders approved by the client (CM3) was identified by Cheung et al. (2004) and several categories were used to measure the performance of projects such as the number of change orders approved by the client which can be considered one of the communication risks that impact on project performance, as described in Table 5.1.

5.2.4 Procurement strategy (PS)

As shown in Table 5.1, from interviews were obtained three measurement items, Design meets the contracting requirement (SP1), Choose the appropriate procurement strategy (SP2), and the Size of the project in terms of selecting appropriate procurement strategies (SP4). The fourth measurement item, Selection of contractors (PS3) is mentioned in this comment The process of selecting the main contractor and subcontractor represents a significant stage affecting the success of the project performance (Horta et al. 2013).

5.2.5 Weather (WE)

Extreme weather such as Rising sea level (WE4), High temperature (WE2), Floods (WE1) and Cyclone (WE3) have the possibility of creating an adverse impact which leads to the demolition of infrastructure projects, including during the implementation phase (Fulbright 2014). Construction projects are constantly affected by physical impacts such as weather conditions, and it is difficult for project management to predict and prevent them from happening (Akanni et al. 2015). Furthermore, reference was made to Extreme weather such as heavy rain and flooding (WE1), Extreme weather such as low and high temperature (WE2), and Extreme weather such as storms and cyclones, during interviews, as shown in Table 5.1.

5.2.6 Experience of staff (SE)

The factors affecting the duration of projects and thus affecting the performance of e projects are Lack of commitment and absence of site staff and workers (SE1), Lack of skills of staff (SE2), Lack of education and training of staff (SE3), Lack of experience and skills to manage and distribute the staff and workers (SE4) (Enshassi et al. 2009). Moreover, the interviewees mentioned that Commitment level of staff (SE1), Skill level of staff (SE2) and Level of education and training of staff (SE3) are the significant measurement items for Staff experience, as shown in Table 5.1.

5.2.7 Site condition (SC)

As shown in Table 5.1, the interviewees argued that Geotechnical investigation (SC1), Earthworks (SC2), Ground condition (old building foundations, archaeological find and water table level) (SC3), and Site access on time (possession in time) (SC4) are the important measurement items for site condition.

5.2.8 Design issues (DI)

As shown in Table 5.1, Design changes (DI4) is one of the significant indicators of project performance (Enshassi et al. 2009; Kim 2010). Enshassi et al. (2009) mention that Incomplete and poor design (DI1), Inadequate design such as lack of documents and unclear details and specifications (DI2), Inefficient design due to little experience of the designer (DI3), and Design changes (DI4) have a negative effect on the performance of the project. The interviewees identified the measurement items for Design issues which are poor and inefficient design (Mistakes in design) (DI1), Inadequate and insufficient design (lack of details, information and specifications) (DI2), and Major design changes (DI4).

5.2.9 Financial Risk (FR)

As shown in Table 5.1, the significant measurement items for Financial risk which were highlighted by interviewees are Inflation rate fluctuations (FR1), Exchange rate fluctuations (FR2), and Interest rate fluctuations (FR3). Funding issues (FR4), such as difficulty and late payments of contractors, influence elements of project performance (Frimpong et al. 2003; Enshassi et al. 2009; Shabbar et al. 2017).

5.2.10 Subcontractor (CO)

As shown in Table 5.1, the interviewees recommended that each of Subcontractors' performance (CO1) and Subcontractors' availability (CO2) reflect the impact of the subcontractor as a risk-related factor on infrastructure project performance. Sambasivan and Soon (2007) mention that project performance can be affected if the subcontractors' performance (CO1) problems are due to the lack of subcontractor skill and experience. Lack of experience and skill of subcontractors (CO3) is one of the significant items of contractors that effect project performance (Enshassi et al. 2009). The organization of relations between the main contractor and the subcontractors (CO3) leads to significantly increased project success (Jin et al. 2013).

5.2.11 Government requirements authority (GR)

Akanni et al. (2015) mention that the government can impact the construction projects through Political decisions (GR2), furthermore, Safety requirements (GR3) are one of the items of the government legislation that impacts performance through impacts on the contractual relationships between project parties. Change in government policy (GR1) and Sovereign government intervention (GR4) are mentioned by interviewees, as shown in Table 5.1.

5.2.12 Materials (MR)

Poor materials procurement (MR1), Lack availability of materials (MR2), Slowness of material delivery, lack of materials on site, a poor commitment to using standard specifications (MR3) and Lack of experience to use materials (MR4) are the significant items of Materials that impact project performance (Enshassi et al. 2009). The interviewees indicated that each of Material procurement (MR1) and Availability of material (MR2) are the significant items used to measure Material as risk-related factor affecting the performance of infrastructure projects.

The fourth part contained one question about complementary weights. This question was designed to provide a simple proportional breakdown of the complementary weight of Cost Performance Index (CPI), Schedule Performance Index (SPI), and Risk Performance Index (RPI); the sum of these proportions must be 100%. This part will be discussed in the next chapter.

A fifth part was added for the purposes of the pilot study. This part will be discussed in the next paragraph.

USQ LimeSurvey was used to create, design and disseminate the questionnaire survey. Lime Survey is an online survey instrument and, in this research, it was used depending on the following features (Engard 2009).

a) Lime Survey is an application to conduct the questionnaire process and collect the largest amount of data from many questionnaires, established on a Web server on the Internet in the form of open source
b) Lime Survey is simple and effortless to learn
c) Lime Survey provides multiple options such as question sets and user administration
d) Lime Survey provides 20 styles of questions as well as the possibility of formulating conditional questions, the possibility of exporting and importing questions and automatic creation of the printed version of the questionnaire

e) One of the main and important features of Lime Survey is that it provides multiple options for users to present and arrange the results of the questionnaire which helps to collect the final data more easily

Invitation letters to participate in this questionnaire were sent by e-mail, mail, fax and hand delivery by visiting some companies.

Table 5-1: Measurement items

NO.	**Factors**	**Measurement items**		**Interview**	**Literature review**	
1	Sustainability (SS)	Design incorporating sustainability requirements	SS1	*		
		Fluctuating market price of sustainable materials	SS2	*		
		Unavailability of materials supply and resources	SS3	*		
		Government legislation of sustainability requirements	SS4	*		
		Understanding the principle of sustainability	SS5	*		
2	Stakeholders' requirements (SH)	Government requirements of stakeholder	SH1	*		
		Diverse requirements of stakeholders	SH2	*		
		Requested changes by clients	SH3		*	(Cheung, Suen & Cheung 2004)
		Type of contract	SH4	*		
3	Communication (CM)	Do not use the appropriate communications strategy	CM1	*		
		Stakeholder experience in terms of communications	CM2	*		
		Delay of change orders approved by the client	CM3		*	(Cheung et al. 2004)
		Relationship between stakeholders in terms of communications	CM4	*		
4	Procurement strategy (PS)	Design meets the contracting requirement	PS1	*		
		Choose the appropriate procurement strategy	PS2	*		
		Selection of contractors	PS3		*	(Horta et al. 2013)
		The size of the project in terms of selecting appropriate procurement strategies	PS4	*		

NO.	Factors	Measurement items		Interview	Literature review	
5	Weather (WE)	Extreme weather such as heavy rain and flooding	WE1	*	*	(Fulbright 2014), (Akanni et al. 2015)
		Extreme weather such as low and high temperature	WE2	*	*	(Fulbright 2014), (Akanni et al. 2015)
		Extreme weather such as storms and cyclones	WE3	*	*	(Fulbright 2014), (Akanni et al. 2015)
		Extreme weather such as sea level rise	WE4		*	(Fulbright 2014), (Akanni et al. 2015)
6	Experience of staff (SE)	Commitment level of staff	SE1	*	*	(Enshassi et al. 2009)
		Skill level of staff	SE2	*	*	(Enshassi et al. 2009)
		Level of education and training of staff	SE3		*	(Enshassi et al. 2009)
		Experience of staff management	SE4	*	*	(Enshassi et al. 2009)
7	Site condition (SC)	Geotechnical investigation	SC1	*		
		Earthworks	SC2	*		
		Ground condition (old building foundations, archaeological find and water table level)	SC3	*		
		Site access on time (possession in time)	SC4	*		
8	Design issues (DI)	Poor and inefficient design (mistakes in design)	DI1	*	*	(Enshassi et al. 2009)
		Inadequate and insufficient design (lack of details, information and specifications)	DI2	*	*	(Enshassi et al. 2009)
		Lack of designer's experience	DI3		*	(Enshassi et al. 2009)
		Major design changes	DI4	*	*	(Enshassi et al. 2009) (Kim 2010)

NO.	Factors	Measurement items		Interview	Literature review	
9	Financial risk (FR)	Inflation rate fluctuations	FR1	*		
		Exchange rate fluctuations	FR2	*		
		Interest rate fluctuations	FR3	*		
		Funding issues (delay of payments)	FR4		*	(Shabbar et al. 2017) (Frimpong et al. 2003) (Enshassi et al. 2009)
10	Subcontractor (CO)	Subcontractors’ performance	CO1	*		
		Subcontractors’ availability	CO2	*		
		Subcontractors’ experience and skills	CO3		*	(Sambasivan & Soon 2007; Enshassi et al. 2009)
		Relationship between general contractor and subcontractors	CO4		*	(Jin et al. 2013)
11	Government requirements authority (GR)	Change in government policy	GR1	*		
		Political decisions	GR2		*	(Akanni et al. 2015)
		Safety quality requirements	GR3		*	(Akanni et al. 2015)
		Sovereign government intervention	GR4	*		
12	Materials (MR)	Material procurement	MR1	*	*	(Enshassi et al. 2009)
		Availability of material	MR2	*	*	(Enshassi et al. 2009)
		Lack of standards in terms of materials	MR3		*	(Enshassi et al. 2009)
		Inexperienced with material (poor material handling on site)	MR4		*	(Enshassi et al. 2009)

5.3 Pilot Study

One of the most important types of pre-test is the pilot study (Cavana 2001). After completing the draft questionnaire, a pilot study is conducted to verify the questionnaire and make the necessary adjustments before conducting the final survey (see Appendix B2). Masrom (2012) mentions that the pilot study is carried out to verify the effectiveness of the questionnaire, and to ensure that the questionnaire content and questions are appropriate, valid, reliable and effective for obtaining different respondent views without any mistakes or trouble. The pilot study is also used to test and verify the structure, content and nature of survey questions, and the time required to complete the answer all questions (Hertzog 2008). The pilot study helps to identify weaknesses and overcome possible mistakes. It also helps to ensure that all participants will understand the questionnaire correctly, which leads to the gathering of accurate answers that serve the purpose of the research.

Once prepared, the draft questionnaire was sent to a small number of the target sample for the purpose of pre-test, then improved based on the pre-test observations (Velde 2004). Respondents answer the questions as they understand them (Masrom 2012).

The pilot online questionnaire survey (LimeSurvey) was distributed by email. An invitation letter (see Appendix B1) and list of participants in the pilot study was prepared. The list included 24 participants, including nine new participants, eight who were invited to the interview but they did not respond to the invitation, and seven who were interviewed. The list contained eight construction management academics. The number of respondents was 17 out of 24. Of the 17, only 10 questionnaires were completely answered. Every two weeks potential participants received a reminder to respond to the questionnaire.

Part five in of the questionnaire was about the pilot study (see Appendix B2). This part contained two questions to assess questionnaire feasibility in terms of time and check the questionnaire structure. The first question had 10 sub-questions. They used a Likert scale with a range of five points starting from (1) Strongly disagree and ending with (5) Strongly agree. Figures 5.2 to 5.11 illustrate the feedback collected from the pilot study. As can be seen in these figures, the answers tended to Agree and Strongly agree of more than 70%. This indicates a good questionnaire. The second question was an open question for anyone with other comments about the questionnaire survey. One participant commented, “The only question that I had some trouble understanding was the last one incorporating the CPI etc. This question probably needs more definition on exactly what you are asking and the meaning of the different terms. I think I answered it properly, but am not 100% sure..... .”. This response helped promote the quality of the questionnaire survey. The problem was solved by adding more details and clearly defining the terms in this question. Accordingly, the revised version of the questionnaire survey had been developed (see Appendix B4). In addition, the invitation letter for the questionnaire was prepared (see Appendix B3). The invitation letter and the questionnaire are were then ready for distribution to the potential research participants.

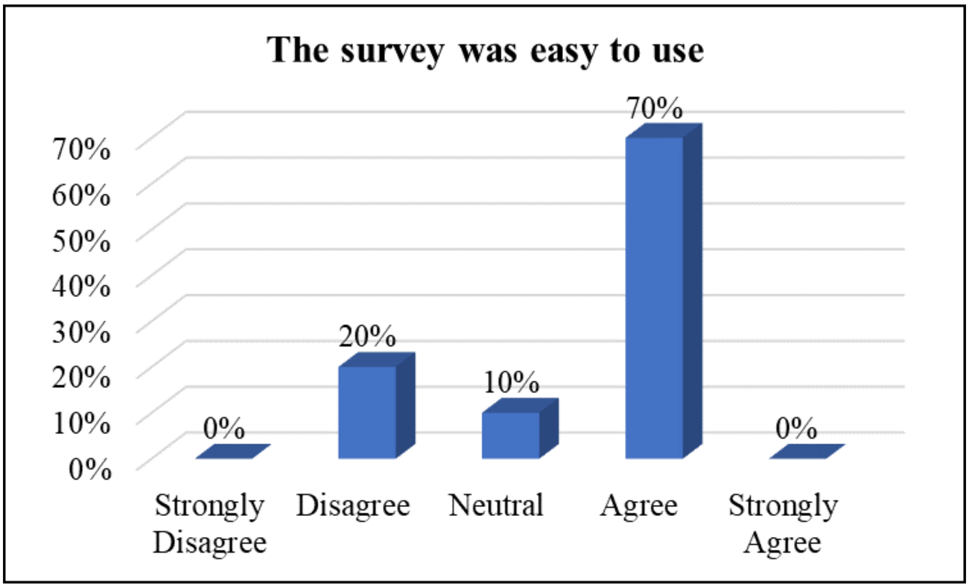


Figure 5-2: The survey was easy to use

As shown in Figure 5.2, most of the participants had answered 70% with agreeing with the question "The survey was easy to used". 20% of participants had answered with disagreeing with this question.

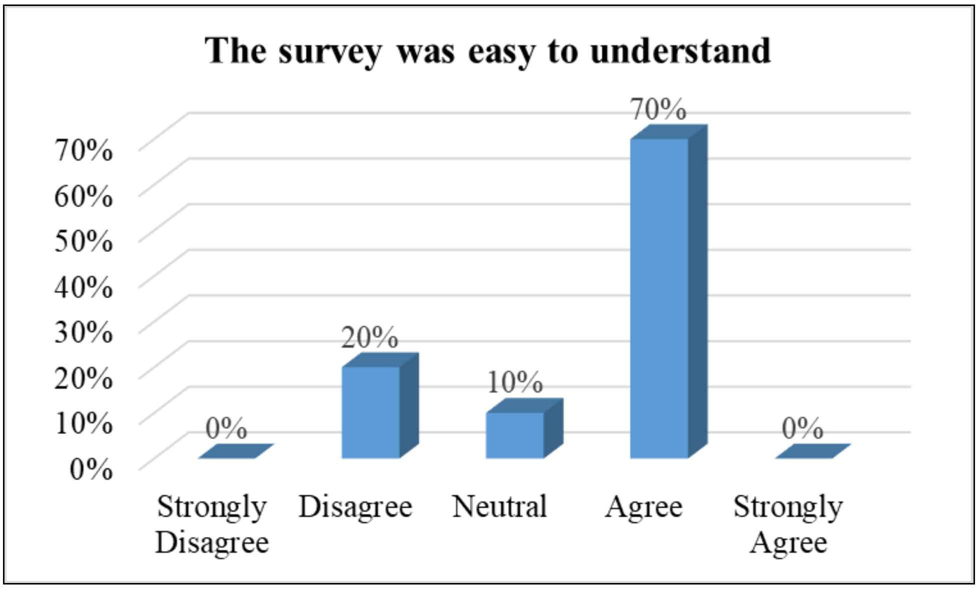


Figure 5-3: The survey was easy to understand

As shown in Figure 5.3, most of the participants had answered 70% with agreeing with the question "The survey was easy to understand". 20% of participants had answered with disagreeing with this question.

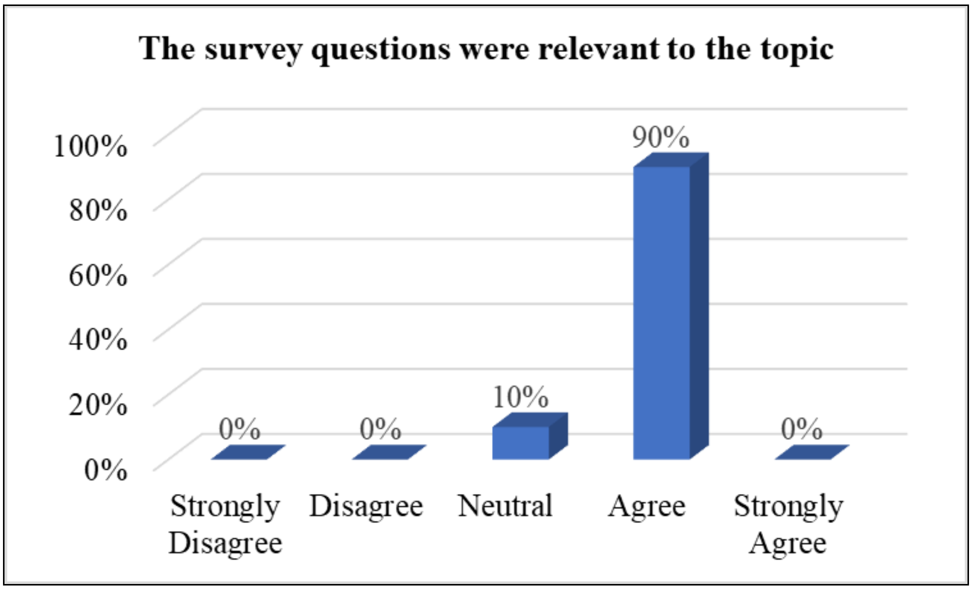


Figure 5-4: The survey questions were relevant to the topic

As shown in Figure 5.4, most respondents responded by 90% agreeing to the question "The survey questions were relevant to the topic" .10% of respondents answered neutrally to this question.

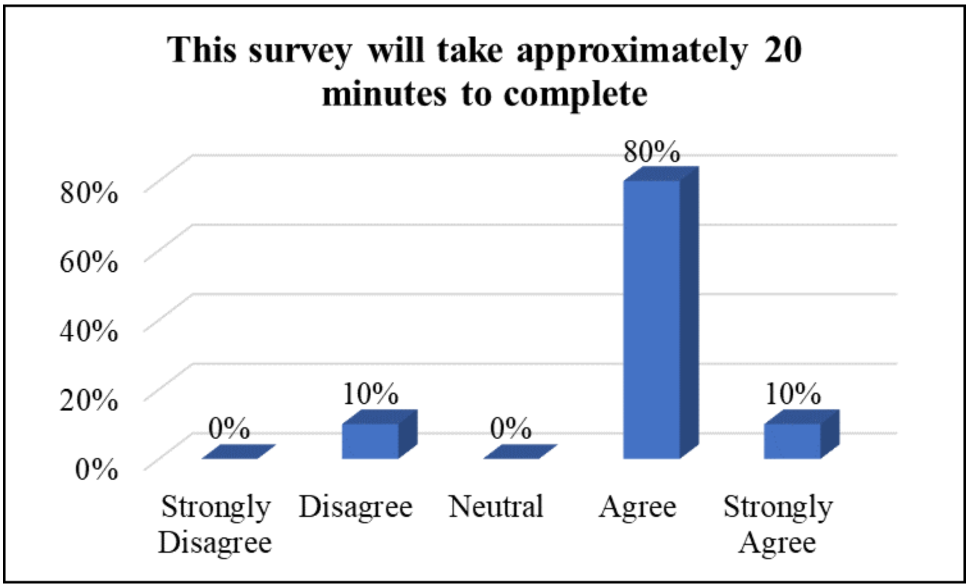


Figure 5-5: This survey will take approximately 20 minutes to complete

As shown in Figure 5.5, most of the participants had answered 80% with agreeing with the question "This survey will take approximately 20 minutes to complete". 10% of participants had answered with strongly agreeing with this question.10% of participants had answered with disagreeing with this question.

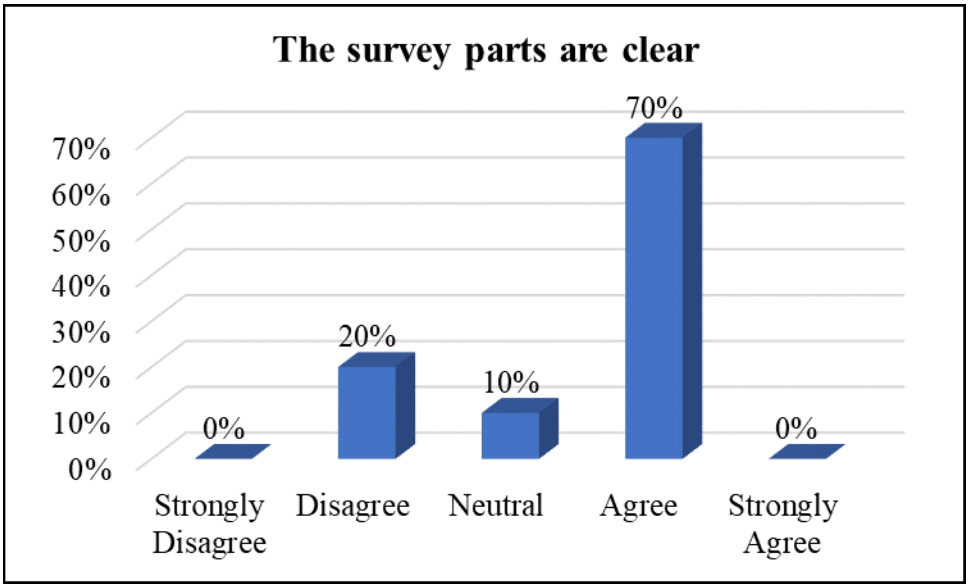


Figure 5-6: The survey parts are clear

As shown in Figure 5.6, most of the participants had answered 70% with agreeing with the question "The survey parts are clear". 10% of respondents answered neutrally to this question. 20% of participants had answered with disagreeing with this question.

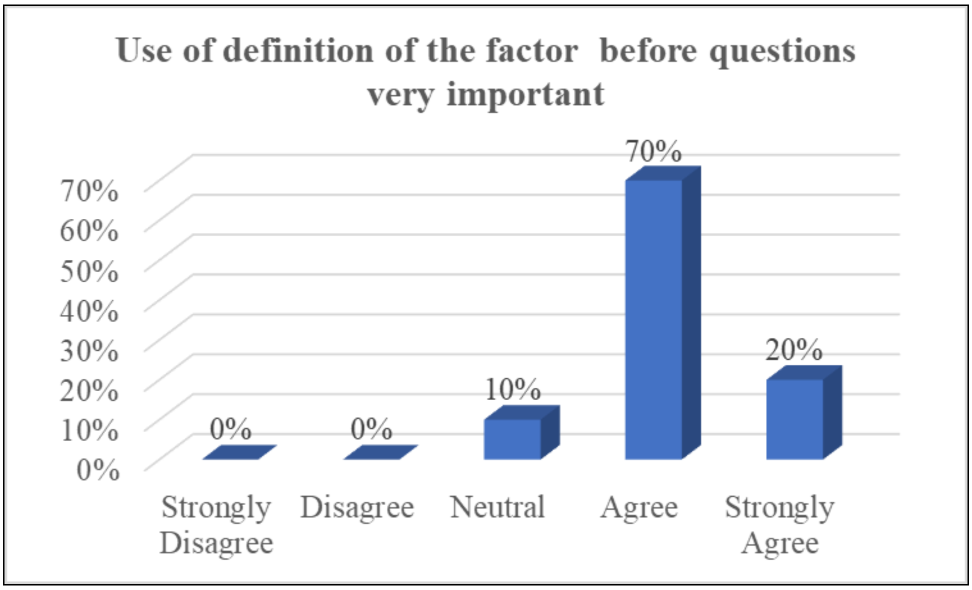


Figure 5-7: Use of definition of the factor before questions very important

As shown in Figure 5.7, most of the participants had answered 70% with agreeing with the question "Use of definition of the factor before questions very important". 20% of participants had answered with strongly agreeing with this question.10% of respondents answered neutrally to this question.

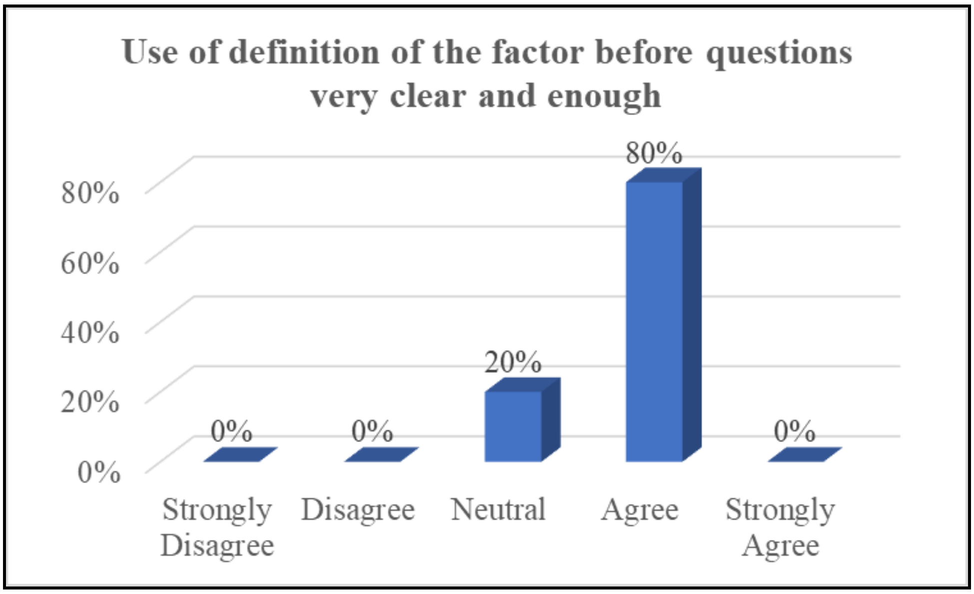


Figure 5-8: Use of definition of the factor before questions very clear and enough

As shown in Figure 5.8, most respondents responded by 80% agreeing to the question "Use of definition of the factor before questions very clear and enough". 20% of respondents answered neutrally to this question.

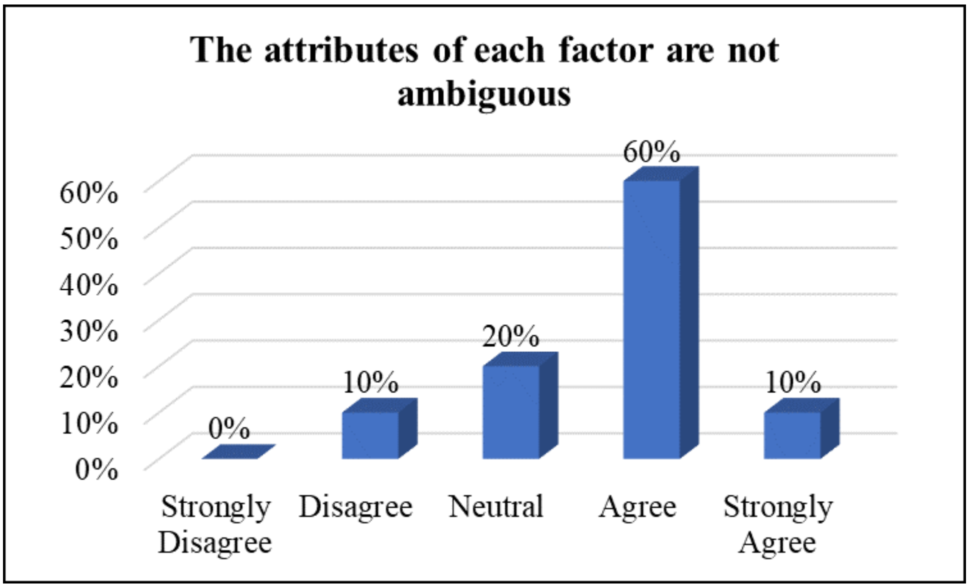


Figure 5-9: The attributes of each factor are not ambiguous

As shown in Figure 5.9, most of the participants had answered 60% with agreeing with the question "The attributes of each factor are not ambiguous". 10% of participants had answered with strongly agreeing with this question. 20% of respondents answered neutrally to this question.10% of participants had answered with disagreeing with this question.

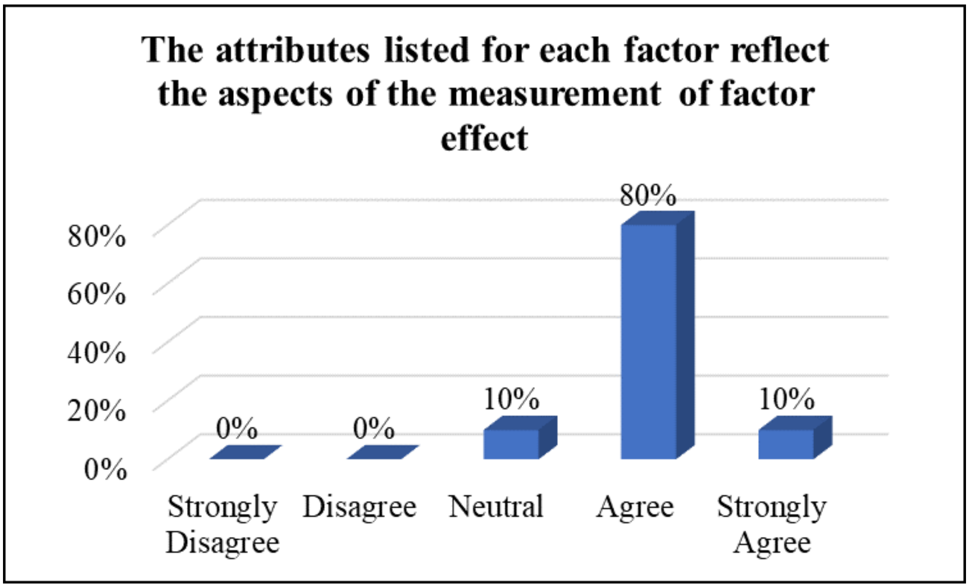


Figure 5-10: The attributes listed for each factor reflect the aspects of the measurement of factor effect

As shown in Figure 5.10, most of the participants had answered 80% with agreeing with the question "The attributes listed for each factor reflect the aspect of the measurement of factor effect". 10% of participants had answered with strongly agreeing with this question. 10% of respondents answered neutrally to this question.

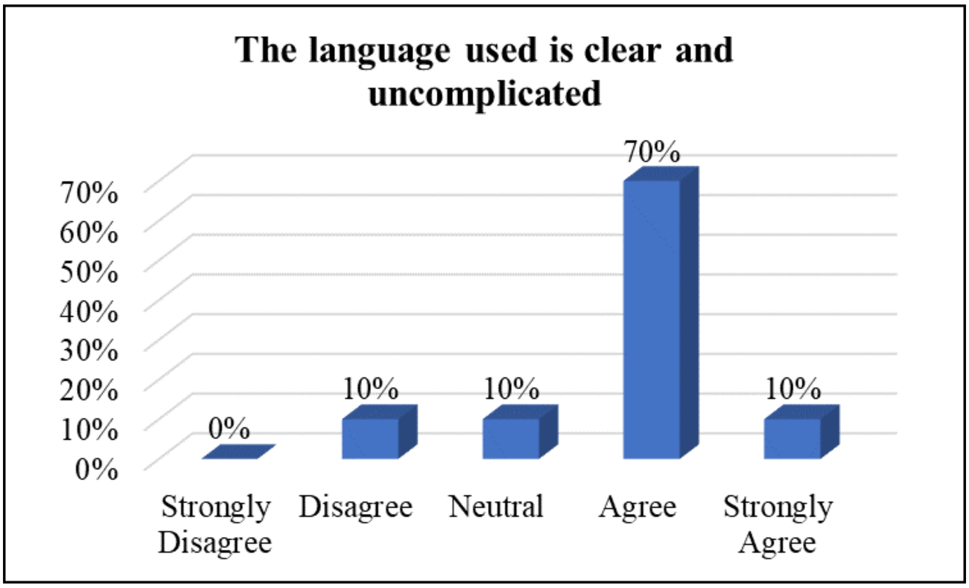


Figure 5-11: The language used is clear and uncomplicated

As shown in Figure 5.11, most of the participants had answered 70% with agreeing with the question "The language used is clear and uncomplicated". 10% of participants had answered with strongly agreeing with this question. 10% of respondents answered neutrally to this question. 10% of participants had answered with disagreeing with this question.

It is clear from the foregoing that most of the answers to the questions of the pilot study strongly tend to approve the study questions with 70%. This is a good indication that the questionnaire is good. Except for a simple problem in understanding the last question of the questionnaire. This problem was solved as previously explained.

5.4 Questionnaire Survey Results

This section provides a brief overview of the research sample. It also discusses the data analysis. The next section will analyse the first part (demographic data) and the third part (risk-related factors data) of the questionnaire.

5.4.1 Sample

As a result of the increased use of Structural Equation Modelling SEM, researchers face a challenge in determining the sample size for structural equation modelling SEM (Wolf et al. 2013). The Free A-priori Sample Size Calculator for Structural Equation Models "http://www.danielsoper.com/statcalc/calculator.aspx?id=89" was used to calculate the sample size. This website calculates the size of the sample needed for the search after entering the effect size (0.35) Cohen (1988) mentions that the effect size between (0.3-0.5) is a moderate effect, statistical power level (0.8), number of latent variables (12), number of observed variables (49) and probability level (0.05). As shown in Figure 5.12 and based on previous inputs, the results were the minimum sample size to detect effect is (136), minimum sample size for the model structure is (97) and the recommended minimum sample size is (136).

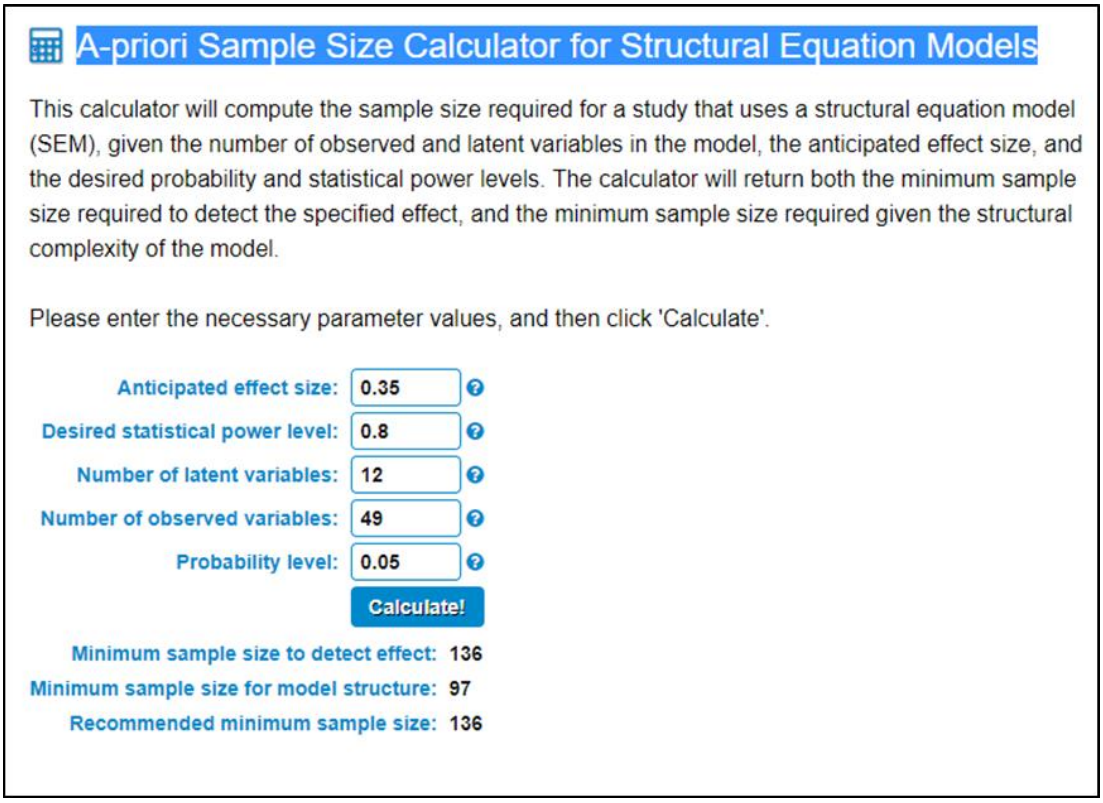


Figure 5-12: The website of "Free A-priori Sample Size Calculator for Structural Equation Models

The final version of the questionnaire was sent to the target sample. The target sample drawn from the Australian infrastructure industry. The target sample consisted of individuals, companies and institutions with expertise in infrastructure projects in Australia. The sample was divided into three sections. Section One was local councils in Australia (public sector). The Australian Local Government Association (ALGA) (2017) mentions that there are more than 537 local councils across the Australia. Section Two was specialized companies, institutions and organizations working in infrastructure projects in Australia (private sector). Section Three was individuals working in infrastructure projects (public sector - private sector - mixed sector).

A Google search was used to obtain the names and email addresses of the local councils and specialized companies, institutions and organizations for the purpose of sending the questionnaire to them. LinkedIn was used to contact the individuals employed in infrastructure projects. During the period from February to September 2018, approximately 500 questionnaires were distributed. The number of responses received was 140, of which 132 were suitable for data analysis. Accordingly, the response rate was 25%, and this ratio is satisfactory according to Baruch and Holtom (2008) and Baruch (1999).

5.4.2 Analysis of demographic data results

This section reflects the results of the analysis of the demographic data of the participants. The results of the analysis of seven questions in terms of years of experience in infrastructure projects, the highest education degree completed, the state (territory) which eorked in, the roles during the years of work in infrastructure projects, the types of infrastructure projects, which sector and the category of organization.

These questions are important because they reflect that participants have participated in infrastructure projects and reflect their roles and years of experience in these projects. This is necessary for the researcher in terms of confirming the strength and truthfulness of the data obtained. The following is an illustration of the sample demographics.

5.4.2.1 Years of experience in infrastructure projects in Australia

Table 5.2 illustrates the participants' years of experience in infrastructure projects in Australia. The table shows that slightly more than a quarter of the sample (35 respondents at 26.5%) with experience 0-10 years, followed by 27 of the respondents (20.5%) reporting experience 11-15 years. Sixteen respondents (12.1%) stated they have experience of 16-20 years. Eighteen respondents (13.6%) stated they have experience of 21-25 years. Sixteen respondents (12.1%) reported experience of 26-30 years, followed by 20 respondents (15.2%) with more than 30 years of experience. The total result demonstrates that 97 respondents (73.5%) have more than 10 years of experience with infrastructure projects in Australia, which is a good amount of experience for the purpose of this research.

Table 5-2: Years of experience in infrastructure projects

Years of experience you have in infrastructure construction projects					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0-10	35	26.5	26.5	26.5
	11-15	27	20.5	20.5	47.0
	16-20	16	12.1	12.1	59.1
	21-25	18	13.6	13.6	72.7
	26-30	16	12.1	12.1	84.8
	>30	20	15.2	15.2	100.0
	Total	132	100.0	100.0	

5.4.2.2 Highest education degree completed

Table 5.3 illustrates the highest education degree completed by participants in this survey. The table shows that 20 (15.2%) have a Diploma degree. Followed by 57 of the respondents (43.2%) had completed a Bachelor degree. Forty-five respondents (34.1%) have a Master degree. Four participants (3%) reported that they have a Doctorate degree. Finally, 6 have another certificate such as Chartered Professional Engineer, Post Graduate Diploma, Postgraduate Certificate, Graduate Diploma, Advanced Diploma and Graduate Certificate. The total result demonstrates that most of the respondents (106 at 80.3%) have degrees ranging from Bachelor to Doctorate. This shows that the sample participating in the questionnaire has a good educational achievement.

Table 5-3: Highest education degree completed

Highest degree you have completed						
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Diploma	20	15.2	15.2	15.2
	Bachelor degree	57	43.2	43.2	58.3
	Master degree	45	34.1	34.1	92.4
	Doctorate	4	3.0	3.0	95.5
	Other Certificate	6	4.5	4.5	100.0
	Total	132	100.0	100.0	

5.4.2.3 State (territory) in Australia

As shown in Table 5.4, participants in this questionnaire were distributed throughout the states of Australia. The table demonstrates that 17 (12.9%) are from Western Australia. Only one participant was the from Northern territory (0.8%). Six participants (4.5%) are from South Australia. Queensland obtained the largest percentage of respondents with 63 participants (47.7% of the total sample). Sixteen participants with (12.1%) are from New South Wales. Six participants (4.5%) are from Australian Capital Territory. The number of participants from Victoria and Tasmania is 18 (13.6%) and 5 (3.8%), respectively. The total result demonstrates that the participants in this questionnaire were distributed almost equally among the Australian states, except for Queensland. This is due to the fact that the 2018 Commonwealth budget allocated. AUD 4.5 billion for the development and expansion of the state's highways network (Australian Government 2018).

Table 5-4: State (Territory) in Australia for the participants

State (Territory)					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Western Australia	17	12.9	12.9	12.9
	Northern Territory	1	.8	.8	13.6
	South Australia	6	4.5	4.5	18.2
	Queensland	63	47.7	47.7	65.9
	New South Wales	16	12.1	12.1	78.0
	Australian Capital Territory	6	4.5	4.5	82.6
	Victoria	18	13.6	13.6	96.2
	Tasmania	5	3.8	3.8	100.0
	Total	132	100.0	100.0	

5.4.2.4 Roles of participants in infrastructure projects

Table 5.5 and Figure 5.13 illustrate the roles of participants in infrastructure projects during the years of their experience. The table and figure demonstrate that most participants, more than 94 %, had worked in most roles: site engineer, senior project manager, project manager, design engineer, senior engineer, operation manager, construction engineer. This indicates that the participants have experience in many roles.

Table 5-5: Roles of participants in infrastructure projects

Roles	Frequency	Percent
Site engineer	127	96.2
Senior project manager	125	94.7

Project manager	126	95.5
Design engineer	126	95.5
Senior engineer	126	95.5
Operation manager	125	94.7
Construction engineer	125	94.7
Planning engineer	126	95.5
Estimate engineer	125	94.7
Management engineer	125	94.7

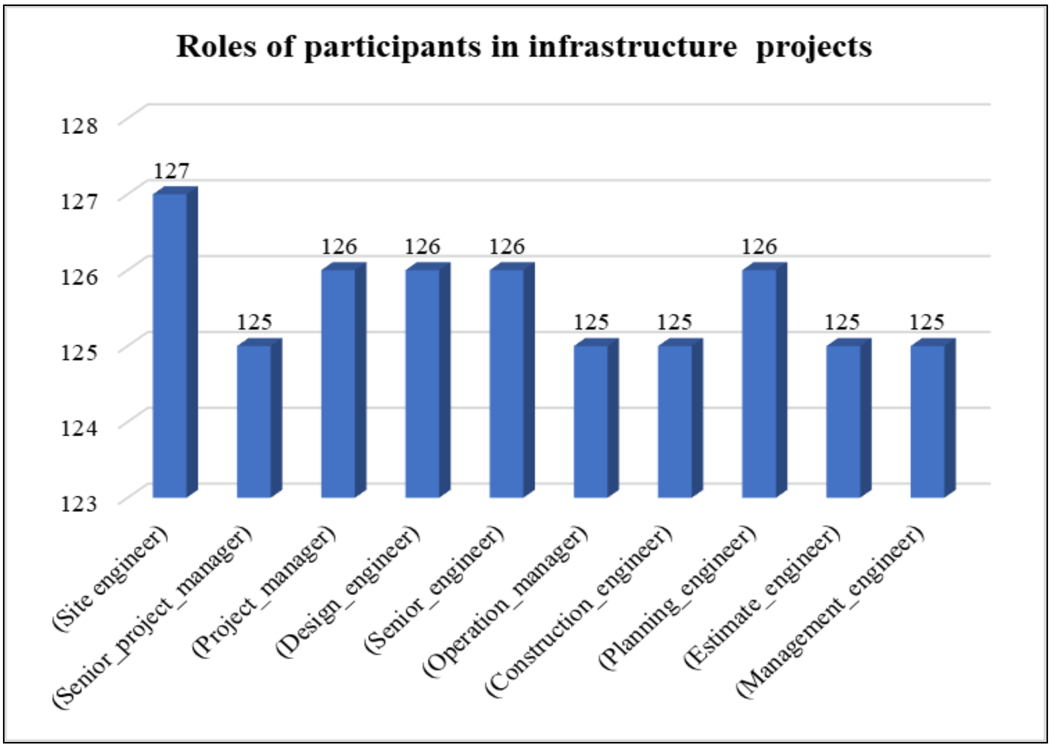


Figure 5-13: Roles of participants in infrastructure projects

5.4.2.5 Types of projects participants involved in

Table 5.6 and Figure 5.14 illustrates types of projects that participants had been involved in during their years of experience. The table and figure demonstrate that most participants, more than 93%, worked in most infrastructure project: roads, tunnels, bridges, airports, railroads, dams, infrastructure maintenance, harbours, water supply and wastewater. This indicates that participants have experience in most types of infrastructure projects in Australia.

Table 5-6: Types of projects

Types of projects	Frequency	Percent
Roads	130	98.5
Tunnels	125	94.7
Bridges	126	95.5
Airports	124	93.9
Railroads	124	93.9
Dams	124	93.9
Infrastructure maintenance	125	94.7
Harbours	123	93.2
Water Supply	125	94.7
Wastewater	124	93.9
Other	123	93.2

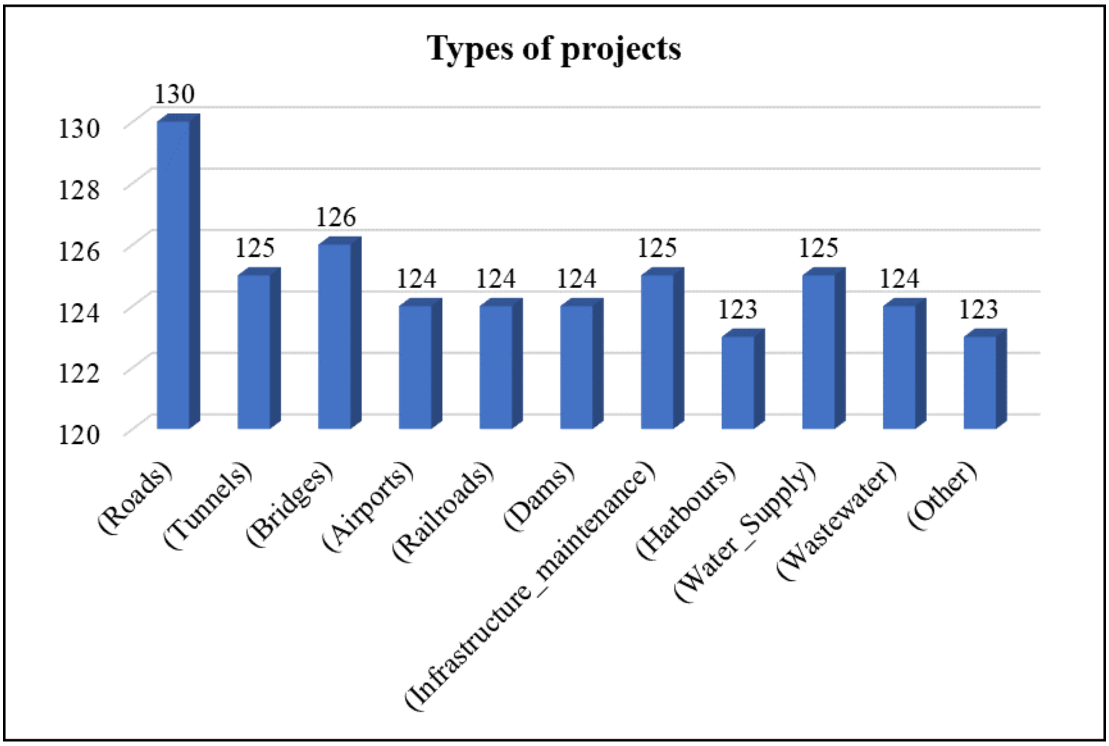


Figure 5-14: Types of projects

5.4.2.6 The sector of infrastructure projects

Table 5.7 shows the sector to which each participant currently belongs. Eighty-two participants (62.1%) were currently working in the public sector. Forty participants belonged to the private sector (30.3%). Finally, nine participants (6.8%) represented the mixed sector (quasi-government sectors). This indicates that most of the participants (more than 60%) have experience in public infrastructure projects in Australia. These projects usually have high budgets and provide experience with a diversity of infrastructure type. This ensures that the sample is able to provide a clear impression of infrastructure projects in Australia.

Table 5-7: Sector of infrastructure projects

The sector of infrastructure projects					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Public sector	82	62.1	62.6	62.6
	Private sector	40	30.3	30.5	93.1
	Mixed sector (quasi-government sectors)	9	6.8	6.9	100.0
	Total	131	99.2	100.0	
Total	132	100.0			

5.4.2.7 The category of the organization

Table 5.8 illustrates the distribution of the sample depending on the type of organization. The table explains that 41 participants (31.1%) worked as a client representative. Followed by 22 (16.7%) who worked as a consultant. Thirty-one participants (23.5%) worked as a contractor. Finally, 38 (28.8%) worked in other organizations such as local government representative, supplier, utility owner, and manufacturer. The total result demonstrates that the sample used in this research covered all types of organizations operating in Australian infrastructure projects in fairly similar proportions.

Table 5-8: The category of the organization

The category of your current organization					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Client representative	41	31.1	31.1	31.1
	Consultant	22	16.7	16.7	47.7
	Contractor	31	23.5	23.5	71.2
	Others	38	28.8	28.8	100.0
	Total	132	100.0	100.0	

5.4.3 Factor Analysis (FA)

Some aspects of research require the restructuring of data by reducing the number of variables. Factor analysis (FA) is used to achieve this target. According to Williams et al. (2010) FA is a significant approach used in data reduction and is a multivariate statistical system used in multi-areas. This approach consists of two steps: Exploratory Factor Analysis (EFA), followed by Confirmatory Factor Analysis (CFA).

5.4.3.1 Exploratory Factor Analysis (EFA)

In this section, an analysis of the 49 questions of the questionnaire survey is undertaken. These questions reflect the measuring items for each factor. EFA will be used to detect the basic structure of a set of variables.

The sample size is a crucial issue for exploratory factor analysis (Williams et al. 2010). The sample size used for this stage is roughly 140 participants. That corresponds to Hair et al. (2010b) that who advice that the sample size should be 100 or greater. So, this sample size can be considered appropriate for exploratory factor analysis.

Before starting to analyse the data, the file should be clean for screening. Data screening is a preliminary step before starting the analysis. It consists of identifying missing values, outliers and unengaged responses (Hair et al. 2010b). After deleting cases that have a majority missing value, are clear for multivariate normality and deleting unengaged responses the samples size was 132.

- **Sustainability (SS), Stakeholders' requirements (SH), Communication (CM) and Procurement strategy (PS).**

There are items used to measure each latent factor of (SS, SH, CM, and PS). SS has five items. There were four items for the other factors (SH, CM, and PS). Many outputs are obtained when running factor analysis in SPSS. Table 5.9 shows that the a. determinant value is 0.21; greater than 0.00001. This value checks if there is a problem with multicollinearity (very highly correlated variables). Field (2009) states that this value should be greater than 0.00001.

Table 5-9: Determinant value for SS, SH, CM and PS

Correlation Matrix[a]
a. Determinant = .210

Table 5.10 shows KMO and Bartlett's test results. The value of the KMO is about 0.624, which is greater than the acceptable range 0.50 (Hair et al. 2010b). The Bartlett's Test (Sig) is 0.000, and should be highly significant with a value less than 0.05 ($p<0.05$) (Field 2006). Based on these results, the data is appropriate for FA.

Table 5-10: KMO and Bartlett's Test for SS, SH, CM and PS

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.624
Bartlett's Test of Sphericity	Approx. Chi-Square	197.962
	df	45
	Sig.	.000

Table 5.11 demonstrates four components with an eigenvalue more than 1(2.442, 1.477, 1.327, and1.197) and, as illustrated, total variance explains (64.427), which tries to explain approximately 50-75% of the variance using the least number of factors. Figure 5.15 illustrates the scree plot which confirms the results of the eigenvalues (Thompson 2004; Henson & Roberts 2006).

Table 5-11: Eigenvalues for SS, SH, CM and PS

Total Variance Explained							
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[a]
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	2.442	24.416	24.416	2.442	24.416	24.416	2.003
2	1.477	14.772	39.188	1.477	14.772	39.188	1.711
3	1.327	13.269	52.456	1.327	13.269	52.456	1.714
4	1.197	11.971	64.427	1.197	11.971	64.427	1.492
5	.845	8.449	72.877				

6	.722	7.215	80.092				
7	.565	5.648	85.740				
8	.515	5.153	90.894				
9	.483	4.831	95.725				
10	.427	4.275	100.000				
Extraction Method: Principal Component Analysis.							
a. When components are correlated, sums of squared loadings cannot be added to obtain a total variance.							

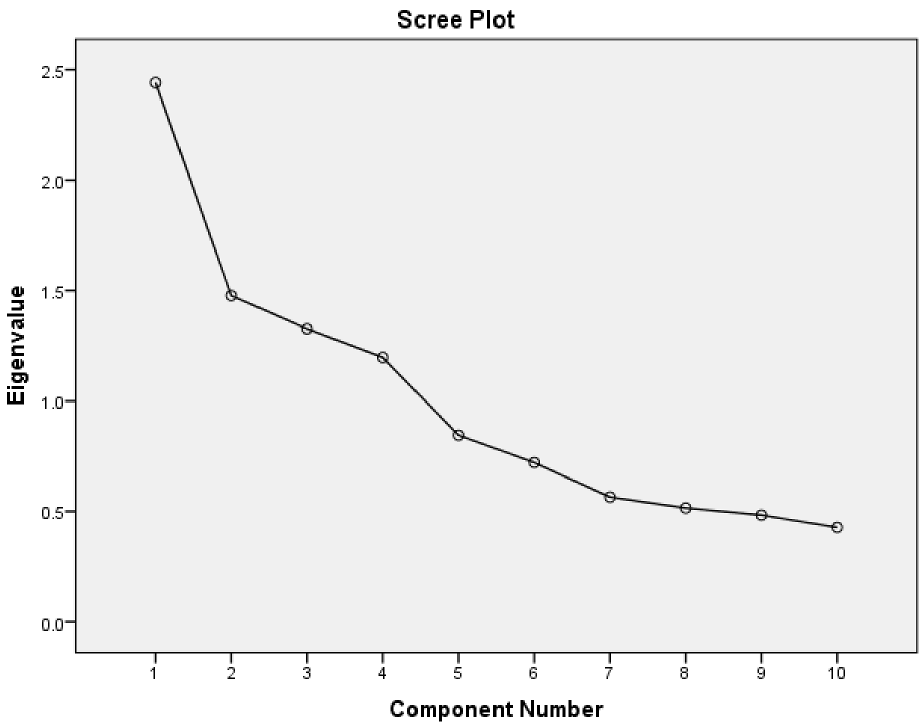


Figure 5-15: Scree plot for SS, SH, CM, and PS

Run the exploratory factor analysis and retry more than once for extracting factors. For items scale development, the number of items is minimized so that the remaining items increase the explanation in the variance and increase the reliability of the scale

(Netemeyer 2003). Selecting the highest loading above 0.4. Any items having less than 0.4 hasn't loaded well onto any factor. Table 5.12 shows the pattern matrix. The pattern matrix explains the results of exploratory factor analysis and creates a basic structure of set items for each variable. As can be seen, the items of Sustainability (SS) was reduced from five items to three items, the items of Stakeholders' requirements (SH) and Communication (CM) were reduced from four items to two items, the items of Procurement strategy (PS) were reduced from four items to three items. Four new obtained variables will be created by SPSS depending on the final number of items. These new variables will be used in the next stage of this research in the SEM.

Table 5-12: Pattern Matrix for SS, SH, CM and PS

Pattern Matrix[a]				
	Component			
	1	2	3	4
SMEAN(SS3)			.535	
SMEAN(SS4)			.779	
SMEAN(SS5)			.808	
SMEAN(SH2)				.828
SMEAN(SH3)				.853
SMEAN(CM1)		.822		
SMEAN(CM2)		.820		
SMEAN(PS2)	.640			
SMEAN(PS3)	.802			
SMEAN(PS4)	.798			
Extraction Method: Principal Component Analysis. Rotation Method: Promax with Kaiser Normalization.[a]				
a. Rotation converged in 5 iterations.				

- **Weather (WE), Experience of staff (SE), Site condition (SC) and Design issues (DI).**

There were four items for each latent factor (WE, SE, SC, and DI). Many outputs are obtained when running factor analysis in SPSS. Table 5.13 shows the a. determinant value is 0.005; greater than 0.00001. This value checks if there is a problem with multicollinearity (very highly correlated variables). Field (2009) states that this value should be greater than 0.00001.

Table 5-13: Determinant values for WE, SE, SC and DI

Correlation Matrix[a]
a. Determinant = .005

Table 5.14 shows KMO and Bartlett's test results. The value of the KMO is about 0.756, which is greater than the acceptable range 0.50 (Hair et al. 2010b). The Bartlett's Test (Sig) is 0.000, and should be highly significant with a value less than 0.05 ($p<0.05$) (Field 2006). Based on these results, the data above is appropriate for FA.

Table 5-14: KMO and Bartlett's Test for WE, SE, SC and DI

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.756
Bartlett's Test of Sphericity	Approx. Chi-Square	671.511
	df	78
	Sig.	.000

Table 5.15 demonstrates that four components with an eigenvalue more than 1 (4.492, 1.977, 1.241, and 1.106) and as illustrated total variance explained (67.824), which tries to explain approximately 50-75% of the variance using the least number of factors. Figure 5.16 illustrates the scree plot confirms the results of eigenvalue (Thompson 2004; Henson & Roberts 2006).

Table 5-15: Eigenvalue for WE, SE, SC and DI

Total Variance Explained							
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[a]
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	4.492	34.558	34.558	4.492	34.558	34.558	3.007
2	1.977	15.209	49.767	1.977	15.209	49.767	2.951
3	1.241	9.548	59.315	1.241	9.548	59.315	3.208
4	1.106	8.509	67.824	1.106	8.509	67.824	2.283
5	.779	5.992	73.816				
6	.754	5.801	79.617				
7	.521	4.005	83.622				
8	.491	3.778	87.400				
9	.469	3.611	91.010				
10	.429	3.301	94.312				
11	.318	2.446	96.758				
12	.269	2.070	98.828				
13	.152	1.172	100.000				
Extraction Method: Principal Component Analysis.							

a. When components are correlated, sums of squared loadings cannot be added to obtain a total variance.

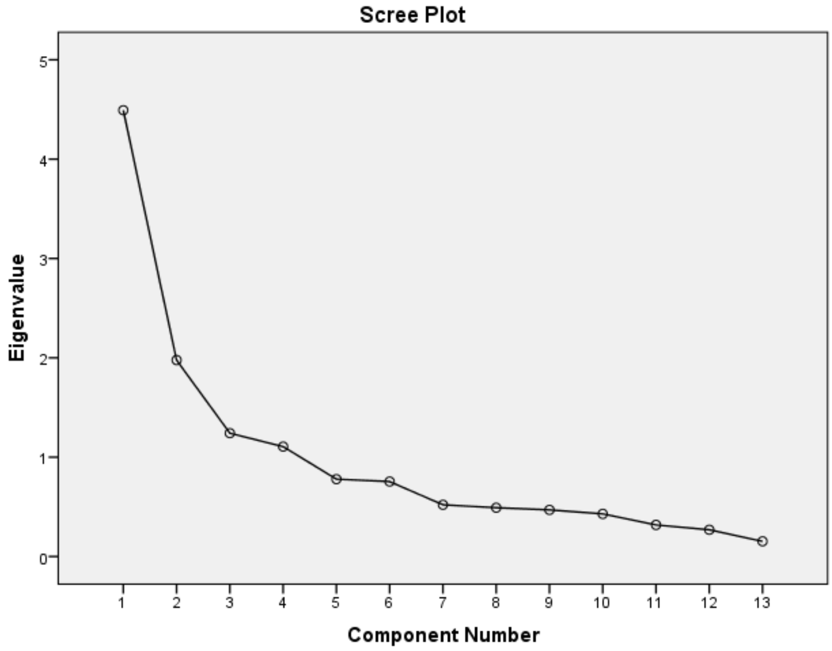


Figure 5-16:Scree plot for WE, SE, SC and DI

Run the exploratory factor analysis and retry more than once for extracting factors. For items scale development, the number of items is minimized so that the remaining items increase the explanation in the variance and increase the reliability of the scale (Netemeyer 2003). Selecting the highest loading above 0.4. Any items with less than 0.4 haven't loaded well onto any factor. Table 5.16 shows the pattern matrix. The pattern matrix explains the results of exploratory factor analysis and creates a basic structure of set items for each variable. As can be seen, the items of Weather (WE) did not change - retained four items, the items of Experience of staff (SE) reduced from four items to two items, the items of Site condition (SC) reduced from four items to three items, the items of Design issues (DI) did not change - retained four items. Four new obtained variables will be created by SPSS depending on the final number of items. These new variables will be used in the next stage of this research in the SEM.

Table 5-16: Pattern Matrix for WE, SE, SC and DI

Pattern Matrix[a]				
	Component			
	1	2	3	4
SMEAN(WE1)		.826		
SMEAN(WE2)		.870		
SMEAN(WE3)		.727		
SMEAN(WE4)		.602		
SMEAN(SE1)				.732
SMEAN(SE2)				.746
SMEAN(SC1)			.797	
SMEAN(SC2)			.925	
SMEAN(SC3)			.780	
SMEAN(DI1)	.646			
SMEAN(DI2)	.821			
SMEAN(DI3)	.771			
SMEAN(DI4)	.611			
Extraction Method: Principal Component Analysis. Rotation Method: Promax with Kaiser Normalization.[a]				
a. Rotation converged in 7 iterations.				

- **Financial risk (FR), Subcontractor (CO), Government requirements authority (GR) and Materials (MR)**

There were four items for each latent factor (FR, CO, GR and MR). Many outputs are obtained when running factor analysis in SPSS. Table 5.17 shows the a. determinant value is 0.003; greater than 0.00001. This value checks if there is a problem with multicollinearity (very highly correlated variables). Field (2009) states that this value should be greater than 0.00001.

Table 5-17: Determinant value for FR, CO, GR and MR

Correlation Matrix[a]
a. Determinant = .003

Table 5.18 shows KMO and Bartlett's test results. The value of the KMO is about 0.793, which is greater than the acceptable range 0.50 (Hair et al. 2010b). The Bartlett's Test (Sig) is 0.000 , should be highly significant with value less than 0.05 ($p<0.05$) (Field 2006). Based on these results, the data above is appropriate for FA.

Table 5-18: KMO and Bartlett's Test for FR, CO, GR and MR

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.793
Bartlett's Test of Sphericity	Approx. Chi-Square	722.938
	df	78
	Sig.	.000

Table 5.19 shows that four components with an eigenvalue more than 1 (4.581, 2.081, 1.345, and 1.197) and as illustrated total variance explained (70.794), which is

trying to explain approximately 50-75% of the variance using the least number of factors. Figure 5.17 illustrates the scree plot confirming the results of the eigenvalue (Thompson 2004; Henson & Roberts 2006).

Table 5-19:Eigenvalue for FR, CO, GR and MR

Total Variance Explained							
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[a]
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	4.581	35.238	35.238	4.581	35.238	35.238	3.610
2	2.081	16.008	51.246	2.081	16.008	51.246	3.450
3	1.345	10.344	61.590	1.345	10.344	61.590	2.768
4	1.197	9.204	70.794	1.197	9.204	70.794	2.096
5	.693	5.327	76.121				
6	.610	4.691	80.812				
7	.490	3.767	84.579				
8	.459	3.535	88.113				
9	.410	3.150	91.264				
10	.368	2.829	94.092				
11	.360	2.772	96.864				
12	.237	1.825	98.689				
13	.170	1.311	100.000				
Extraction Method: Principal Component Analysis.							
a. When components are correlated, sums of squared loadings cannot be added to obtain a total variance.							

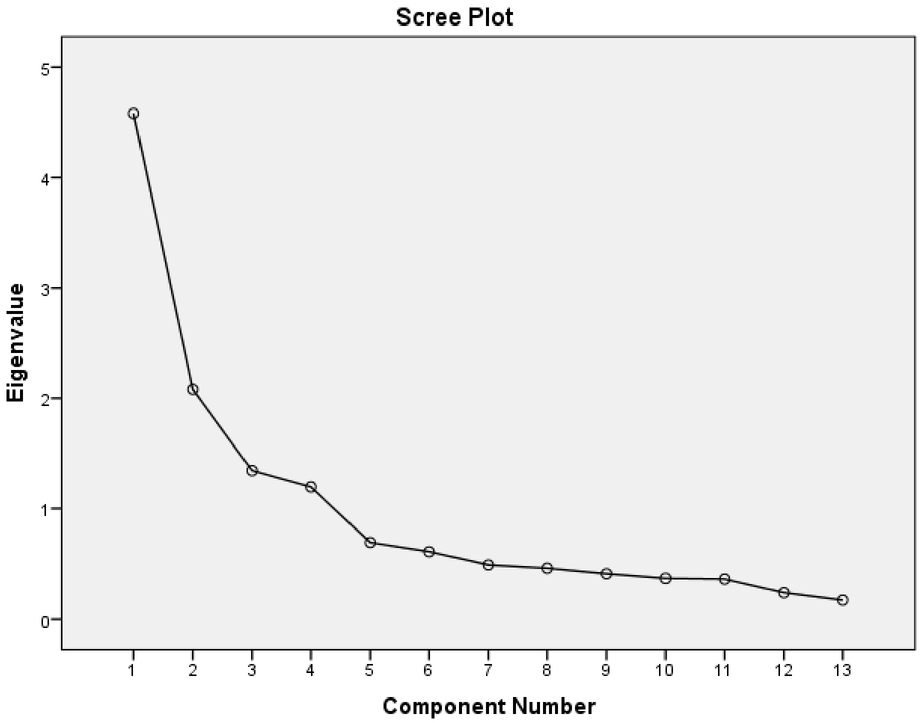


Figure 5-17: Scree plot for FR, CO, GR and MR

Run the exploratory factor analysis and retry more than once for extracting factors. For items scale development, the number of items is minimized so that the remaining items increase the explanation in the variance and increase the reliability of the scale (Netemeyer 2003). Selecting the highest loading above 0.4. Any items with less than 0.4 haven't loaded well onto any factor. Table 5.20 shows the pattern matrix. The pattern matrix explains the results of exploratory factor analysis and creates a basic structure of set items of each variable. As can see the items of Financial risk (FR) reduced from four items to three items, the items of Subcontractor (CO) did not change - retained four items, the items of Government requirements authority (GR) reduced from four items to two items, the items of Materials (MR) did not change - retained four items. Four new obtained variables will be created by SPSS depending on the final number of items. These new variables will be used in the next stage of this research in the SEM.

Table 5-20: Pattern Matrix for FR, CO, GR and MR

Pattern Matrix[a]				
	Component			
	1	2	3	4
SMEAN(FR1)			.795	
SMEAN(FR2)			.929	
SMEAN(FR3)			.924	
SMEAN(CO1)		.868		
SMEAN(CO2)		.845		
SMEAN(CO3)		.783		
SMEAN(CO4)		.655		
SMEAN(GR1)				.791
SMEAN(GR2)				.911
SMEAN(MR1)	.827			
SMEAN(MR2)	.873			
SMEAN(MR3)	.823			
SMEAN(MR4)	.645			
Extraction Method: Principal Component Analysis. Rotation Method: Promax with Kaiser Normalization.[a]				
a. Rotation converged in 5 iterations.				

5.4.3.2 Confirmatory Factor Analysis (CFA) and Structural Equation Modelling (SEM)

Confirmatory Factor Analysis (CFA) is one of the steps of Factor Analysis. CFA is extensively used for testing the relationship hypotheses between variables (Flora & Curran 2004). CFA is the step to check the efficacy of measurement items and prepare the foundation for the Structural Equation Modelling (SEM) (Xiong et al. 2014). CFA is also sub-paradigm of SEM (Swisher et al. 2004). SEM is a statistical approach or statistical program, which is used to test structural relationships between measuring items and the latent factors by using Factor Analysis and Multiple Regression Analysis (Xiong et al. 2014). According to Teo (2010) and Raykov and Marcoulides (2012), three types of SEM are used commonly: path analysis models, confirmatory factor analysis models and structure regression models. Each model of measurement needs to be evaluated using a number of various fit indicators (Yuan 2005). These indices assist in providing an adequate perspective on statistical testing (Bentler & Bonett 1980). Some of the fit indicators in SEM are used frequently despite the availability of many indicators to evaluate the goodness of fit in SEM (Sun 2005). The use of three or four fit indicators is sufficient as a proof of model fit (Hair et al. 2010b). Table 5.21 demonstrates the limits of the most important fit indicator measurements to achieve the best fit model. The main purpose of this table is to assess the output of modelling measurement for SEM which is used in the next stages.

CFA models are created to study and test patterns of the interrelationship between various combinations, measuring each combination in a CFA model is done through a set of measurement items (Teo 2010).

Table 5-21: Goodness of fit indices of SEM

SEM Fit Indices				
Fit Measures	**Name of index**	**Level of Acceptance**	**Comments**	**References**
Chisq	Chi-square	p > 0.05	The value great than 0.05 for good model fit	(Bentler & Bonett 1980); (Hair et al. 2010b)
Chisq/df	Normall Chi-square	< 5.0	The value should be less than 5	(Bollen 1989); (Hair et al. 2010b)
RMSEA	Root Mean Square of Error Approximation	< 0.08	The extent of value should be from 0.05 to 0.1	(Hu & Bentler 1999); (Hair et al. 2010b); (Byrne 2010)
GFI	Goodness of Fit Index	> 0.90	The value greater than 0.9 indicates an agreeable fit and a value greater than 0.95 indicates a satisfactory fit	(Bollen 1989); (Sun 2005); (Hair et al. 2010b) ; (Byrne 2010)
AGFI	Adjusted goodness of fit	> 0.90	The value greater than 0.9 indicates an agreeable fit and a value greater than 0.95 indicates a satisfactory fit	(Bollen 1989); (Sun 2005); (Hair et al. 2010b); (Byrne 2010)
CFI	Comparative Fit Index	> 0.90	The value near 0.95 indicates a satisfactory fit	(Bentler 1990); (Bentler 1992); (Hu & Bentler 1999); (Byrne 2001); (Sun 2005); (Hair et al. 2010b); (Byrne 2010)
TLI	Tuckler-Lewis Index	> 0.90	The value near 0.95 indicates a satisfactory fit	(Hu & Bentler 1999); (Sun 2005); (Hair et al. 2010b); (Byrne 2010)
NFI	Normed Fit Index	> 0.90	The value near 0.95 indicates a satisfactory fit	(Bentler 1990); (Hair et al. 2010b); (Field 2006); (Byrne 2010)
IFI	Incremental Fit Index	> 0.90	The value near 0.95 indicates a satisfactory fit	(Bentler 1990); (Byrne 2001); (Byrne 2010)

In research, the structural equation modelling technique was applied through the Analysis of Moment Structure (AMOS) software (IBM SPSS AMOS 25 Graphics) to achieve the following research objectives.

Objective 2: Inspect the influence of the set of risk-related factors such as sustainability, requirements of stakeholders, communication, procurement strategies and other factors on the performance of infrastructure projects in Australia. In addition, identify the relationships between these factors.

Objective 3: Account for the Risk Performance Index (RPI) resulting from the impact of the set of risk-related factors such as sustainability, stakeholder requirements, communication, procurement strategies and other factors on the performance of infrastructure projects in Australia.

Furthermore, to answer the following research questions which originated based on these objectives.

RQ3: Are these risk-related factors likely to have significant impacts on the performance of infrastructure projects in Australia?

RQ4: What are the significant relationships between these risk-related factors?

RQ5: What is the Risk Performance Index value resulting from the effect of the risk-related factors on the performance of infrastructure projects in Australia?

5.4.4 Testing of the structural model

Accordingly, the conceptual model proposed in this research was converted to a SEM model, as shown in Figure 5.18. This initial model included an analysis of the effect of virtual relations among the sets of risk-related factors (12 factors) and Risk Performance Index.

In this process, the risk-related factor values obtained from the exploratory factor analysis phase were used. In addition, the value of the RPI is $0 \leq RPI \leq 1$ (Babar et al. 2016). This value is estimated depending on the mean of responses of participants in the questionnaire survey. This mean was converted to a value of between 0 and 1 with a simple calculation. This value reflected the performance of infrastructure projects as a result of all the risk-related factors. The value of the RPI reflects a perfect situation of performance when close to 1, while the value of the risk performance index reflects the worst situation of performance when close to 0.

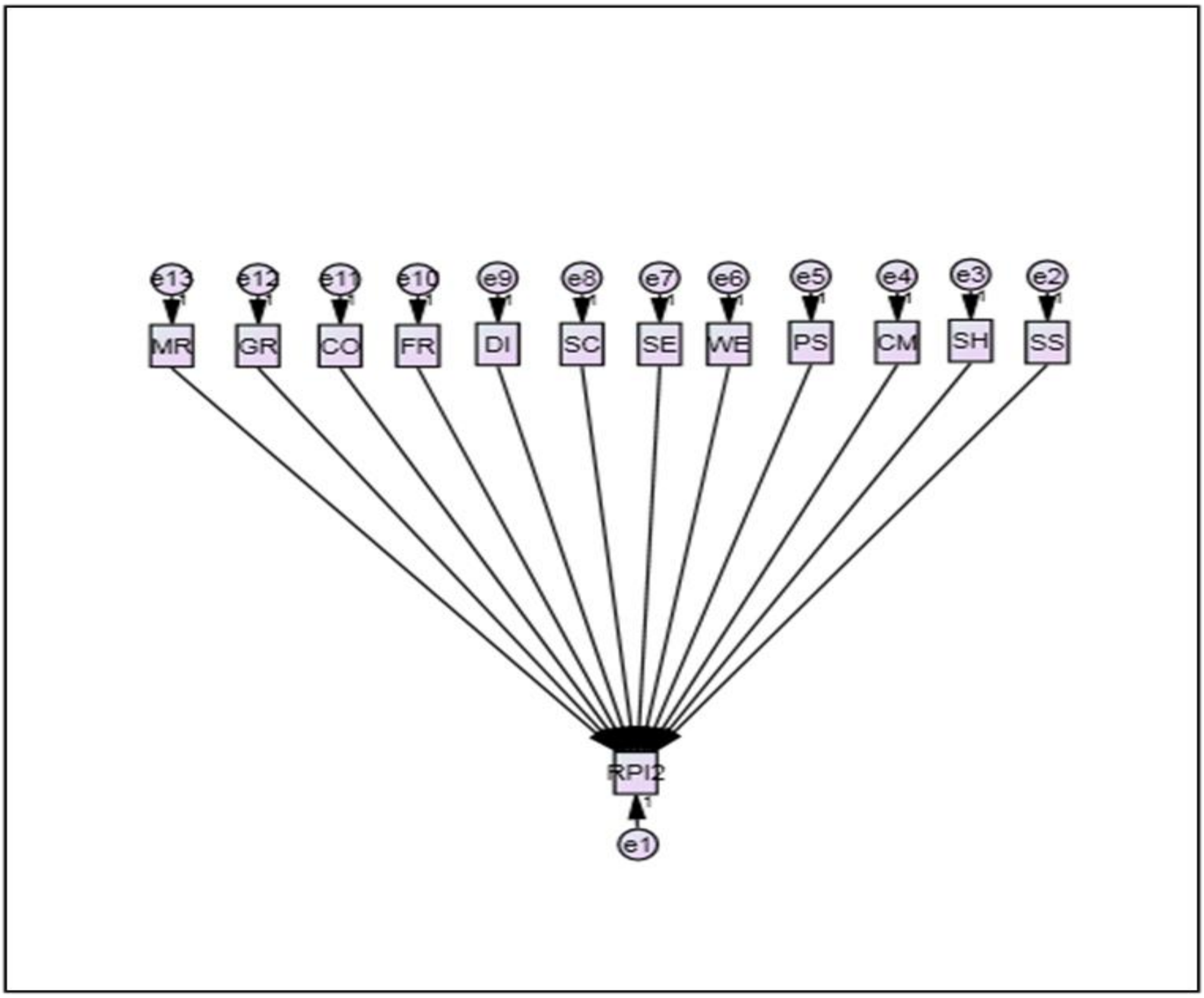


Figure 5-18: The initial conceptual model for analysing the sets of risk-related factors (12 factors) and RPI created using AMOS 25

5.4.4.1 Overall measurement of model fit

The initial model in Figure 5.18 presents the schematic model created by AMOS 25. This figure shows the full initial analysis model. This model is evaluated in terms of quality by relying on the fit indicators measurement in Table 5.21.

For the purpose of testing the efficiency of the model, all relationships are tested. Table 5.22 explain the initial outcomes of the fit measurements of the initial model. The evaluation of these outcomes indicates that the initial model was a poor fit (not suitable). This is because all the measurement indices were less than the level of acceptance. Accordingly, the model was re-evaluated until a highly suitable fit model is reached.

Table 5-22: Fit measurements of the initial model

Initial model measurement indices			
Fit Measures	**Level of Acceptance**	**Initial measurement**	**Evaluate of Acceptance**
Chisq	p > 0.05	342.605	Unacceptable
Chisq/df	< 5.0	5.191	Unacceptable
RMSEA	< 0.08	0.179	Unacceptable
GFI	> 0.90	0.593	Unacceptable
AGFI	> 0.90	0.439	Unacceptable
CFI	> 0.90	0.611	Unacceptable
TLI	> 0.90	0.541	Unacceptable
NFI	> 0.90	0.566	Unacceptable
IFI	> 0.90	0.618	Unacceptable

Based on the outcomes in Table 5.22, the model needed to be re-evaluated by making a number of modifications to obtain the fit measurement of the model.

In this case, the Modification Indices (MI) must be examined. The highest value of (MI) should be sought since this value indicates that the factors which have the highest value of MI are highly correlated or excessively related, and point out that there is a correlation between their errors.

To obtain a fit measurement of the model, this problem is solved by resetting the relationship between their errors. This process was repeated several times and each time the Modification Indices (MI) -were examined. In the 27th repetition, the regression weights table and covariance table did not give any modification indices.

So, this model is best. The outcomes of the fit measurements of this final model are shown in Table 5.23.

Table 5-23: Fit measurements of the final model

Final model Measurement Indices			
Fit Measures	**Level of Acceptance**	**Initial measurement**	**Evaluate of Acceptance**
Chisq	p > 0.05	33.661	Acceptable
Chisq/df	< 5.0	0.910	Acceptable
RMSEA	< 0.08	0.000	Acceptable
GFI	> 0.90	0.962	Acceptable
AGFI	> 0.90	0.908	Acceptable
CFI	> 0.90	1.000	Acceptable
TLI	> 0.90	1.010	Acceptable
NFI	> 0.90	0.957	Acceptable
IFI	> 0.90	1.004	Acceptable

Table 5.24 illustrates the results of the final model and confirms that this model represents a comprehensive measurement model fit. These results correspond with the recommended level of the acceptance: all are good. Furthermore, Figure 5.19 illustrates the final model based on the acceptance indicators shown in Table 5.24. This model is made up of 12 risk related factors and their impact on risk performance index.

Table 5-24: Fit measurements of the final model

Fit Measures	Final measurement	Evaluate of Acceptance
Chisq	33.661	Good
Chisq/df	0.910	Good
RMSEA	0.000	Good
GFI	0.962	Good
AGFI	0.908	Good
CFI	1.000	Good
TLI	1.010	Good
NFI	0.957	Good
IFI	1.004	Good

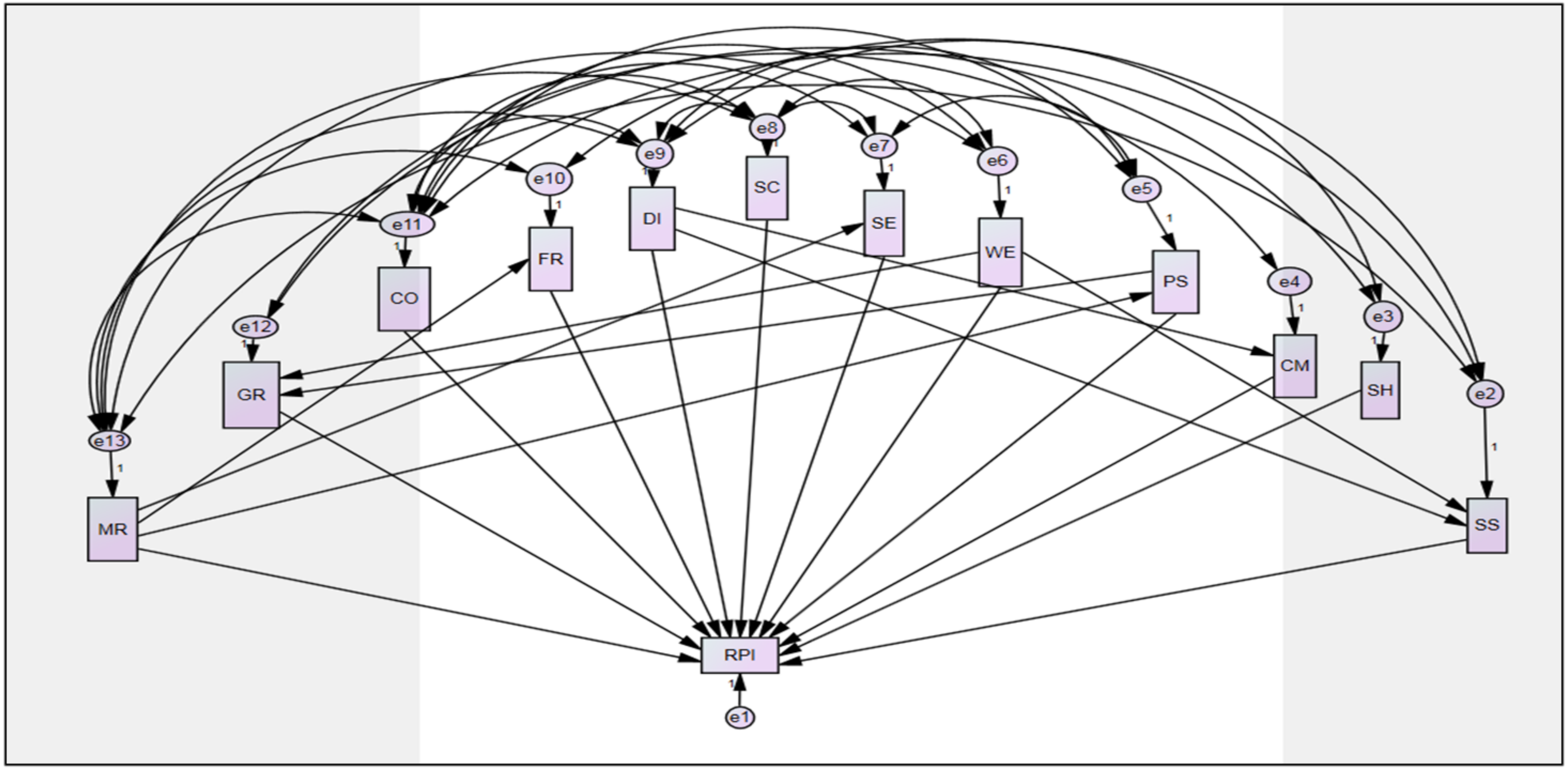


Figure 5-19: The final measurement model

5.4.4.2 Reliability testing

In addition to the Goodness of Fit indices in Table 5.21, Table 5.25 illustrates the Cronbach's alpha for reliability value by IBM SPSS Statistics 24. The value is 0.781. Cronbach's alpha is one of the default choices that reflects overall reliability, with the acceptable level above (0.7) (Field 2013).

Table 5-25: Cronbach's Alpha of the final model

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	No of Items
.781	.781	12

5.4.4.3 Validity testing

In order to arrive at a good fit model which reflects a strong model of testing, the validity is tested. The validity of the proposed model is tested or validated by a Construct Validity test. The Construct Validity test is conducted by assessing the fit measurements of the final model (Netemeyer 2003; Hair et al. 2010b). Table 5.24 presents the fit measurements of the final model; all results have reached good fit measurements, and this gives a proof of constructs validity.

5.5 The Result of the Final Model

Objectives 2 and 3 were developed in the Chapter 1 to investigate the significant influence of the sets of risk-related factors, and to identify the relationships between these factors, and to account for the Risk Performance Index resulting from the impact of the sets of risk-related factors like Sustainability, Stakeholder requirements, Communication, Procurement strategies and other factors on the performance of Australian infrastructure projects. Furthermore, in order to obtain an adequate and sufficient answer to questions RQ3, RQ4 and RQ5 in the Chapter 1, SEM was developed and used to determine the significant level of risk resulting from the set of risk-related factors that impacts on the performance of infrastructure projects and to identify the relationship between these factors. In addition, to calculate the risk performance index value resulting from the effect of the risk-related factors on the performance of infrastructure projects in Australia.

Testing of the final model (Risk Performance Index), which consists of 12 independent risk-related factors and one dependent variable, as is shown in Figure 5.20. Table 5.26 explains the final result of the regression weights of the final model. These results indicate acceptance of 12 factors in the proposed research model; all with a statistically significant at $p < 0.05$ (Field 2006). These factors are (Sustainability (SS), Stakeholders' requirements (SH), Communication (CM), Procurement strategy (PS), Weather (WE), Experience of staff (SE), Site condition (SC), Design issues (DI), Financial risk (FR), Subcontractor (CO), Government requirements authority(GR) and Materials (MR)).These factors are the significant risk-related factors impacting the performance of the infrastructure project in Australia. In addition, Figure 5.20 and Table 5.26 illustrate some of the relationships between the risk-related factors.

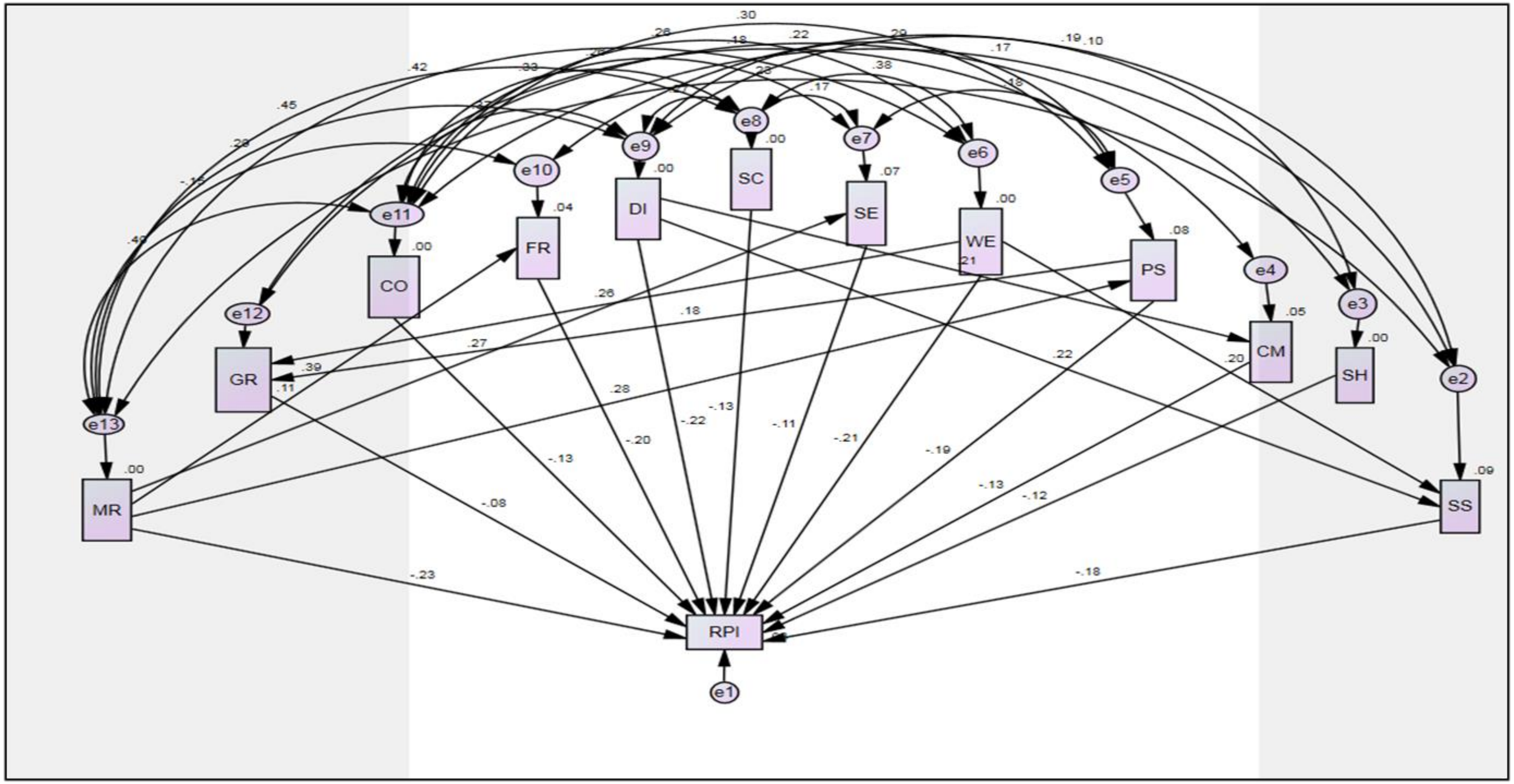


Figure 5-20: The standardized final measurement model

Table 5-26: Regression weights of the final model

Path			**Beta Value Estimate**	**Standard Error (S.E.)**	**Critical Ratio (C.R.)**	***p***
PS	<---	**MR**	.285	.084	3.389	***
GR	<---	**WE**	.252	.078	3.208	.001
FR	<---	**MR**	.398	.135	2.942	.003
SE	<---	**MR**	.274	.086	3.190	.001
SS	<---	**DI**	.216	.083	2.604	.009
CM	<---	**DI**	.214	.085	2.522	.012
GR	<---	**PS**	.177	.080	2.223	.026
SS	<---	**WE**	.197	.082	2.391	.017
RPI	<---	**SS**	-.012	.001	-9.087	***
RPI	<---	**SH**	-.008	.001	-6.687	***
RPI	<---	**CM**	-.008	.001	-6.813	***
RPI	<---	**PS**	-.013	.001	-9.245	***
RPI	<---	**WE**	-.014	.001	-10.054	***
RPI	<---	**SE**	-.007	.001	-5.450	***
RPI	<---	**SC**	-.009	.001	-6.158	***
RPI	<---	**DI**	-.015	.001	-10.034	***
RPI	<---	**FR**	-.013	.001	-10.830	***
RPI	<---	**CO**	-.009	.002	-5.601	***
RPI	<---	**GR**	-.005	.001	-4.067	***
RPI	<---	**MR**	-.016	.002	-9.774	***

*** Statistical probability < 0.000

5.5.1 The relationships between risk-related factors

To achieve Objective 2, Question 4 must be answered by analysing the results of the structural equation modelling that helps investigate the significant relationships between the risk-related factors. SEM has the ability to test and interpret relationships between constructs. Table 5.26 illustrates the outputs of SEM regarding the relationship between the risk-related factors. This table illustrates the estimated beta coefficient value (β) and the critical ratio (C.R.) with standard error (S.E.). As shown in this table, all C.R. values are greater than ±2.223 >±1.96 (Byrne 2010), and all values are of statistical significance (*p*) less than 0.05 (Byrne 2001, 2010). These outputs were resorted to define the significant path coefficient between variables (Byrne 2010). The results of the examination of all the relationship between the risk-related factors are explained as follows:

1. **The relationship between Materials (MR) and Procurement strategy (PS)**

As shown in Table 5.27, when Material (MR) increases by 1 unit, the Procurement strategy (PS) prophesy to increase 0.285 unit. The regression weight estimates 0.285, with a standard error (S.E.) 0.084. The probability of getting a critical ratio 3.389 greater than ±1.98 is less than 0.000. In other words, Materials (MR) has a highly significant impact on Procurement strategy (PS) $p < 0.000$.

2. **The relationship between Weather (WE) and Government requirements authority (GR)**

   As shown in Table 5.27, when Weather (WE) increases by 1 unit, the Government requirements authority (GR) prophesy to increase 0.252 unit. The regression weight estimates 0.252, with a standard error (S.E.) 0.078. The probability of getting a critical ratio of 3.208 greater than ±1.98 is less than 0.001. In other words, Weather (WE) has a significant impact on Government requirements authority (GR) $p < 0.05$.

3. **The relationship between Materials (MR) and Financial risk (FR)**

   As shown in Table 5.27, when Material (MR) increases by 1 unit, the Financial risk (FR) prophesy to increase 0.398 unit. The regression weight estimates 0.398, with a standard error (S.E.) 0.135. The probability of getting a critical ratio of 2.942 greater than ±1.98 is less than 0.003. In other words, Materials (MR) has a significant impact on Financial risk (FR) $p < 0.05$.

4. **The relationship between Materials (MR) and Experience of staff (SE)**

   As shown in Table 5.27, when Material (MR) increases by 1 unit, the Experience of staff (SE) prophesy to increase 0.274 unit. The regression weight estimates 0.274, with a standard error (S.E.) 0.086. The probability of getting a critical ratio of 3.190 greater than ±1.98 is less than 0.001. In other words, Materials (MR) has a significant impact on the Experience of staff (SE) $p < 0.05$.

5. **The relationship between Design issues (DI) and Sustainability (SS)**
   As shown in Table 5.27, when Design issues (DI) increases by 1 unit, the Sustainability (SS) prophesy to increase 0.216 unit. The regression weight estimates 0.216, with a standard error (S.E.) 0.083. The probability of getting a critical ratio of 2.604 greater than ±1.98 is less than 0.009. In other words, Design issues have a significant impact on Sustainability (SS) $p < 0.05$.

6. **The relationship between Design issues (DI) and Communication (CM)**
   As shown in Table 5.27, when Design issues (DI) increases by 1 unit, the Communication (CM) prophesy to increase 0.214 unit. The regression weight estimates 0.214, with a standard error (S.E.) 0.085. The probability of getting a critical ratio of 2.522 greater than ±1.98 is less than 0.012. In other words, Design issues (DI) has a significant impact on Communication (CM) $p < 0.05$.

7. **The relationship between Procurement strategy (PS) and Government requirements authority (GR)**
   As shown in Table 5.27, when Procurement strategy (PS) increases by 1 unit, the Government requirements authority (GR) prophesy to increase 0.177 unit. The regression weight estimates 0.177, with a standard error (S.E.) .080. The probability of getting a critical ratio of 2.223 greater than ±1.98 is less than .026. In other words, Procurement strategy (PS) has a significant impact on Government requirements authority (GR) $p < 0.05$.

8. **The relationship between Weather (WE) and Sustainability (SS)**
   As shown in Table 5.27, when Weather (WE) increases by 1 unit, the Sustainability (SS) prophesy to increase 0.197 unit. The regression weight estimates 0.197, with a standard error (S.E.) 0.82. The probability of getting a critical ratio 2.391 greater than ±1.98 is less than 0.017. In other words, Weather (WE) has a significant impact on Sustainability (SS) $p < 0.05$.

Table 5-27: Regression weights of the final model between the risk-related factors

Path			Beta Value Estimate	Standard Error (S.E.)	Critical Ratio (C.R.)	*p*
PS	<---	**MR**	.285	.084	3.389	***
GR	<---	**WE**	.252	.078	3.208	.001
FR	<---	**MR**	.398	.135	2.942	.003
SE	<---	**MR**	.274	.086	3.190	.001
SS	<---	**DI**	.216	.083	2.604	.009
CM	<---	**DI**	.214	.085	2.522	.012
GR	<---	**PS**	.177	.080	2.223	.026
SS	<---	**WE**	.197	.082	2.391	.017

*** Statistical probability < 0.000

5.5.2 Level of influence of risk-related factors on projects performance

To achieve Objective 2, Question RQ3 must be answered by analysing the results of the SEM that helps test hypotheses. Structural equation modelling has the ability to test and interpret relationships between constructs. Table 5.28 illustrates the outputs of SEM for the research hypotheses. This table illustrates the estimated beta coefficient value (β) and the critical ratio (C.R.) with standard error (S.E.). In addition, for testing the hypotheses, the value of statistically significant (*p*) was evaluated. As shown in this table, all C.R. values are greater than -4.067 which is greatsr than ±1.96 (Byrne 2010), and all values of statistically significant (*p*) are less than 0.05 (Byrne 2001, 2010). These outputs are resorted to define the significant path coefficient between the dependent and independent variable (Byrne 2010). The results of the examination of all the hypotheses are explained as follows:

Hypothesis 1: Sustainability is likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

Table 5.28 illustrates that the estimated beta coefficient value (β) was -0.012 and the critical ratio (C.R.) was -9.087 > ±1.96 (Byrne 2010) with standard error (S.E.) 0.001. In addition, the value of statistically significant (*p*) was highly significant 0.000<0.01. These outputs of regression weights prove that Sustainability (SS) has a highly significant risk that impacts the performance of infrastructure projects. This suggests that the research result confirms acceptance of Hypothesis 1.

Hypothesis 2: Stakeholders' requirements are likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

Table 5.28 illustrates that the estimated beta coefficient value (β) was -0.008 and the critical ratio (C.R.) was -6.687 > ±1.96 (Byrne 2010) with standard error (S.E.) 0.001. In addition, the value of statistically significant (*p*) was highly significant 0.000<0.01. These outputs of regression weights prove that Stakeholders' requirements (SH) has a highly significant risk that impacts the performance of infrastructure projects. This suggests that the research result confirms acceptance of Hypothesis 2.

Hypothesis 3: Communications are likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

Table 5.28 illustrates that the estimated beta coefficient value (β) was -0.008 and the critical ratio (C.R.) was -6.813 >±1.96 (Byrne 2010) with standard error (S.E.) 0.001. In addition, the value of statistically significant (*p*) was highly significant 0.000<0.01. These outputs of regression weights prove that Communications (CM) has a highly significant risk that impacts the performance of infrastructure projects. This suggests that the research result confirms acceptance of Hypothesis 3.

Hypothesis 4: Procurement strategy is likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

Table 5.28 illustrates that the estimated beta coefficient value (β) was -0.013 and the critical ratio (C.R.) was -9.245 >±1.96 (Byrne 2010) with standard error (S.E.) 0.001. In addition, the value of statistically significant (*p*) was highly significant 0.000<0.01. These outputs of regression weights prove that Procurement strategy (PS) has a highly significant risk that impacts the performance of infrastructure projects. This suggests that the research result confirms acceptance of Hypothesis 4.

Hypothesis 5: Weather is likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

Table 5.28 illustrates that the estimated beta coefficient value (β) was -0.014 and the critical ratio (C.R.) was -10.054 >±1.96 (Byrne 2010) with standard error (S.E.) .001. In addition, the value of statistically significant (*p*) was highly significant 0.000<0.01. These outputs of regression weights prove that Weather (WE) have a highly significant risk that impacts the performance of infrastructure projects. This suggests that the research result confirms acceptance of Hypothesis 5.

Hypothesis 6: Experience of staff is likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

Table 5.28 illustrates that the estimated beta coefficient value (β) was -0.007 and the critical ratio (C.R.) was -5.450 >±1.96 (Byrne 2010) with standard error (S.E.) 0.001. In addition, the value of statistically significant (*p*) was highly significant 0.000<0.01. These outputs of regression weights prove that Experience of staff (SE) have a highly significant risk that impacts the performance of infrastructure projects. This suggests that the research result confirms acceptance of Hypothesis 6.

Hypothesis 7: Site conditions are likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

Table 5.28 illustrates that the estimated beta coefficient value (β) was -0.009 and the critical ratio (C.R.) was -6.158 >±1.96 (Byrne 2010) with standard error (S.E.) 0.001. In addition, the value of statistically significant (*p*) was highly significant 0.000<0.01. These outputs of regression weights prove that Site conditions (SC) has a highly significant risk that impacts the performance of infrastructure projects. This suggests that the research result confirms acceptance of Hypothesis 7.

Hypothesis 8: Design issues is likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

Table 5.28 illustrates that the estimated beta coefficient value (β) was -0.015 and the critical ratio (C.R.) was -10.034 >±1.96 (Byrne 2010) with standard error (S.E.) 0.001. In addition, the value of statistically significant (*p*) was highly significant

0.000<0.01. These outputs of regression weights prove that Design issues (DI) has a highly significant risk that impacts the performance of infrastructure projects. This suggests that the research result confirms acceptance of Hypothesis 8.

Hypothesis 9: Financial risk is likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

Table 5.28 illustrates that the estimated beta coefficient value (β) was -0.013 and the critical ratio (C.R.) was -10.830 >±1.96 (Byrne 2010) with standard error (S.E.) 0.001. In addition, the value of statistically significant (*p*) was highly significant 0.000<0.01. These outputs of regression weights prove that Financial risk (FR) has a highly significant risk that impacts the performance of infrastructure projects. This suggests that the research result confirms acceptance of Hypothesis 9.

Hypothesis 10: Subcontractors are likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

Table 5.28 illustrates that the estimated beta coefficient value (β) was -0.009 and the critical ratio (C.R.) was -5.601 >±1.96 (Byrne 2010) with standard error (S.E.) 0.002. In addition, the value of statistically significant (*p*) was highly significant 0.000<0.01. These outputs of regression weights prove that Subcontractors (CO) has a highly significant risk that impacts the performance of infrastructure projects. This suggests that the research result confirms acceptance of Hypothesis 10.

Hypothesis 11: Government requirements are likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

Table 5.28 illustrates that the estimated beta coefficient value (β) was -0.005 and the critical ratio (C.R.) was -4.067 >±1.96 (Byrne 2010) with standard error (S.E.) 0.001. In addition, the value of statistically significant (*p*) was highly significant 0.000<0.01. These outputs of regression weights prove that Government requirements (GR) has a highly significant risk that impacts the performance of infrastructure projects. This suggests that the research result confirms acceptance of Hypothesis 11.

Hypothesis 12: Materials are likely to have a significant risk that impacts the performance of infrastructure projects in Australia.

Table 5.28 illustrates that the estimated beta coefficient value (β) was -0.016 and the critical ratio (C.R.) was -9.774 >±1.96 (Byrne 2010) with standard error (S.E.) 0.002. In addition, the value of statistically significant (*p*) was highly significant 0.000<0.01. These outputs of regression weights prove that Materials (MR) has a highly significant risk that impacts the performance of infrastructure projects. This suggests that the research result confirms acceptance of Hypothesis 12.

Table 5-28: The outputs of SEM for research hypotheses

Hypotheses	Path			Beta value Estimate	Standard error (S.E.)	Critical ratio (C.R.)	*p*	Decision on hypotheses
H1: Sustainability is likely to have a significant risk that impacts the performance of infrastructure projects in Australia.	RPI	<---	SS	-.012	.001	-9.087	***	Acceptable
H2: Stakeholders' requirements are likely to have a significant risk that impacts the performance of infrastructure projects in Australia.	RPI	<---	SH	-.008	.001	-6.687	***	Acceptable
H3: Communications are likely to have a significant risk that impacts the performance of infrastructure projects in Australia.	RPI	<---	CM	-.008	.001	-6.813	***	Acceptable
H4: Procurement strategy is likely to have a significant risk that impacts the performance of infrastructure projects in Australia.	RPI	<---	PS	-.013	.001	-9.245	***	Acceptable
H5: Weather is likely to have a significant risk that impacts the performance of infrastructure projects in Australia.	RPI	<---	WE	-.014	.001	-10.054	***	Acceptable
H6: Experience of staff is likely to have a significant risk that impacts the performance of infrastructure projects in Australia.	RPI	<---	SE	-.007	.001	-5.450	***	Acceptable
H7: Site conditions are likely to have a significant risk that impacts the performance of infrastructure projects in Australia.	RPI	<---	SC	-.009	.001	-6.158	***	Acceptable
H8: Design issues is likely to have a significant risk that impacts the performance of infrastructure projects in Australia.	RPI	<---	DI	-.015	.001	-10.034	***	Acceptable
H9: Financial risk is likely to have a significant risk that impacts the performance of infrastructure projects in Australia.	RPI	<---	FR	-.013	.001	-10.830	***	Acceptable
H10: Subcontractors are likely to have a significant risk that impacts the performance of infrastructure projects in Australia.	RPI	<---	CO	-.009	.002	-5.601	***	Acceptable
H11: Government requirements are likely to have a significant risk that impacts the performance of infrastructure projects in Australia.	RPI	<---	GR	-.005	.001	-4.067	***	Acceptable
H12: Materials are likely to have a significant risk that impacts the performance of infrastructure projects in Australia.	RPI	<---	MR	-.016	.002	-9.774	***	Acceptable

5.5.3 The value of Risk Performance Index

To achieve the Objective 3, Question RQ5 must be answered by testing the final model of SEM, which consists of 12 independent risk-related factors and one dependent variable (RPI) as shown in Figure 5.20. The results of structural equation modelling evaluate the squared multiple correlations (R^2). Table 5.29 illustrates the squared multiple correlations (R^2), the maximum value of (R^2) is 0. 959, that means this model estimated the variation in RPI due to the impact of the set of risk-related factors is 95.9%. This value will be used in the next stage to modify the EVM.

Table 5-29: Squared Multiple Correlations (R^2)

Constructs	Estimate
MR	.000
DI	.000
WE	.000
PS	.079
SC	.000
CM	.045
GR	.107
CO	.000
FR	.039
SE	.072
SH	.000
SS	.086
RPI	.959

5.6 Chapter Summary

This chapter described the procedures for collecting the quantitative data, testing the questionnaire survey with the pilot study and modifying the questionnaire according to the results of the study, and distribution of the questionnaire survey to the target sample by e-mail. This chapter also showed procedures for analysing the quantitative survey outputs, and demonstrated the results of risk-related factor analysis using the factor analysis technique (FA). In order to answer the research questions, the structural equation modelling (SEM) technique was used to analyse the research model. The model analysis outputs were also described to obtain the impact value of the risk-related factors on the performance of infrastructure projects in Australia. This value will be used in the next chapter to modify the concept of EVM.

6 CHAPTER SIX: - MODIFIED EARNED VALUE MANAGEMENT CONCEPT

6.1 Introduction

This chapter addresses the EVM concept as a technique to assess the performance of infrastructure projects in Australia. This chapter discusses two issues. The first is to assess the extent to which the concept of EVM is used in Australia. The second is to modify the concept of EVM based on the effect of the risk-related factors obtained, and the calculation of their effect in the previous stages of research. Finally, the revised concept is validated through an application to historical data from previously implemented projects.

6.2 The extent of EVM Use in Australian Infrastructure Projects

This section will discuss the second part of the questionnaire survey. The second part of the questionnaire survey is about EVM and consists of two questions (see Appendix B4). The first question was "Is the EVM concept is likely to use widely in infrastructure projects in Australia?". To answer this question, the Likert scale was used with a five-point range starting from (1) Strongly disagree and ending with (5) Strongly agree. The second question was an open question to determine the reasons for choosing the answer to the first question. In other words, by answering this question, the reasons for the widespread use, or not, of the Earned Value Management (EVM) concept in Australia are identified. In this section, the first part (demographic data) and the second part (EVM) of the questionnaire will be analysed.

6.2.1 Sample

The final version of the questionnaire was sent to the target sample. The target sample was drawn from the Australian infrastructure industry. The target sample was individuals, companies and institutions with expertise in infrastructure projects in Australia. The sample was divided into three sections. Section one was local councils in Australia (public sector). The Australian Local Government Association (ALGA) (2017) report that there are more than 537 local councils across the Australia. Section two is specialized companies, institutions and organizations in infrastructure projects in Australia (private sector). Section three is individuals working in infrastructure projects (public sector - private sector - mixed sector). A Google search was used to obtain the names and email addresses of these local councils and specialized companies, institutions and organizations for the purpose of sending the questionnaire to them. LinkedIn was used to contact individuals employed in infrastructure projects. During the period from February to September 2018, approximately 500 questionnaires were distributed. The number of responses received was 304 and 194 were suitable for analysis. Accordingly, the response rate was 39% and this ratio is satisfactory according to Baruch (1999) and Baruch and Holtom (2008).

6.2.2 Analysis of demographic data results

This section discusses the results of the analysis of the participants' demographic data. Seven questions were asked: years of experience in infrastructure projects, the highest education degree completed, the state (territory) in which currently working, the roles performed during the years of work in infrastructure projects, the types of infrastructure projects, sector of infrastructure projects and the category of organization.

These answers are important because they reflect the extent of infrastructure projects captured by the research, the roles of participants and the years of experience of participants. Having these details is necessary for the researcher who must be able to confirm the strength and truthfulness of the data obtained.

6.2.2.1 Years of experience in Australian infrastructure projects

Table 6.1 illustrates the participant's years of experience in Australian infrastructure projects. The table shows that slightly more than a quarter of the sample has experience of 0-10 years (57 participants at 29.4%). This is followed by 11-15 years for 39 respondents (20.1%).Twenty-four respondents (12.4%) had 16-20 years' experience, while 13.9% (27 respondents) had experience of 21-25 years. Twenty respondents (10.3%) reported 26-30 years and 27 respondents (13.9%) had over 30 years' experience. The total result demonstrates that 137 respondents (69.5%) have more than 10 years' experience with Australian infrastructure projects. This is considered good experience for this research.

Table 6-1: Years of experience in infrastructure projects

Years of experience you have in infrastructure construction projects						
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0-10	57	29.4	29.4	29.4
	11-15	39	20.1	20.1	49.5
	16-20	24	12.4	12.4	61.9
	21-25	27	13.9	13.9	75.8
	26-30	20	10.3	10.3	86.1
	>30	27	13.9	13.9	100.0
	Total	194	100.0	100.0	

6.2.2.2 Highest education degree completed

Table 6.2 illustrates the highest education degree completed by participants in this survey. The table shows that 27 participants have a Diploma (13.9%). Ninety-four respondents (48.5%) completed a Bachelor degree. Master's degree is held by 57 participants (29.4%) and 9 (4.6%) have a Doctorate degree. Finally, 7 respondents (3.6%) have another certificate such as Chartered Professional Engineer, Post Graduate Diploma, Postgraduate Certificate, Graduate Diploma, Advanced Diploma or Graduate Certificate. The total result demonstrates that most of the respondents (160 at 82.4%) have degrees ranging from Bachelor to Doctorate. This sample can be said to have a good educational achievement.

Table 6-2: Highest education degree completed

Highest degree you have completed					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Diploma	27	13.9	13.9	13.9
	Bachelor degree	94	48.5	48.5	62.4
	Master degree	57	29.4	29.4	91.8
	Doctorate	9	4.6	4.6	96.4
	Other Certificate	7	3.6	3.6	100.0
	Total	194	100.0	100.0	

6.2.2.3 State (territory) in Australia

As shown in Table 6.3, participants were located across the states and territories of Australia. The table demonstrates that 23 participants (11.9%) were working in Western Australia at the time of the survey. One participant (0.5%) was working in the Northern territory, and eight participants (4.1%) were working in South Australia. The largest proportion of respondents were currently working in Queensland (84 participants at 43.3%). Thirty-two participants (16.5%) were working in New South Wales and seven (3.6%) in the Australian Capital Territory (ACT). Thirty-two participants were working in Victoria at the time of the survey (16.5%) and seven (3.6%) were working in Tasmania. The total result demonstrates that the participants in this questionnaire were distributed across all states and territories, with the greatest number in Queensland. This was because the 2018 Commonwealth budget allocated AUD 4 billion to develop and expand Queensland's highways network (Australian Government 2018).

Table 6-3: State/Territory in which participants currently working

State (Territory)					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Western Australia	23	11.9	11.9	11.9
	Northern Territory	1	.5	.5	12.4
	South Australia	8	4.1	4.1	16.5
	Queensland	84	43.3	43.3	59.8
	New South Wales	32	16.5	16.5	76.3
	Australian Capital Territory	7	3.6	3.6	79.9
	Victoria	32	16.5	16.5	96.4
	Tasmania	7	3.6	3.6	100.0
	Total	194	100.0	100.0	

6.2.2.4 Roles of participants in infrastructure projects

Table 6.4 and Figure 6.1 illustrate the roles of participants in infrastructure projects during the years of their experience. The table and figure demonstrate that most participants, 16% to 60% percent, worked in most roles: site engineer, senior project manager, project manager, design engineer, senior engineer, operation manager and construction engineer. This indicates that the participants have experience in many areas of engineering, construction and project management.

Table 6-4: Roles of participants in infrastructure projects

Roles	Frequency	Percent
Site engineer	92	47 %
Senior project manager	66	34 %
Project manager	116	60 %
Design engineer	80	41 %
Senior engineer	60	31 %
Operation manager	31	16 %
Construction engineer	59	30 %

Planning engineer	31	16 %
Estimate engineer	35	18 %
Management engineer	53	27 %

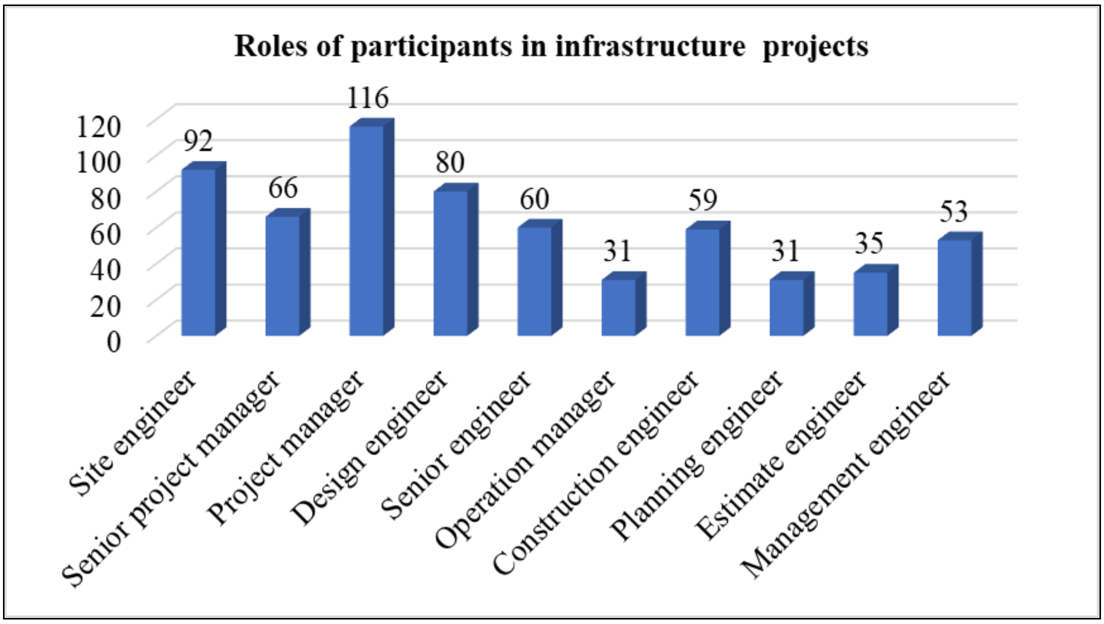


Figure 6-1:Roles of participants in infrastructure projects

6.2.2.5 Types of projects that participants involved in

Table 6.5 and Figure 6.2 illustrate the types of projects that participants have been involved in throughout their years of experience. The table and figure demonstrate that 81% of participants worked in roads projects, and 50% and 49% of participants had worked in bridges projects and infrastructure maintenance projects respectively. Moreover, 5%-49% had worked in most infrastructure projects, such as tunnels, airports, railroads, dams, harbours, water supply and wastewater. This indicates that the participants have experience in most types of infrastructure projects in Australia.

Table 6-5: Types of projects

Types of projects	Frequency	Percent
Roads	158	81%
Tunnels	29	15%
Bridges	97	50%
Airports	27	14%
Railroads	36	19%
Dams	22	11%
Infrastructure maintenance	96	49%
Harbours	10	5%
Water Supply	68	35%
Wastewater	60	31%
Other	40	21%

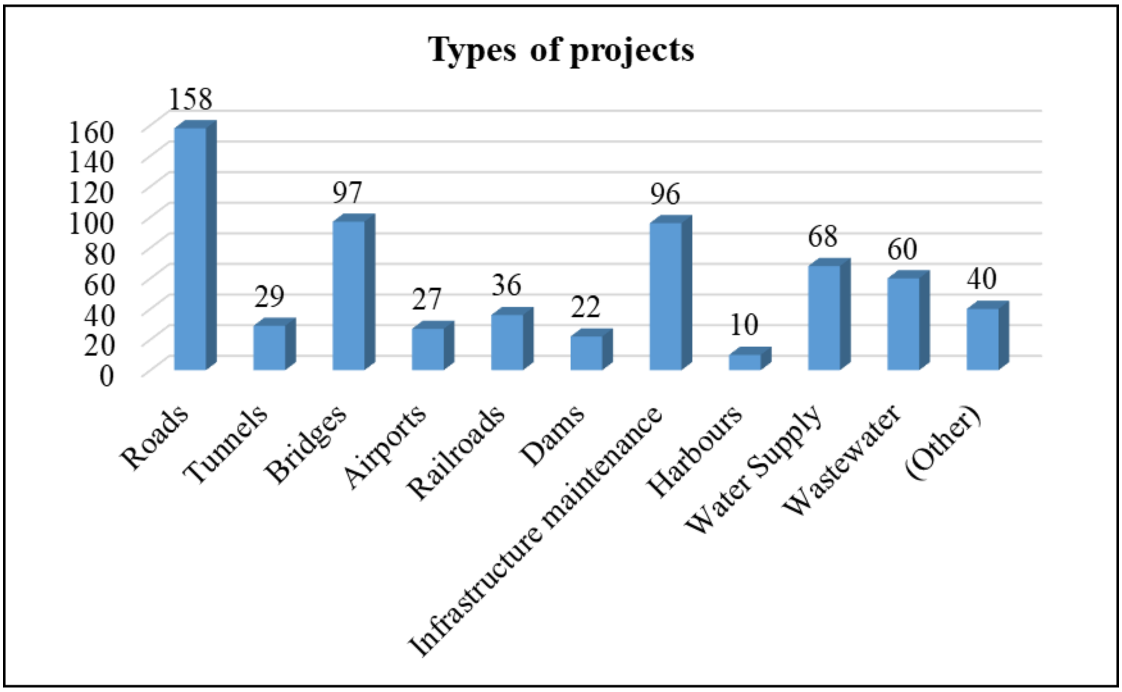


Figure 6-2: Types of projects

6.2.2.6 The sector in infrastructure projects

Table 6.6 shows the sector to which the participants belong. The table shows that 116 participants (59.8%) worked in the public sector. Followed by 61 (31.4%) who worked in the private sector. Finally, 16 (8.2%) worked in the mixed (Quasi-government sectors). This indicates that most of the participants (more than 60%) in have experience in public infrastructure projects in Australia. These are usually high budget and represent a diversity in types of infrastructure projects. This allows the sample to give a clear impression of infrastructure projects in Australia.

Table 6-6: Sector of infrastructure projects

The sector of infrastructure projects						
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Public sector	116	59.8	60.1	60.1
	Private sector	61	31.4	31.6	91.7
	Mixed sector (quasi-government sectors)	16	8.2	8.3	100.0
	Total	193	99.5	100.0	
Total		194	100.0		

6.2.2.7 The category of the organization

Table 6.7 shows the distribution of the sample by categories depending on the type of organization. The table explains that 62 participants (32%) worked as a client representative. Thirty-eight respondents (19.6%) worked as a consultant. Forty four (22.7%) worked as a contractor. Finally, 50 (25.8%) worked in other organizations such as local government representative, supplier, utility owner and manufacturer. The total result demonstrates that the sample covered all types of organizations operating in infrastructure projects in Australia, and in similar proportions.

Table 6-7: The category of the organization

The category of your current organization					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Client representative	62	32.0	32.0	32.0
	Consultant	38	19.6	19.6	51.5
	Contractor	44	22.7	22.7	74.2
	Others	50	25.8	25.8	100.0
	Total	194	100.0	100.0	

6.2.3 Analysis of EVM in Australian infrastructure projects

In this section, the answers of two questions will be analysed. The first question is about the use of EVM in Australia. The question is: EVM concept is likely to use widely in infrastructure projects in Australia?. Table 6.8 and Figure 6.3 illustrate that 3 respondents disagree and 32 respondents strongly disagree that the concept of EVM is widely used in Australia. Thus, it is possible to say that 18% of respondents disagreed or strongly disagreed with the first question. Sixty-five respondents agreed and 4 respondents strongly agreed that EVM is widely used in Australia. Thus, it is possible to say that 55.6 % of the respondents agreed or strongly agreed with the first question. Furthermore, 90 participants (46.6%) were neutral. Accordingly, the percentage of those who agree and strongly agree is higher than the percentage of those who disagree and strongly disagree.

Table 6-8: Use of EVM in Australia

EVM concept is likely to use widely in infrastructure projects in Australia					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly disagree	3	1.5	1.5	1.5
	Disagree	32	16.5	16.5	18.0

	Undecided (Neutral)	90	46.4	46.4	64.4
	Agree	65	33.5	33.5	97.9
	Strongly agree	4	2.1	2.1	100.0
	Total	194	100.0	100.0	

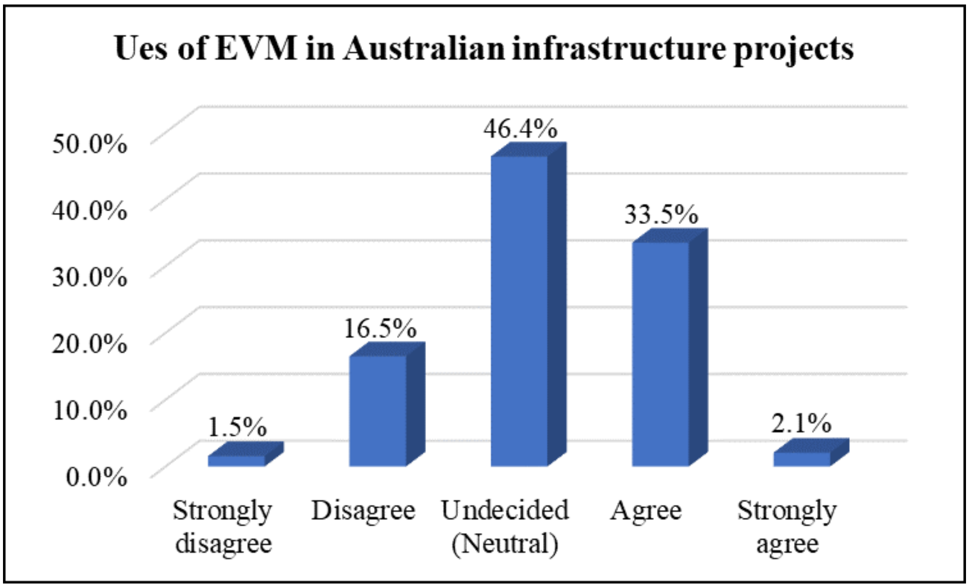


Figure 6-3: Use of EVM in Australia

The second question asks: Why do you think this is the case? This question explains the reasons for choosing the answer regarding the use of the concept of EVM in Australia.

The reasons for disagreement and strong disagreement were:

1. Small local government bodies do not use EVM. Many employers on local government projects had not heard of this concept because local government works to fixed budgets on a yearly basis
2. EVM is used in major new projects such as highways, tunnels and bridges, which cost more than AUD 10 million. Most government projects are focusing on renewing existing infrastructure or minor upgrades EVM is not justified for projects that are AUD 0.5 to less than AUD1 million. Small

budget projects just review monthly expenditure against the total project budget, to understand if the project is on track from a financial perspective. Therefore, the use of EVM or not depends largely on the size and cost of the project

3. In Australia, many people in government organization do not understand the application of EVM due to: lack of awareness of EVM principles, the experience of the team and the maturity of the organization , immature organizations not using the available tools, EVM not properly used, concept not well known and widely misunderstood. In addition, Australia lacks a long-term vision for infrastructure issues. Accordingly, further training and marketing for this concept are required

The reasons that people agreed and strongly agreed were:

1. The features and benefits of the EVM, such as lower margins and the control of cost variation, encourage it's use
2. EVM helps project managers understand the project site and ensure that funding is sufficient to complete the project
3. The sophistication of EVM helps the progress of project implementation significantly
4. EVM is a simple tool that can easily be employed to help track project status and variability against any project baseline
5. With increasing competition in project delivery and the need to improve on customer outcomes, EVM gives clients and their communities greater outcomes
6. Local Councils that complete infrastructure projects with external grant funding are becoming more accountable, in particular where project expenditure exceeds their initial cost estimates. EVM (and similar concepts) are used to carefully monitor the project and identify design/reporting errors which may require the project to be terminated or request of additional funds to see completion. In addition, local government is becoming more aware of and accountable, for its spending. Increases in labour costs also means that

project costs have risen and therefore, the value proposition of infrastructure works must always be considered

7. EVM is a valuable resource and is used extensively by Tier 1 and Tier 2 contractors
8. EVM helps spend public funds more efficiently
9. EVM assists the monitoring and controlling of projects, and so predict the final results of the project. It is a better way to measure works completed and project estimated final cost. It also provides for continuous improvement, quality outcomes and achieving value for money outcomes
10. EVM is codified in Australia as standard AS 4817-2006 (Project performance measurement using Earned Value)
11. EVM provides for innovation & arising issues
12. Continual analysis and review of variables are beneficial in projections of project performance, estimations of variations and predicting out-of-scope items that may be encountered
13. EVM is a widely used on mega projects in Australia. It has been accepted by Standards Australia and has been documented through AS 4817-2006. It may be irrelevant on smaller residential projects, due to the absence of standard platform (viz. business analytics system) to compare schedule vs budget on a real-time basis (against actual status). Various apps and online software are available to synchronize actual completion versus planned, but most fail to link the cost component
14. EVM helps predict the worst and best case that may occur during construction
15. EVM helps control unidentified cost and time overruns caused by poor progress assessment and forecasting processes
16. EVM justifies the value for money in building infrastructure, especially in the public sector.

The summaries of the reasons to answer Undecided (Neutral) are following:

1. The use of the acquired value management concept depends on the size and type of the project. It is used in larger, more complex and more technical high-level projects. In addition, this concept is employed at higher management levels. These requirements are not available in all organizations and companies
2. Most of the participants answering this question have no experience in this concept or do not have much information or knowledge about it. They have not heard about this concept. In addition, they are not accustomed to it, or have limited interest.

Accordingly, the results of the questionnaire are in line with the statement that EVM is widely used in infrastructure projects (Fleming & Koppelman 2003; Mohammed et al. 2015; Mubarak 2015). However, this use is limited by a number of parameters such as the size of the project, as it is used in larger projects rather than in small projects, as well as in more complex projects. Furthermore, it tends to be used at high levels of the organization or company.

Although EVM is easy to use, makes project financing easy to understand, allows the monitoring and control of project cost, etc, there is a need for increased awareness for those involved in controlling the performance of infrastructure projects to increase their understanding of concept further by increasing their experience, information and knowledge

6.2.4 Modified EVM in Australian infrastructure projects

EVM plays a key and effective role in monitoring project performance by clearly measuring the actual performance deviation from planned performance in terms of traditional elements (time and cost) (Colin & Vanhoucke 2014). Project assessment EVM concentrates on the traditional elements (cost and time), only without taking into account the impact of many factors (Babar et al. 2016). There is a need to establish and develop a comprehensive concept for the assessment and measurement of project performance that expands the focus on traditional elements and adds to the influence of other factors (Eccles & Pyburn 1992). To achieve the Objective 4

(Develop a new performance evaluation system using a modified concept of EVM that enhances the forecasting accuracy of the project estimate, and accomplished by considering risk-related factors such as sustainability, stakeholder requirements, communication, procurement strategies and other factors.) and to answer the question (RQ6) (How can EVM be modified to enhance the forecasting accuracy of the project estimate through the consideration of risk-related factors, such as sustainability, stakeholder requirements, communication, procurement strategies and other factors?), the effect of risk-related factors must be taken into account. A new index has been presented, the RPI to measure the impact of risk-related factors on infrastructure project performance. The value of the RPI is obtained from the maximum of squared multiple correlations (R^2). This value reflects the variation in RPI due to the set of risk-related factors. The value of RPI was calculated in Chapter Five, Section 5.5.3. The maximum value of (R^2) is 0. 959. This means that the structural equation modelling model estimated the variance in the risk performance index as a dependent variable due to the set of 12 independent risk-related factors is 95.9%.

To integrate the impact of RPI (calculated in the Chapter Five, Section 5.5.3), in EAC equation, the EAC equation was adopted used by Babar et al. (2016). Equation (6.1) takes into account the influence of the RPI on the EAC equation (Babar et al. 2016). The RPI will be used to modify EVM through the insertion of the effect of RPI in the EAC equation. Furthermore, the complementary weight (W1, W2 and W3) of each index were identified:

$$\mathrm{EAC} = \mathrm{AC} + \frac{\mathrm{BAC} - \mathrm{BCWP}}{\mathrm{W1CPI} + \mathrm{W2SPI} + \mathrm{W3RPI}} \qquad (6.1)$$

Where, AC = Actual Cost or the Actual Cost of Work Performed (ACWP), BAC = the total value of the PV for accomplishing the project, BCWP = the Budgeted Cost of the Work Performed = Earned Value (EV), CPI = Cost Performance Index (CPI = EV/AC), SPI = Schedule Performance Index (SPI = EV/PV), RPI = Risk Performance Index. W1, W2, W3 are the complementary weights for each indicator. These weights were calculated through the average of the results of the fourth part of the questionnaire survey (see appendix B4). This section contains one question about supplemental or complementary weights. The question was (For each period of infrastructure project life, could you provide a simple proportional breakdown of the complementary weight (proportional weight or relative weight) of Cost Performance Index (CPI) (CPI = EV/AC), Schedule Performance Index (SPI) (SPI = EV/PV) and Risk Performance Index (RPI)).The objective of this question is to provide a simple relative weight distribution for the CPI, SPI and RPI (the total of these percentages should be 100%). The participants will determine the effect or weight of each of the three indicators, CPI, SPI and RPI, during a certain period of the project. The project was divided into four periods 0% to 25%, 26% to 50%, 51% to 75% and 76% to 100%. This process was adopted by Riedel and Chance (1989) and Babar et al. (2016). The complementary weight is estimated for each period by calculating the mean of overall weight of all participants. These weights can be worth between 0 and 1(Christensen et al. 1992; Christensen, D. S 1993; Christensen, David S 1993; Poulos & White 2010). Table 6.9 illustrates the complementary weights of CPI, SPI, and RPI during project life.

Table 6-9:The complementary weights of CPI, SPI, and RPI during project life.

Period of the project life	Complementary weight of CPI	Complementary weight of SPI	Complementary weight of RPI
0% to 25%	0.3446	0.2802	0.3752
26% to 50%	0.3690	0.2988	0.3321
51% to 75%	0.4037	0.3027	0.2937
76% to 100%	0.4306	0.2940	0.2754

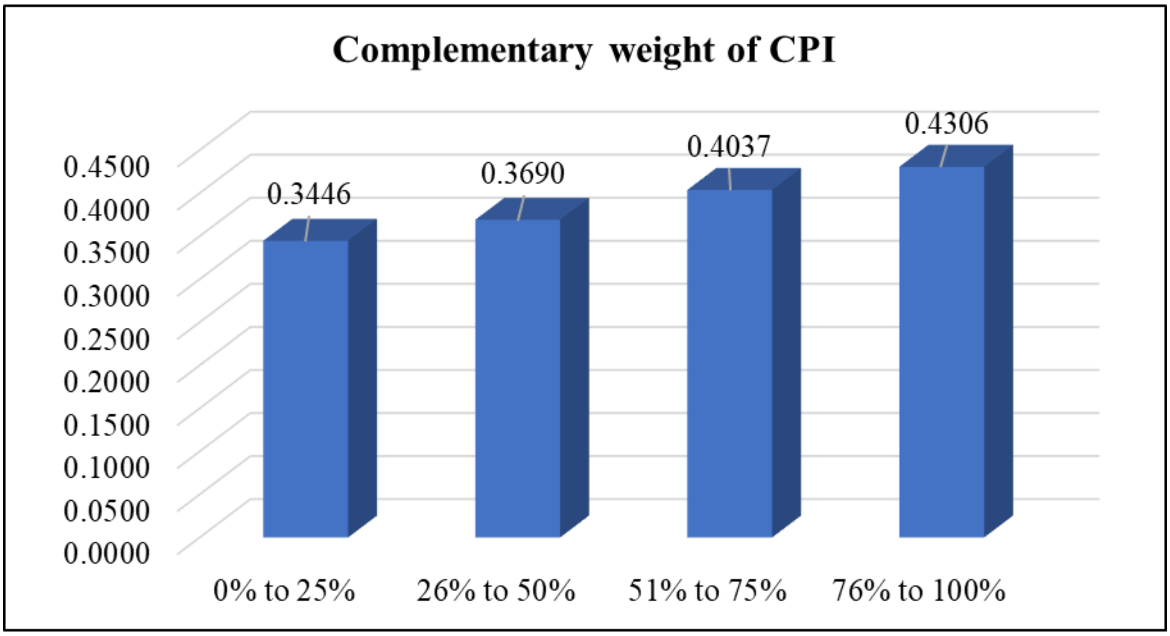


Figure 6-4: Complementary weight of CPI during the project life

As shown in Table 6.9 and Figure 6.4, the complementary weight of CPI increased slightly between the first and fourth quarters of project life. The value of the increase is 0.086.

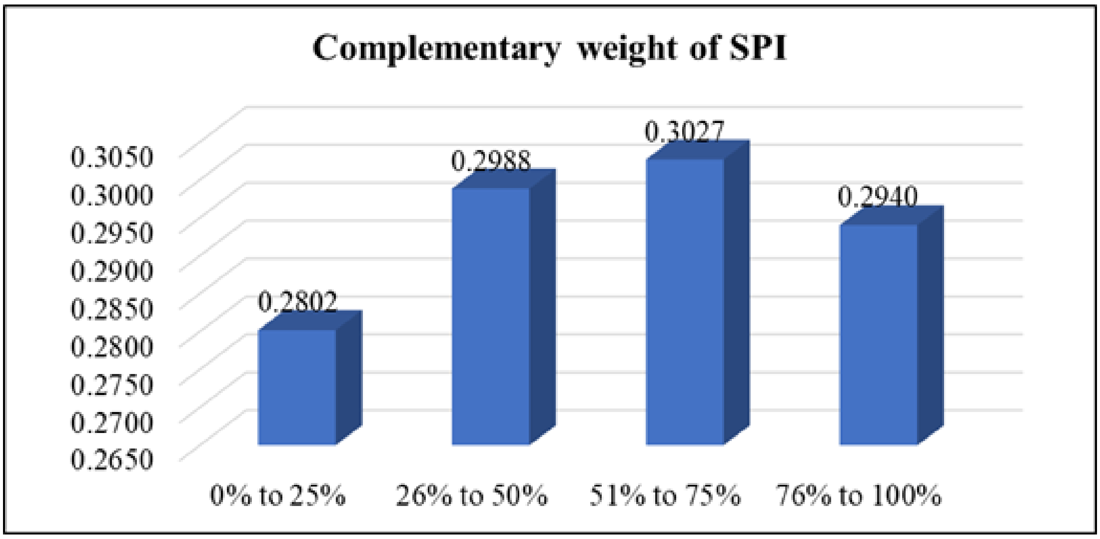


Figure 6-5: Complementary weight of SPI during the project life

Table 6.9 and Figure 6.5 demonstrate that the complementary weight of SPI increased slightly between the first and third quarters of project life. The value of the decrease is 0.0225. Then the value decreased by 0.0087 in the fourth quarter.

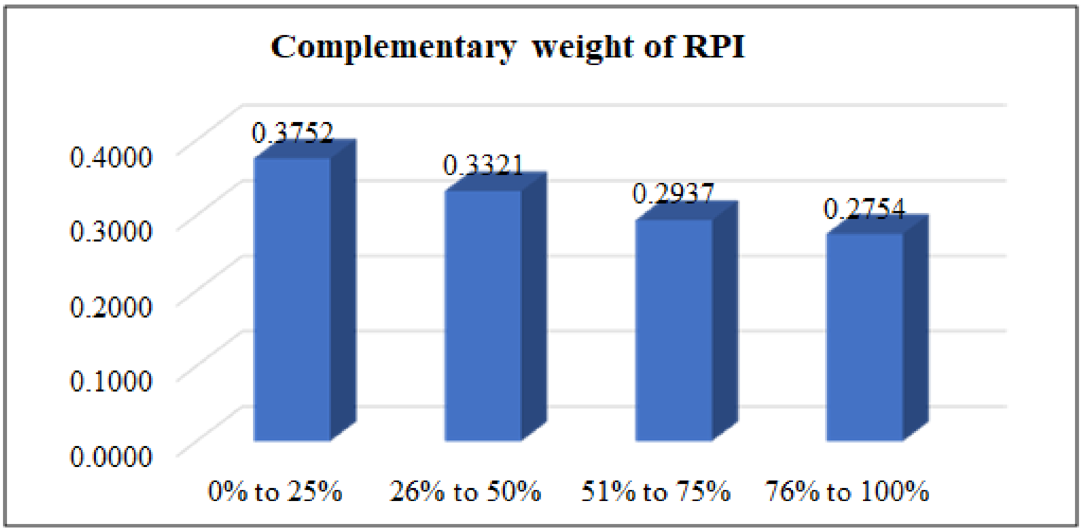


Figure 6-6: Complementary weight of RPI during the project life

As shown in Table 6.9 and Figure 6.6, the complementary weight of RPI decreased slightly between the first and fourth quarters of project life. The value of the decrease is 0.0998.

It is clear from the above that CPI will play an important role during the lifetime of the project in calculating the value EAC (Babar et al. 2016). In addition, SPI plays a less important role than CPI during the life of the project. SPI loses its importance in the calculation of EAC especially at the end of the life of the project and this is consistent with Christensen et al. (1992) and Babar et al. (2016). However, SPI plays a more important role during the middle of the life of the project than its role at the beginning and end of the project and this is consistent with Ford (2002) and Babar et al. (2016). Finally, the role of RPI in the calculation of EAC is less important than each of CPI and SPI, especially in the last quarter of the project life. However, the difference between CPI and RPI is small during the project life, indicating the importance of including RPI in the calculation EAC. This is in line with the fact that construction projects are subject to risk impact throughout their lives (Martin & Tate 2002).

As a result of combining the results of Table 6.9 in Equation (6.1), four new equations are created for the EAC, accounting for each quarter of the life of the project (Q1, Q2, Q3 and Q4). This can be seen in Equations (6.2) to (6.5)

$$\text{EAC at Q1} = \text{AC} + \frac{\text{BAC} - \text{BCWP}}{0.3446\text{CPI} + 0.2802\text{SPI} + 0.3752\text{RPI}} \tag{6.2}$$

$$\text{EAC at Q2} = \text{AC} + \frac{\text{BAC} - \text{BCWP}}{0.3690\text{CPI} + 0.2988\text{SPI} + 0.3321\text{RPI}} \tag{6.3}$$

$$\text{EAC at Q3} = \text{AC} + \frac{\text{BAC} - \text{BCWP}}{0.4037\text{CPI} + 0.3027\text{SPI} + 0.2937\text{RPI}} \tag{6.4}$$

$$\text{EAC at Q4} = \text{AC} + \frac{\text{BAC} - \text{BCWP}}{0.4306\text{CPI} + 0.2940\text{SPI} + 0.2754\text{RPI}} \tag{6.5}$$

Inserting the value of RPI obtained in the previous chapter in Equations (6.2) to (6.5), four new equations are created for the EAC, accounting for each quarter of the life of the project (Q1, Q2, Q3 and Q4). As shown in the Equations (6.6) to (6.9).

$$\text{EAC at Q1} = \text{AC} + \frac{\text{BAC} - \text{BCWP}}{0.3446\text{CPI} + 0.2802\text{SPI} + 0.3564} \tag{6.6}$$

$$\text{EAC at Q2} = \text{AC} + \frac{\text{BAC} - \text{BCWP}}{0.3690\text{CPI} + 0.2988\text{SPI} + 0.3155} \tag{6.7}$$

$$\text{EAC at Q3} = \text{AC} + \frac{\text{BAC} - \text{BCWP}}{0.4037\text{CPI} + 0.3027\text{SPI} + 0.2790} \tag{6.8}$$

$$\text{EAC at Q4} = \text{AC} + \frac{\text{BAC} - \text{BCWP}}{0.4306\text{CPI} + 0.2940\text{SPI} + 0.2618} \qquad (6.9)$$

To modify the EVM, these equations ((6.6) to (6.9)) will be used for the calculation of EAC during the project life by including the effect of risk-related factors in the form of RPI. This procedure will make EVM more accurate at predicting the final cost of the project. This is because the procedure does not rely on traditional elements only (cost and time) and this modified concept will take into account the impact of risk-related factors.

6.3 Validation of Modified EVM in Australian Infrastructure Projects

To verify the effectiveness and validity of the modified concept, it was tested on historical data of previously executed projects.

Tables 6.10 and 6.11 illustrate the case study of the first and second projects, respectively. These tables describe the actual financial details (in million AUD) of the two projects in terms of the values of the Planned Value (PV), the Actual Cost (AC) and the Earned Value (EV) for four different accomplished percentages during the lifetime of the project. These tables also show the total project Cost at Completion (CAC) and the total Planned Value (PV) which equal the Budget at Completion (BAC). These costs help to assess the EVM.

Table 6-10: Case study first project (million AUD)

Case Study first project					
	20%	**40%**	**70%**	**90%**	**100%**
Planned Value (PV)	3.664	6.466	11.933	15.205	17.163
Actual Cost (AC)	3.616	6.590	11.402	15.472	17.093
Earned Value (EV)	3.682	6.656	11.771	16.053	17.358

Table 6-11: Case study second project (million AUD)

Case Study second project					
	20%	**40%**	**70%**	**90%**	**100%**
Planned Value (PV)	1.357	7.025	15.720	22.330	24000
Actual Cost (AC)	1.396	5.938	14.280	20.880	23250
Earned Value (EV)	1.552	6.410	14.700	21.310	23500

Due to the confidentiality and importance of the information, the name of the company or institution is not mentioned. We have been provided with the following information only. In addition, this information will be treated with the appropriate level of confidentiality.

The project of the first case study is a school building, with a duration of 18 months and a budgeted planned cost of AUD 17. 163 million. The project was completed in time and with a final project cost of AUD 17.093 million.

The project of the second case study is a road infrastructure upgrade project, including road reconstruction, stormwater upgrades, etc. With a duration of 24 months and a budgeted planned cost of AUD 24. 000 million. The project was completed in 28 months and with a final project cost of AUD 23.250 million.

The results of the revised concept are compared with the final project BAC. Also, the results of the revised concept are compared with the results obtained from the traditional method presented by PMI (2017) to calculate EAC in Equation (6.10 and 6.11). In Equation (6.10), CPI reflects the cost performance which is constant until the end of the project, and in Equation (6.11) an additional cost may be paid for compensation in the case of any delay in the schedule (Narbaev & De Marco 2011).This comparison reflects the performance, behaviour and attitude of the modified concept when used on a real project.

$$\text{Traditional EAC (1)} = \text{AC} + \frac{\text{BAC} - \text{BCWP}}{\text{CPI}} \qquad (6.10)$$

$$\text{Traditional EAC (2)} = \text{AC} + \frac{\text{BAC} - \text{BCWP}}{\text{CPI} * \text{SPI}} \qquad (6.11)$$

Tables 6.12 and 6.13 illustrate the calculation EAC for the case studies of the first and second projects, respectively.

6.3.1 Case study for the first project

As shown in Table 6.12, when calculating EAC by equation of the traditional EAC (1) and EAC (2), it is noted that the value of both the CPI and the SPI are semi-fixed and convergent from 1. In addition, the value of EAC (1) and EAC (2) at 20% completion (16.856 and16.793 respectively) are much lower than the value of Cost at Completion CAC (17.093), indicating that there is an index or several factors other than CPI and SPI that affect the calculation of EAC. This is in line with the purpose of this research. In terms of the effect of RPI on the equation, the value of the modified EAC will be 20% (17.249) larger and closer to the Cost at Completion CAC value (17.093). Therefore, the value of the modified EAC is more realistic and more accurate.

This situation was somewhat ideal in terms of performance of the project within the estimated cost and estimated duration, due to the value of CPI (value) and SPI (value) being close to 1. If the value of index equals 1, the performance goes as planned. If the value of index great than 1, the performance is perfect and excellent. If the value of index less than 1, the performance is incompetent (De Marco & Narbaev 2013).

This indicates that there is good supervision and perfect control of the costs and duration of the project during its implementation. In addition, this helps explain the effect of the value of RPI on the value of EAC, where it can be said that the value of both SPI and CPI were neglected because of the proximity to 1. In addition, despite the result of these indicators indicating that there was no defect in the project performance, the output of the final project was inaccurate, which clearly indicates an additional effect on this outcome.

Although the value of SPI and CPI is consistent with the cost line and the planned duration, it does not warn of any risk to the performance of the project implementation. However, the impact of the RPI value clearly shows on the cost and duration of the project.

6.3.2 Case study for the second project

As shown in Table 6.13, the CPI is 1.112 at 20% completion and by 90% completion, it had fallen to 1.021. Being above 1, this indicates that supervision and cost control was perfect. The SPI is 1.144 at 20% completion, and by 90% completion, it had fallen to 0.954. Being less than 1, this indicates that supervision and control was incompetent throughout the project.

When calculating EAC by equation of traditional EAC (1) and (2), it is noted that the value of both the CPI and the SPI in the first quarter of project are greater than 1. In addition, the value of EAC (1) is (21.588) is lower than the value of cost at Completion CAC (23.250), and the value of EAC (2) is (19.051) lower than the value of Cost at Completion CAC (23.250). This indicates that there is an index or several factors other than CPI and SPI that affect the calculation of EAC. This is in line with the purpose of this research. In terms of the effect of RPI on the equation, the value of modified EAC (22.573) at 20% closer to the Cost at Completion CAC (23.250) value than the value of EAC calculated by the equations of traditional EAC (1) and EAC (2). Therefore, the value of the modified EAC is more realistic and more accurate.

This situation was rather complex compared to the first case of project performance within the estimated cost and estimated duration, due to the value of the SPI index gradually decreasing to less than 1. If the value of the index is less than 1, the performance is incompetent (De Marco & Narbaev 2013). Therefore, when calculating EAC by equation traditional EAC (2), additional payments may have been made as a result of the delay in the schedule (Narbaev & De Marco 2011).

Although the values of EAC (1) and EAC (2) are more realistic and closer to the value of CAC during the life of the project, the most important stage in which project outputs are evaluated and the forecast is in the first quarter of the life of the project. EAC is more effective for the forecasting of the outputs of the project in the first quarter (Lipke 2004). Therefore, the comparison was concentrated at 20% of the project life between the value of modified EAC and EAC (1), EAC (2).

Evaluating the performance of the project using EVM needs to provide sufficient data in terms of the project environment, as well as the many factors mentioned in this research. This research seeks to reduce the deviation or gap between planned values and actual values of the cost and duration of the project. This research provides a more realistic and accurate formula by integrating the effect of risk-related factors on the performance of infrastructure projects in Australia. The percentage of the difference between the planned cost and the actual cost of the project ranges from 3% to18% (Mak & Picken 2000). Therefore, infrastructure projects need to be more accurate in estimating the cost and duration of projects according to the circumstances and the project environment.

The value of modified EAC gave more accurate and realistic results for predicting the final project outputs compared with the traditional EAC (1) and EAC (2), in both cases; when the management and control of the project were good and when there was a delay in the planned schedule of the project. This is because the impact of risk-related factors was taken into account when predicting the cost and duration of the project. So, this modified EVM to calculate EAC will assist project managers and managers of companies and organizations accurately predict project outputs from the first quarter of a project, thus minimising the costs and duration of project implementation and taking the necessary measures from the first quarter of project life.

Table 6-12: Calculation EAC for a case study of the first project

Case study first project																		
Quarters	**Percentage**	**Planned value (PV)**	**Actual cost (AC)**	**Earned value (EV)**	**CPI= EV/AC**	**SPI= EV/PV**	**BAC**	**(BAC-BCWP)**	**(CPI*SPI)**	**Traditional EAC (1)**	**Traditional EAC (2)**	**W1**	**W1*CPI**	**W2**	**W2*SPI**	**W3*RPI**	**(W1CPI+W2SPI+W3RPI)**	**Modified EAC**
Q1	20%	3.664	3.616	3.682	1.018	1.005	17.163	13.481	1.02	16.856	16.793	0.3446	0.3509	0.2802	0.2815	0.3564	0.9889	17.249
Q2	40%	6.466	6.590	6.656	1.010	1.029	17.163	10.507	1.04	16.993	16.696	0.3690	0.3727	0.2988	0.3076	0.3155	0.9958	17.141
Q3	70%	11.933	11.402	11.771	1.032	0.986	17.163	5.392	1.02	16.625	16.697	0.4037	0.4167	0.3027	0.2986	0.2790	0.9943	16.825
Q4	90%	15.205	15.472	16.053	1.038	1.056	17.163	1.109	1.10	16.541	16.484	0.4306	0.4468	0.2940	0.3104	0.2616	1.0188	16.561
	100%	17.163	17.093	17.358														

Table 6-13: Calculation EAC for a case study of the second project

Case study second project																		
Quarters	**Percentage**	**Planned value (PV)**	**Actual cost (AC)**	**Earned value (EV)**	**CPI= EV/AC**	**SPI= EV/PV**	**BAC**	**(BAC-BCWP)**	**(CPI*SPI)**	**Traditional EAC (1)**	**Traditional EAC (2)**	**W1**	**W1*CPI**	**W2**	**W2*SPI**	**W3*RPI**	**(W1CPI+W2SPI+W3RPI)**	**Modified EAC**
Q1	20%	1.357	1.396	1.552	1.112	1.144	24.000	22.448	1.27	21.588	19.051	0.3446	0.3831	0.2802	0.3205	0.3564	1.0600	22.573
Q2	40%	7.025	5.938	6.410	1.079	0.912	24.000	17.590	0.98	22.233	23.796	0.3690	0.3984	0.2988	0.2727	0.3155	0.9866	23.768
Q3	70%	15.720	14.280	14.700	1.029	0.935	24.000	9.300	0.96	23.314	23.941	0.4037	0.4155	0.3027	0.2831	0.2790	0.9775	23.794
Q4	90%	22.330	20.880	21.310	1.021	0.954	24.000	2.690	0.97	23.516	23.642	0.4306	0.4394	0.2940	0.2806	0.2616	0.9817	23.620
	100%	24.000	23.250	23.500														

6.4 Summary

This chapter described the procedures for adjusting and modifying EVM by integrating the impact of risk-related factors as the RPI into the EAC equation. The validity of this revised or modified concept has been confirmed by applying two historical case studies. The results obtained confirm that this modified concept can predict project performance more accurately as compared to the traditional concept. The modified concept takes into account the impact of risk-related factors on the performance of a project. In addition, this modified concept reduces the gap between real values and estimated and planned values. This concept will provide a suitable environment for Australian project managers to control project implementation, and to forecast the final outputs of projects in a more accurate and realistic manner.

7 CHAPTER SEVEN: - CONCLUSIONS, CONTRIBUTIONS, LIMITATIONS AND FUTURE RESEARCHES

7.1 Introduction

This chapter discusses the research results and research objectives achived. Project performance assessment is an important component of construction project management. A fairly common method of assessing performance during project execution is EVM. A weakness of this approach is that it does not specifically measure the impact of a number of factors on project performance. The current EVM approach is not sufficient to accurately predict project performance in the complex infrastructure construction environment. The purpose of this research was to modify EVM used to assess the performance of infrastructure projects in Australia. This was done by exploring a range of risk-related factors and measuring their impact on EVM as an assessment method for modern sustainable infrastructure construction projects. EVM provides stakeholders in Australian infrastructure projects with greater accuracy and credibility in project monitoring and forecasting final project outputs.

7.2 The Thesis Summary

The first chapter explained the importance of infrastructure projects in the national economy and the importance of evaluating the performance of infrastructure projects. It also identified the research problem statement, research objectives and research questions designed to achieve these objectives, and the research hypotheses to be tested.

Chapter Two provided a comprehensive review of the literature on performance appraisal techniques for construction projects. It also illustrated the weaknesses in EVM and the factors influencing this concept to demonstrate the scope of research.

The research objectives and questions were established on the basis of the literature review.

The third chapter explained the research methodology used to achieve the research objectives. A mixed approach (qualitative and quantitative approaches) was employed to answer the research questions.

Chapter Two and Four identified a range of risk-related factors using a qualitative approach to data collection by reviewing the literature and conducting interviews. In Chapter Five, these data were tested using a quantitative method and the extraction of the Risk Performance Index (RPI) associated with the impact of the risk-related factors. In Chapter Six, EVM was modified by modifying an Estimation at Completion (EAC) equation as well as examining the validity of the modified concept on previously executed projects and comparing the variation in results.

7.3 Summary of Research Objectives and Finding

This section addresses the achievement of the four objectives of this research. The research objectives were stated and achieved by answering six research questions. The following are each of the research objectives and research questions:

Objective 1: Investigate the influence of risk management approaches on the technique for assessment of construction project performance (infrastructure projects in Australia), including contributing a set of risk-related factors such as the sustainability, requirements of stakeholders, communication, procurement strategies and other factors. In addition, identify the measurement items of these factors.

This objective focuses on the research and identification of risk-related factors and their measurement items that affect the viability of EVM in evaluating project performance and accurately predicting project outputs. To achieve this objective, the following research questions were answered:

RQ1: What are the risk-related factors that impact infrastructure project performance in Australia?

RQ2: What are the significant measuring items for these risk-related factors?

To answer the first research question (RQ1), four risk-related factors were identified by reviewing the literature as described in Chapter Two. These factors are (1) Sustainability (SS), (2) Stakeholders' requirements (SH), (3) Communication (CM), and (4) Procurement strategy (PS). The impact of these factors on the performance of infrastructure projects in Australia was confirmed by interviews as described in Chapter Four, and shown in Table 4.1. In addition, eight significant risk-related factors were identified during the interviews. These factors are (5) Weather (WE), (6) Experience of staff (SE), (7) Site condition (SC), (8) Design issues, (DI), (9) Financial risk (FR), (10) Subcontractor (CO), (11) Government requirements authority (GR), and (12) Materials (MR). As shown in Table 4.2, these findings reinforce the exploration and identification of risk-related factors that affect the performance of infrastructure projects in Australia. The participants pointed out the importance of taking into consideration the impact of these factors as risk factors in preparing the initial project designs, preparing the bills of quantities, estimating the total cost of the project and thus the appropriate budget for the project and, preparing the project schedule.

To answer the second research question (RQ2), 36 measurement items were identified in the fourth chapter, as shown in Table 4.4. In Chapter Five, it was necessary to obtain the minimum measurement items for each factor. As these factors are latent factors, the impact of measurement items as risk factors on project performance must be calculated. A total of 13 additional measurement items were identified. So, the total number of measurement items was 49, as shown in Table 5.1.

Understanding and identifying these risk-related factors and their measurement items, will support a more accurate evaluation of the performance of Australian infrastructure projects. In addition, the results of this research will provide a base for researchers in the field of project management in terms of management and evaluation of project performance.

Objective 2: Inspect the influence of the set of risk-related factors such as sustainability, requirements of stakeholders, communication, procurement strategies and other factors on the performance of infrastructure projects in Australia. In addition, identify the relationships between these factors.

This objective focuses on testing the impact of the risk factors on the performance of infrastructure projects in Australia, in addition to determining the relationships between these factors and calculating the impact of each factor on the other. To achieve this objective, the following research questions had to be answered:

RQ3: Are these risk-related factors likely to have significant impacts on the performance of infrastructure projects in Australia?

RQ4: What are the significant relationships between these risk-related factors?

To answer these questions (RQ3) and (RQ4), data obtained from the first research objective were analyzed. SPSS and AMOS were used for this purpose. The effect of risk-related factors (12 factors as independent factors) was tested on one variable, the Risk Performance Index (RPI), as shown in Figure 5.20. The test indicated acceptance of all these factors based on regression weights indicated in Table 5.26. These findings confirm that all factors obtained from the literature review and interviews have a significant impact as risk-related factors affecting the performance of Australian infrastructure projects. In addition, Table 5.27 shows the relationships between risk-related factors. The analysis demonstrated the existence of a sets of risk-related factors such as Sustainability (SS), Stakeholders' requirements (SH), Communication (CM), Procurement strategy (PS), Weather (WE), Experience of staff (SE), Site condition (SC), Design issues (DI), Financial risk (FR), Subcontractor (CO), Government requirements authority (GR) and Materials (MR) that affect the performance of infrastructure projects in Australia.

The industry appears to lack an understanding of the impact of these factors during different project phases. These results are expected to help project managers in Australia's infrastructure projects implementation sector increase the accuracy of project performance evaluation.

Objective 3: Account for the Risk Performance Index (RPI) resulting from the impact of the set of risk-related factors such as sustainability, stakeholder requirements, communication, procurement strategies and other factors on the performance of infrastructure projects in Australia.

This objective focuses on calculating the value of the Risk Performance Index (RPI) resulting from the impact of Sustainability (SS), Stakeholders' requirements (SH), Communication (CM), Procurement strategy (PS), Weather (WE), Experience of staff (SE), Site condition (SC), Design issues (DI), Financial risk (FR), Subcontractor (CO), Government requirements authority (GR) and Materials (MR) which were classified as risk factors in Australian infrastructure projects. To achieve this objective, the following research question was answered:

RQ5: What is the Risk Performance Index value resulting from the effect of the risk-related factors on the performance of infrastructure projects in Australia?

To answer these questions (RQ5), the results of SEM were analyzed for risk-related factors. The results of the analysis showed that the maximum value of the squared multiple correlations (R^2) was (0. 959) for the RPI as shown in Table 5.29. The results showed that the 95.5% variance in the RPI was due to the impact of risk-related factors. These results will help infrastructure project managers calculate the risk of these factors when forecasting project outputs.

Objective 4: Develop a new performance evaluation system using a modified concept of EVM that enhances the forecasting accuracy of the project estimate and accomplished by considering risk-related factors such as sustainability, stakeholder requirements, communication, procurement strategies and other factors.

This objective focuses on developing and modifying the EVM by integrating the impact of the RPI resulting from the impact of Sustainability (SS), Stakeholders' requirements (SH), Communication (CM), Procurement strategy (PS), Weather (WE), Experience of staff (SE), Site condition (SC), Design issues (DI), Financial risk (FR), Subcontractor (CO), Government requirements authority (GR) and Materials (MR).To achieve this objective, the following research question was answered:

RQ6: RQ6: How can EVM be modified to enhance the forecasting accuracy of the project estimate through the consideration of risk-related factors such as sustainability, stakeholder requirements, communication, procurement strategies and other factors?

To answer this question (RQ6), the value of RPI obtained from Table 5.29, was integrated into the equation of Estimate at Completion (EAC). The revised concept will be more accurate in predicting and estimating project outcomes by considering the impact of risk-related factors on Australian infrastructure projects such as Sustainability (SS), Stakeholders' requirements (SH), Communication (CM), Procurement strategy (PS), Weather (WE), Experience of staff (SE), Site condition (SC), Design issues (DI), Financial risk (FR), Subcontractor (CO), Government requirements authority (GR) and Materials (MR).

7.4 Discussion and conclusions

The focal point of this study is to increase the trust and credibility of EVM by developing this concept to be more comprehensive and inclusive of several factors that can be classified as risk-related factors, rather than concentrate on the key elements of performance measurement (time, cost, scope). This is done by including the impact of these factors as a Risk Performance Index (RPI) in the equation of Estimate at Completion (EAC) as is the case how to integrate the Cost Performance Index (CPI) and the Schedule Performance Index (SPI) in the equation, as shown in equation 6.1. This process led to a closer match between the predicted values and the real values and makes variation between them less possible.

The results of this research are consistent with what is mentioned in chapter two (review of literature) (Baloi & Price 2003; Standards Australia & Standards New Zealand 2009; Sun & Meng 2009; Aritua et al. 2011; Akanni et al. 2015; Lindhard & Larsen 2016) in terms of the set of risk factors which should be considered in the process of measuring the performance of infrastructure projects. The Factors are Sustainability (SS), Stakeholders' requirements (SH), Communication (CM), Procurement strategy (PS), Weather (WE), Experience of staff (SE), Site condition (SC), Design issues (DI), Financial risk (FR), Subcontractor (CO), Government requirements authority (GR) and Materials (MR). In addition, the measurement items (as shown in Table 4.4) were determined for each factor.

The validity of the modified EVM was validated by applying it to historical data form infrastructure projects previously executed in Australia. The results proved that the modified EAC predicted the final project outputs more accurately and realistically than the traditional EAC, as shown in Tables 6.12 and 6.13.

This new modified approach will assist those managing Australian infrastructure projects to better measure project performance by warning them of risk-related factors and taking them into account in project design, estimation and construction.

In addition, the results of this research regarding the widespread use of the concept of EVM in infrastructure projects in Australia are consistent with several studies (Fleming & Koppelman 2003; Mohammed et al. 2015; Mubarak 2015). However, there are limitations to this use cited by respondents, such as the size of the project where the concept is used in large projects, the type of project where the concept is used in more complex projects, and the type and level of management where it is used at the higher levels of management of the organization or company.

Respondents also pointed to the need for awareness of the participants in the management of projects in terms of increasing understanding of the EVM concept of managing the value gained through the development of their experience and knowledge.

It is clear that there are a number of risk-related factors (Sustainability (SS), Stakeholders' requirements (SH), Communication (CM), Procurement strategy (PS), Weather (WE), Experience of staff (SE), Site condition (SC), Design issues (DI), Financial risk (FR), Subcontractor (CO), Government requirements authority (GR) and Materials (MR)) that affect the performance assessment of infrastructure projects in Australia. These factors affect the basic elements of the EVM concept (time, cost) and thus affect the final outputs of the project evaluation. These factors must be taken into consideration during the measuring process of project outputs in terms of time and cost to be somewhat identical to actual final outputs. Moreover, the results of this research demonstrate that EVM is used fairly extensively in Australia, especially in large projects, as shown in Figure 6.3.

7.5 Contributions

The contributions of this research can be divided into two parts: contributions in academic circles and contributions in the practical field as follows:

7.5.1 Contributions to academia

This research contributes to the academic field, by providing a deeper understanding of the problems and weaknesses of EVM. In addition, this research presents a list of risk-related factors and their measurement items. This list provides a significant contribution to identifying the most important factors associated with the risks that affect the performance of Australian infrastructure projects. These factors represent a database of research from which to develop risk management systems, as well as the development of performance evaluation systems for construction projects in the construction industry generally.

7.5.2 Contributions to practice

This research contributes to Australian infrastructure projects. It will help project managers improve the evaluation process of infrastructure construction performance by incorporating a range of factors likely to impact on that performance and which are not included in current EVM calculations. The results provide a list of risk-related factors and their measurement items that should be taken into account in the implementation stages of Australian construction projects (planning, design, estimation, construction). The modified concept assists estimators to estimate the cost and duration of projects more accurately and determine the required budget correctly, thereby avoiding excess costs and ensuring project delivery within the planned period. The modified concept assists project owners and infrastructure project managers in Australia to monitor and evaluate project performance more accurately and predict the project outcomes more realistically, thus achieving key objectives properly.

7.6 Limitations and Future Research

This field of research was infrastructure projects in Australia and, therefore, the results obtained are specific for a specific type of construction industry (infrastructure projects) and a specific country (Australia). More research is proposed in all types of the construction industry. Furthermore, these factors can be examined in future research by identifying one area of infrastructure projects, such as bridge projects only. In addition, future research can be carried out to examine risk-related factors and to modify the concept in countries other than Australia.

The factors (obtained during the interviews) which received less than 40% of the confirmation of the respondents, were neglected due to the difficulty of conducting research on a large number of factors. Future research can be done to examine and test these factors and make sure that they are not significant factors, or prove the opposite.

Although the results of the interviews were tested and validated by the questionnaire in all states of Australia, most interviews were conducted in Queensland compared to other states.

Although the results of the research showed the use of EVM fairly widely in Australia, the proportion of Neutral responses was somewhat high. Future research can be conducted to develop skills in using EVM in Australia.

7.7 Chapter Summary

This research sought to examine the weaknesses of the concept of Earned Value Management (EVM) in infrastructure projects in Australia. The research proposed a new modified concept based on integrating the impact of a range of risk-related factors on the performance of infrastructure projects. This new modified concept has been tested with previous project implementation data. It was found that the evaluation process that uses the new modified concept was more accurate and closer to the actual final outputs of the project. This new modified concept will provide sponsors and managers of Australian infrastructure projects with a greater ability to control the performance of infrastructure projects.

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APPENDICES

Appendix A

Appendix A1:- Invitation letter to Interview

Dear Sir / Madam

Hi

My name is Maan Nihad Ibrahim. I am a PhD student at the University of Southern Queensland (USQ) in the Faculty of Health, Engineering and Sciences (School of Civil Engineering and Surveying). My Research topic is "Evaluation of assessment of infrastructure construction project performance in Australia using a modified concept of Earned Value Management (EVM)". In this context, I am seeking your help to collect data regarding this project. Your time and assistance in this regard, are highly appreciated.

The overall aim of this research is to develop a performance evaluation system that uses a modified EVM approach for the assessment of project performance, by including an assessment of the various risks associated with project sustainability, different procurement strategies, stakeholders requirements and communication.

To achieve this, I require the support of industry. This involves conducting interviews with experienced construction managers and engineers, who have been directly involved in infrastructure construction projects, from either a client, consultant, or contractor perspective. From these interviews, it is hoped to identify and define the risk factors affecting not only project performance, but also the use of Earned Value Management, as a performance measurement approach. These initial interviews will provide topic focus and help with the design and structure of the questions in the main questionnaire survey.

Due to your company's reputation for high quality delivery of infrastructure projects, I would like to conduct interviews with your project managers and engineering managers, who have more than 10 years of experience on infrastructure projects in Australia, at varying levels.

For those in your company who are willing to participate, the interview is expected to last approximately 30-minutes and may be audio recorded for accuracy and transcription purposes only. Interviews will be arranged to take place at a time and venue that is convenient to them. For safety reasons, the interview will not be conducted on a construction site.

As participation in this project is entirely voluntary, if they decide to take part and later change their mind, they are free to withdraw from the project at any stage. They may also request that any data collected from them, be destroyed. If they have any questions about this research please feel free to contact the Research Team (contact details at the end of this letter).Their decision whether they take part, do not take part, or to take part and then withdraw, will in no way impact their current or future relationship with the University of Southern Queensland.

If they have any concerns or complaints about the ethical conduct of the project(ethics approval No.H16REA261) you may contact Manager of Research Integrity and Ethics at the University of Southern Queensland on +61 7 4631 2214 or email researchintegrity@usq.edu.au or contact

Ethics Officer

Office of Research I University of Southern Queensland

Toowoomba I Queensland I 4350 I Australia

Ph: +61 7 4687 5703 I Fax: +61 7 4631 1995 I Email: human.ethics@usq.edu.au

For those who are interested in assisting with this research, please ask them to send their email addresses to allow us to contact them, so that a consent form can be sent to them to sign (via email) and arrangements made for the interview to be arranged at their convenience.

Please find the attached the Participant Information for USQ Research Project Interview document, which provides additional information.

Thank you

Regards

Maan Nihad Ibrahim

Contact details of research team

Principal Investigator Details

Mr. Maan Nihad Ibrahim

Email: Maannihad.Ibrahim@usq.edu.au

Mobile: +61 435 721 581

Supervisor Details

A/Prof David Thorpe

Email: David.Thorpe@usq.edu.au

Telephone: +61 7 3470 4532

Dr Nateque Mahmood

Email: nateque.mahmood@usq.edu.au

Telephone: +61 7 4631 2549

Mr Paul Tilley

Email: Paul.Tilley@usq.edu.au

Phone: +61 7 3470 4533

Maan Nihad Ibrahim

PhD Student University of Southern Queensland (USQ)

M.Sc. (Construction Management Engineering)

B.Sc. (Civil Eng.)

Email: Maannihad.Ibrahim@usq.edu.au

Mobile: +61 435 721 581

Appendix A2:- Higher Research Ethic Approval

Higher Research Ethic Approval

UNIVERSITY OF SOUTHERN QUEENSLAND AUSTRALIA

OFFICE OF RESEARCH

Human Research Ethics Committee

PHONE +61 7 4687 5703| FAX +61 7 4631 5555

EMAIL human.ethics@usq.edu.au

20 January 2017

Mr Maan Nihad Ibrahim

Dear Maan

The USQ Human Research Ethics Committee has recently reviewed your responses to the conditions placed upon the ethical approval for the project outlined below. Your proposal is now deemed to meet the requirements of the *National Statement on Ethical Conduct in Human Research (2007)* and full ethical approval has been granted.

Approval No.	**H16REA261**
Project Title	**Evaluation of assessment of infrastructure construction project performance in Australia using a modified concept of earned**
Approval date	**20 January 2017**
Expiry date	**20 January 2020**

HREC	**Approved**

The standard conditions of this approval are:

(a) Conduct the project strictly in accordance with the proposal submitted and granted ethics approval, including any amendments made to the proposal required by the HREC

(b) Advise (email: human.ethics@usq.edu.au) immediately of any complaints or other issues in relation to the project which may warrant review of the ethical approval of the project

(c) Make submission for approval of amendments to the approved project before implementing such changes

(d) Provide a 'progress report' for every year of approval

(e) Provide a 'final report' when the project is complete

(f) Advise in writing if the project has been discontinued, using a 'final report'

For (c) to (f) forms are available on the USQ ethics website: http://www.usq.edu.au/research/support-development/research-services/research- integrity-ethics/human/forms

Samantha Davis

Ethics Officer

Appendix A3:- Interview consent form

Interview consent form

University of Southern Queensland

Consent Form for USQ Research Project Interview

Project Details	
Title of Project:	**Evaluation of assessment of infrastructure construction project performance in Australia using a modified concept of earned value management**
Human Research Ethics Approval Number:	

Research Team Contact Details

Principal Investigator Details

Mr Maan Nihad Ibrahim
Email: Maannihad.Ibrahim@usq.edu.au
Mobile: 0435721581

Supervisor Details

Associate Professor David Thorpe
Email: David.Thorpe@usq.edu.au
Telephone: (07) 3470 4532

Dr Nateque Mahmood

Email nateque.mahmood@usq.edu.au
Position: Lecturer (Construction)
Section: School of Civil Engineering and Surveying
Telephone: +61 7 4631 2549

Mr Paul Tilley

Email Paul.Tilley@usq.edu.au
Position: Lecturer (Construction)

Section: School of Civil Engineering and Surveying
Phone: +61 7 3470 4533

Statement of Consent

By signing below, you are indicating that you:

- Have read and understood the information document regarding this project.
- Have had any questions answered to your satisfaction.
- Understand that if you have any additional questions you can contact the research team.
- Understand that the interview will be audio recorded.
- Understand that you will not be provided with a copy of the transcript of the interview for your perusal and endorsement prior to inclusion of this data in the project.
- Understand that you are free to withdraw at any time, without comment or penalty.
- Understand that you can contact the University of Southern Queensland Manager of Research Integrity and Ethics on +61 7 4631 2214 or email researchintegrity@usq.edu.au, if you have any concern or complaint about the ethical conduct of this project.
- Are over 18 years of age.
- The data will be used for the purpose of this project only and it will be exclusively shared with my supervisors.
- Agree to participate in the project.

Participant Name	
Participant Signature	
Date	

Please return this sheet to a Research Team member prior to undertaking the interview.

Appendix A4:- Map of frequencies of each theme

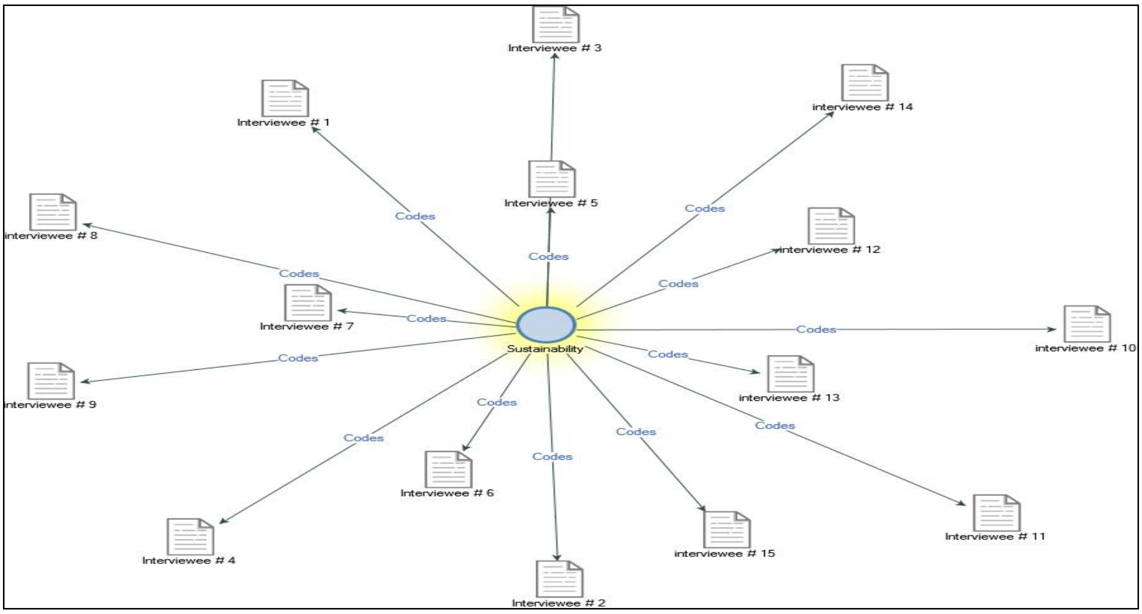

Figure A4-1: Sustainability nodes by NVivo

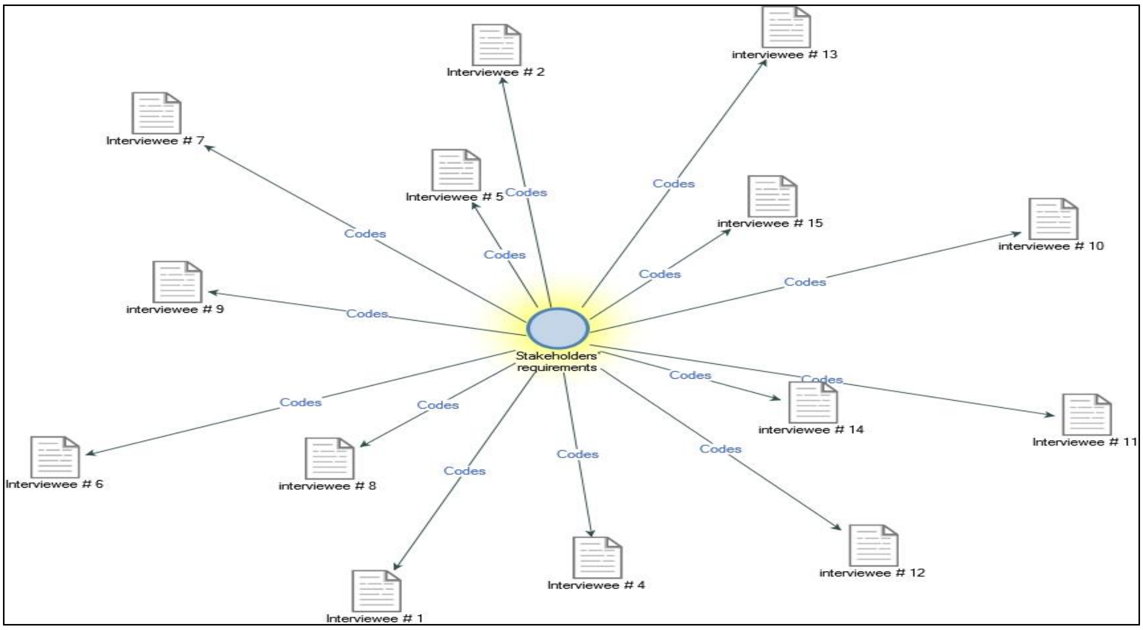

Figure A4-2: Stakeholder requirements nodes by NVivo

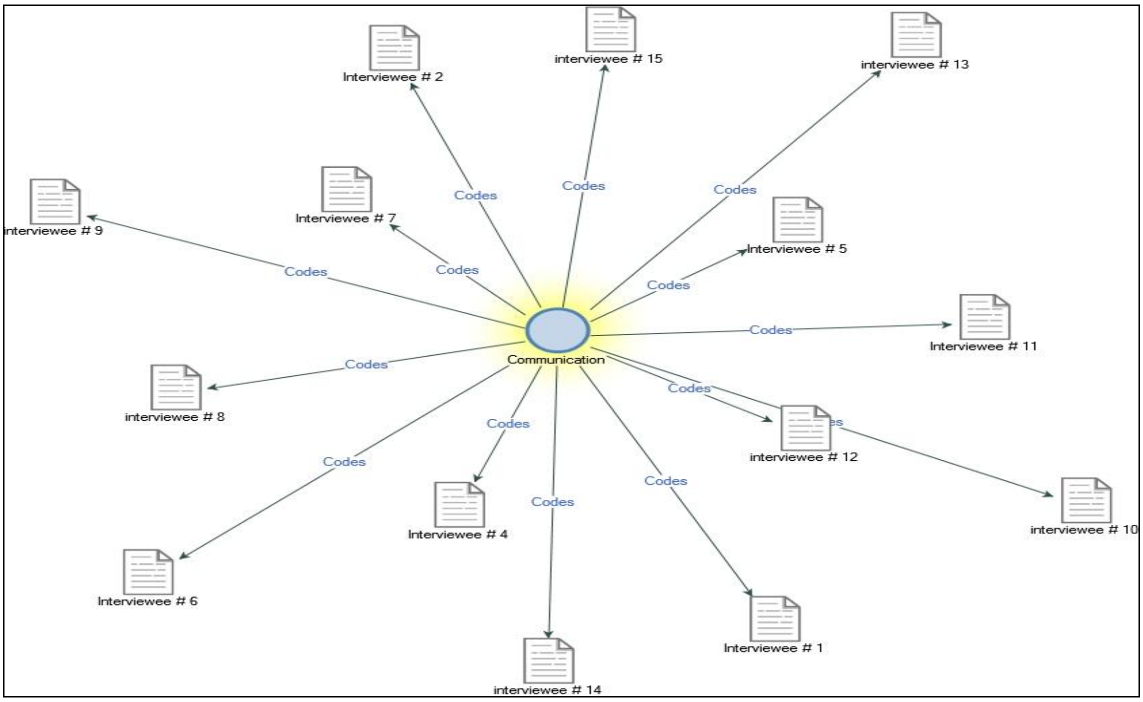

Figure A4-3: Communication nodes by NVivo

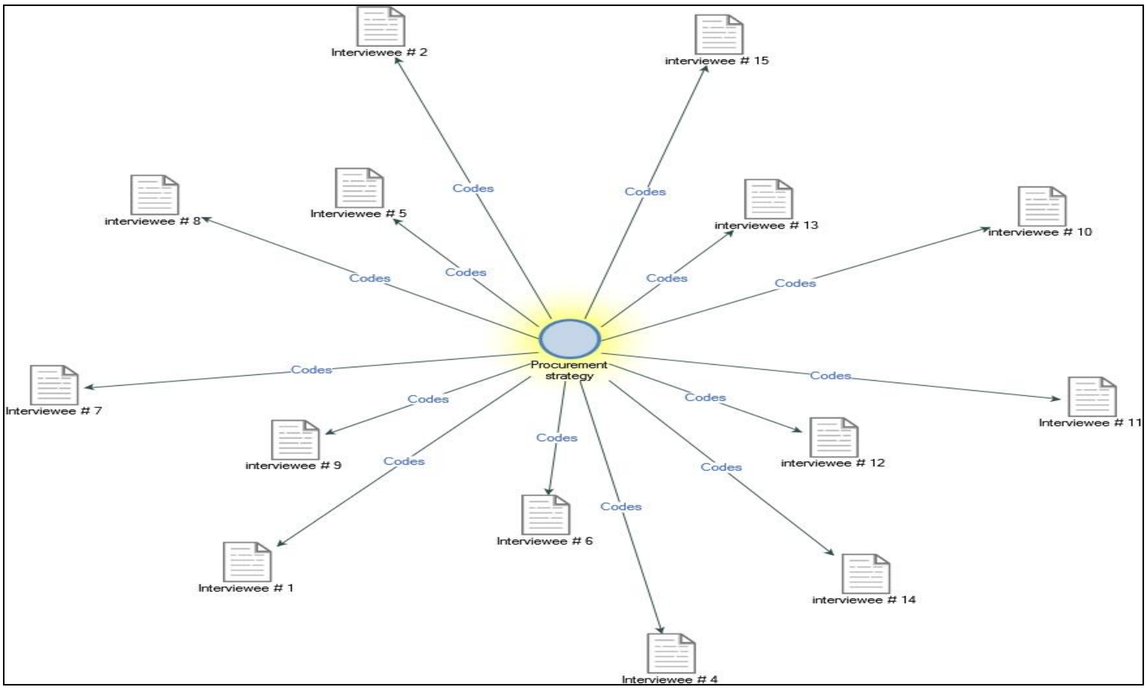

Figure A4-4: Procurement strategy nodes by NVivo

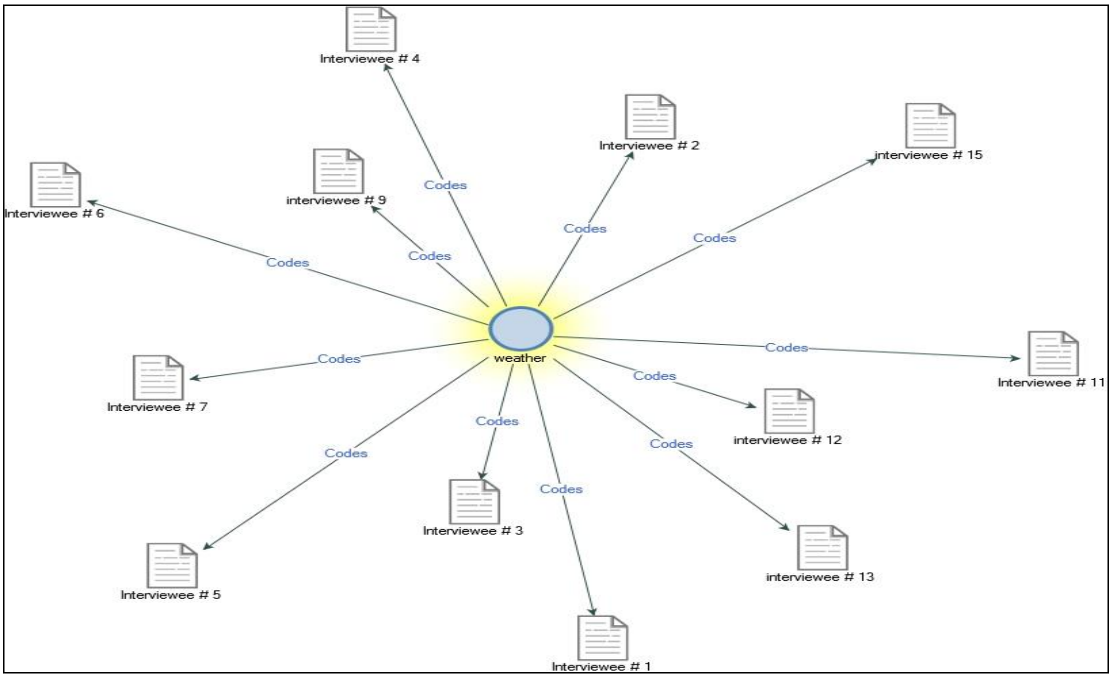

Figure A4-5: Weather nodes by NVivo

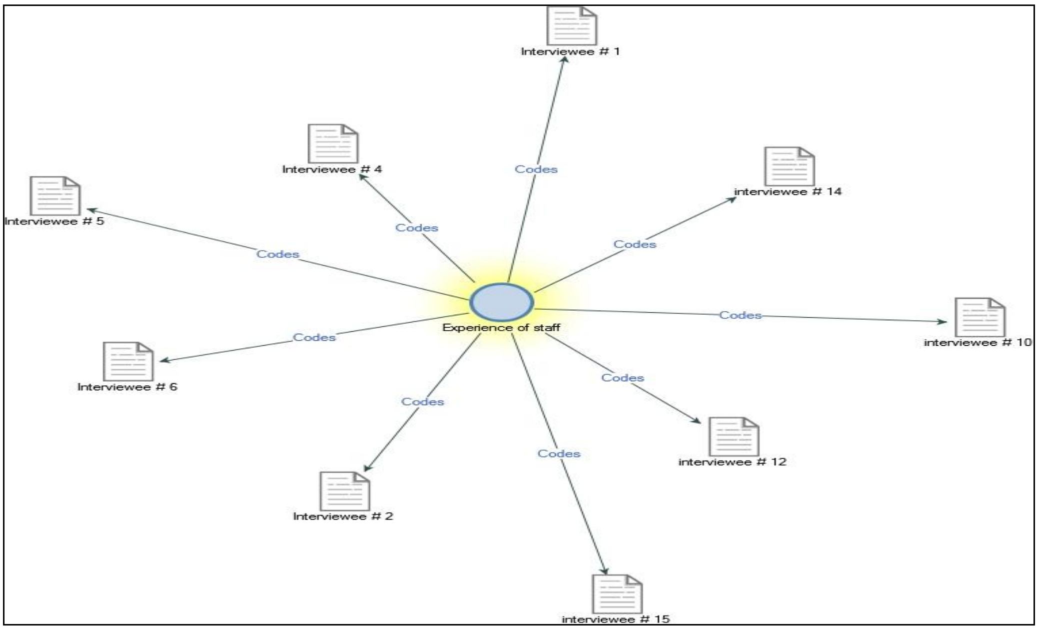

Figure A4-6: Experience of staff nodes by NVivo

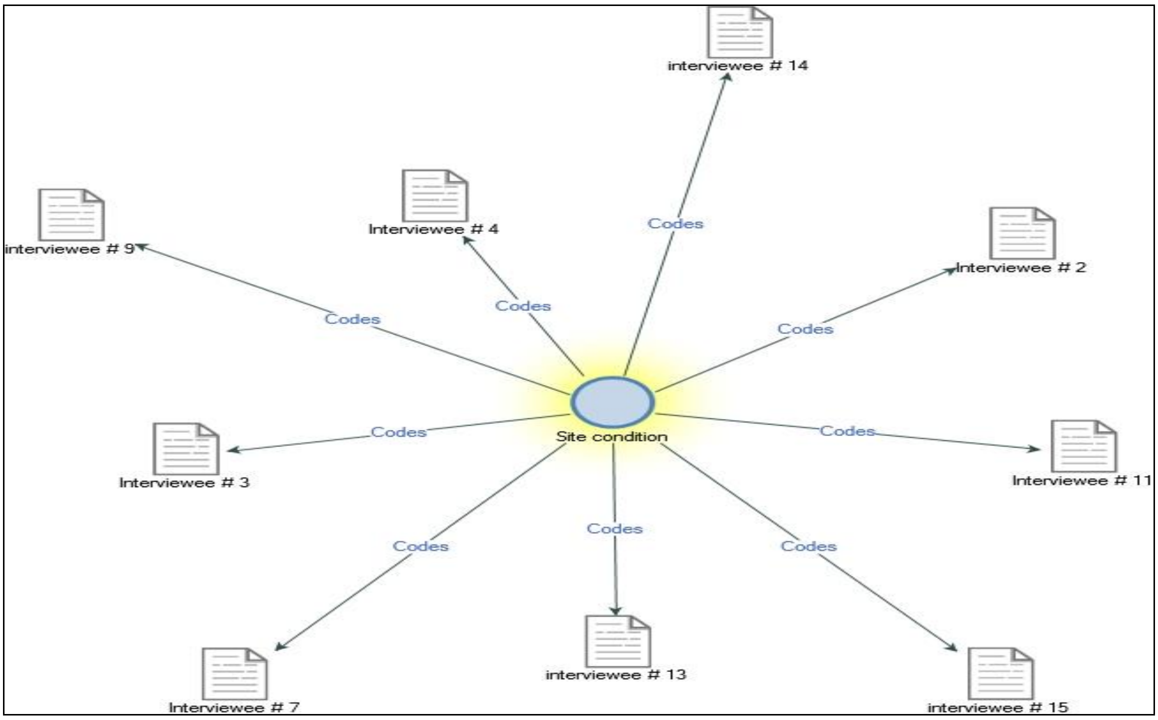

Figure A4-7: Site condition nodes by NVivo

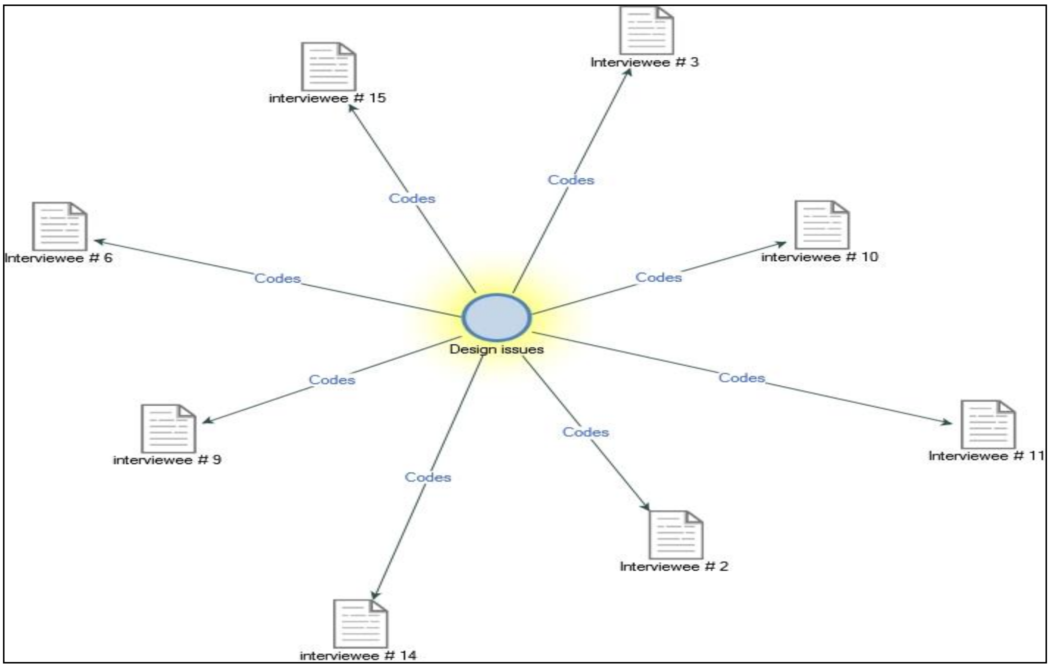

Figure A4-8: Design issues nodes by NVivo

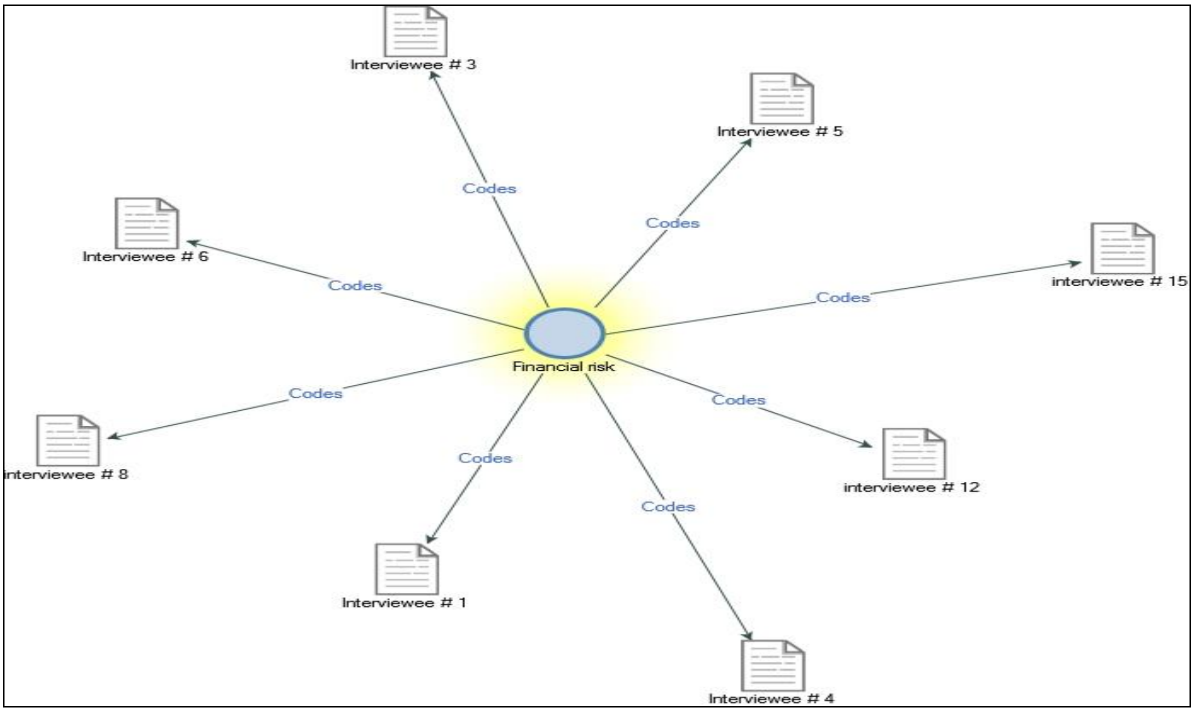

Figure A4-9: Financial risk nodes by NVivo

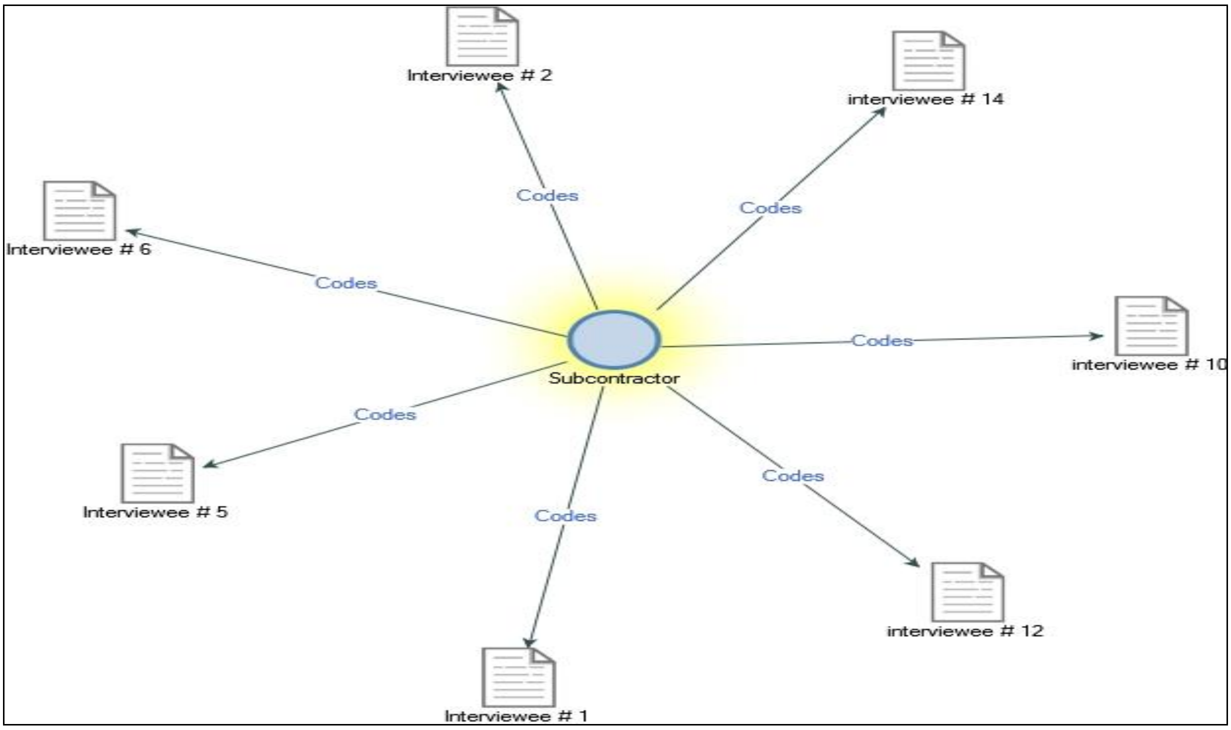

Figure A4-10: Subcontractor nodes by NVivo

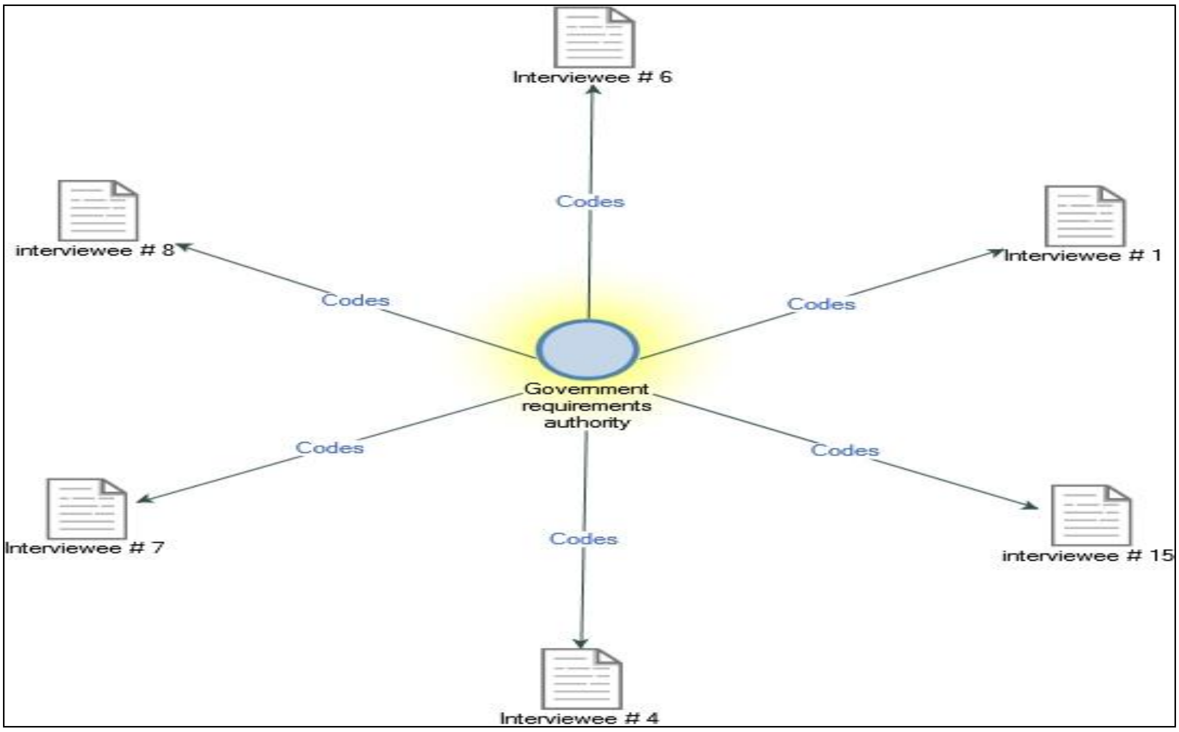

Figure A4-11: Government requirements authority nodes by NVivo

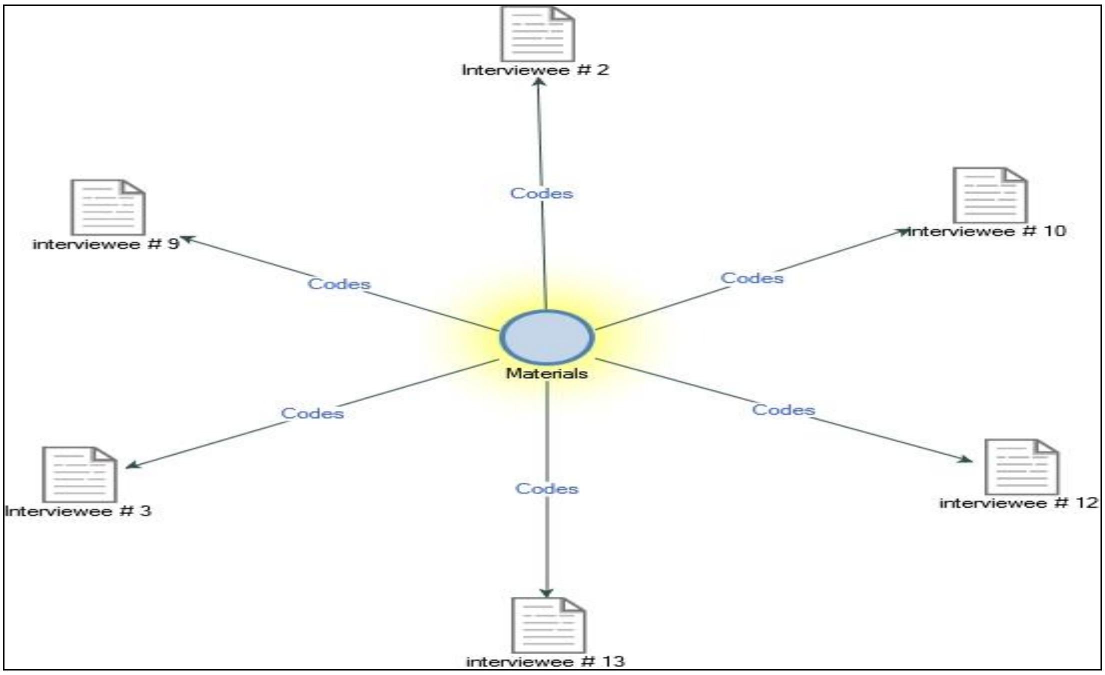

Figure A4-12: Materials nodes by NVivo

Appendix B

Appendix B1:- Invitation letter of pilot study

Invitation letter of pilot study

Dear Sir / Madam

Hi

My name is Maan Nihad Ibrahim. I am a PhD student at the University of Southern Queensland (USQ) in Faculty of Health, Engineering and Sciences. One of the requirements of my research is to conduct a pilot study with experienced construction managers and engineers to assess the feasibility in terms of time and check the structure of questionnaire surveying. In this context, I am seeking your help to complete this pilot study. This study will take approximately 15 minutes to complete.

Your time, your experience, thoughts and opinions are very much appreciated.

Please, complete this pilot study, the link is

http://eresearch-surveys.usq.edu.au/index.php/132861?lang=en

If you have any concerns or complaints about the ethical conduct of the project(ethics approval No.H16REA261) you may contact Manager of Research Integrity and Ethics at the University of Southern Queensland on +61 7 4631 2214 or email researchintegrity@usq.edu.au or contact

Ethics Officer
Office of Research - University of Southern Queensland
Toowoomba - Queensland - 4350 - Australia
Ph: +61 7 4687 5703 I Fax: +61 7 4631 1995 I Email: human.ethics@usq.edu.au

Thank you

Regards

Maan Nihad Ibrahim

PhD Student University of Southern Queensland (USQ)

M.Sc. (Construction Management Engineering)

B.Sc. (Civil Eng.)

Email: Maannihad.Ibrahim@usq.edu.au

Mobile: +61 435 721 581

Appendix B2:- Sample of pilot study

Sample of pilot study

Pilot study

Dear Sir / Madam

Thank you for your interest in participating in this pilot study.

My name is Maan.Ibrahim, I am PhD student at University of Southern Queensland (USQ). My research topic is “evaluation of assessment of infrastructure construction project in Australia using a modified concept of earned value management”.

This is a pilot study and the purpose of this pilot study is to assess the feasibility in terms of time and check the structure of questionnaire surveying.

Please read the last part (part 5) before answer the survey questions, there are no right or wrong answers. It is your views and experiences that are important.

All the information that you provide us with is confidential and will be used only for the purposes of this research.

If you have any concerns or complaints about the ethical conduct of the project(ethics approval No.H16REA261) you may contact Manager of Research Integrity and Ethics at the University of Southern Queensland on +61 7 4631 2214 or email researchintegrity@usq.edu.au or contact

Ethics Officer
Office of Research I University of Southern Queensland
Toowoomba - Queensland - 4350 - Australia
Ph: +61 7 4687 5703 I Fax: +61 7 4631 1995 I Email: human.ethics@usq.edu.au

Questions

Part 1

Q1: How many years of experience in infrastructure construction projects do you have?

- ☐ 0-10
- ☐ 10-15
- ☐ 15-20
- ☐ 20-30
- ☐ More than 30

Q2: What is the highest degree you have completed? (if currently enrolled, highest degree received) (Choose only one)?

- ☐ Diploma
- ☐ Bachelor's degree
- ☐ Master's degree
- ☐ Doctorate
- ☐ Other certificate

Q3: From which State (territory) are you?

- ☐ Western Australia
- ☐ Northern Territory
- ☐ South Australia
- ☐ Queensland
- ☐ New South Wales
- ☐ Australian Capital Territory
- ☐ Victoria
- ☐ Tasmania

Q4: What roles have you had during the years of work in infrastructure projects? (Choose as many as appropriate)

- ☐ Site engineer

- ☐ Senior project manager
- ☐ Project manager
- ☐ Design engineer
- ☐ senior engineer
- ☐ Operation manager
- ☐ Construction engineer
- ☐ Planning engineer
- ☐ Estimate engineer
- ☐ Management engineer
- ☐ Others

Q5: Please, select the type of project(s) you are experienced in? (Choose as many as appropriate)

- ☐ Roads
- ☐ Tunnels
- ☐ Bridges
- ☐ Airports
- ☐ Railroads
- ☐ Dams
- ☐ Infrastructure maintenance
- ☐ Harbours
- ☐ Others

Q6: Please, select the appropriate sector you are represented in? (Choose only one)

- ☐ Public sector
- ☐ Private sector
- ☐ Mixed sector (quasi-government sectors.)

Q7: How do you describe the category of your current organization? (Choose only one)

- ☐ Client representative
- ☐ Consultant
- ☐ Contractor
- ☐ Others

Part 2

Earned value management (EVM).

Earned value management (EVM) concept is used in monitoring and controlling projects to predict the final results of the project through the analysis of the project variables and project environment and the study of their relations with some.

Q8: EVM concept is likely to use widely in infrastructure projects in Australia?

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Undecided (neutral)
- ☐ Agree
- ☐ Strongly agree

Q9: Why do you think this is the case?

Part 3

Related risk factors impact on the infrastructure projects

Sustainability (SS)

Sustainability is becoming an increasingly important factor in modern infrastructure projects. Sustainable Infrastructure can be defined as "Infrastructure that is designed, constructed and operated to optimize environmental, social and economic outcomes in the long term".

For each attribute below, indicate your opinion of the effect level of this statement

"The following attributes are likely to have a significant risk that impacts on the performance of infrastructure projects in Australia".

Q	Attributes	(1)Strongly Disagree	(2)Disagree	(3)Neutral	(4)Agree	(5)Strongly Agree
10	**SS1:** Design does not incorporate sustainability requirements					
11	**SS2:** Fluctuating current market price in terms of sustainability material					
12	**SS3:** Unavailability of Materials					

	supply and resources of sustainability					
13	**SS4:** Government legislation of sustainability requirements					
14	**SS5:** Understanding the principle of sustainability					

Stakeholders' requirements (SH)

When considering stakeholders' requirements and communication, most literature sources divide stakeholders into three main groups; **clients, consultants, and contractors.**

For each attribute below, indicate your opinion of the effect level of this statement "The following attributes are likely to have a significant risk that impacts on the performance of infrastructure projects in Australia".

Q	**Attributes**	**(1)Strongly Disagree**	**(2)Disagree**	**(3)Neutral**	**(4)Agree**	**(5)Strongly Agree**
15	**SH1:** Government requirements of stakeholder					
16	**SH2:** Risk of different requirements of stakeholder					

17	**SH3:**Client changes in terms of stakeholders' requirement					
18	**SH4:** Type of contract in terms of stakeholders' requirement					

Communication (CM)

For each attribute below, indicate your opinion of the effect level of this statement "The following attributes are likely to have a significant risk that impacts on the performance of infrastructure projects in Australia".

Q	**Attributes**	**(1)Strongly Disagree**	**(2)Disagree**	**(3)Neutral**	**(4)Agree**	**(5)Strongly Agree**
19	**CM1:** Do not use the appropriate communications strategy					
20	**CM2:** Stakeholder experience in terms of communications					
21	**CM3:** Delay of change orders approved by the client					
22	**CM4:** Relationship between					

	stakeholders in terms of communications					

Procurement strategy (PS)

Procurement strategies used in infrastructure project delivery, generally include: Traditional contracting, Design and Construct, Alliance contracting, Private Finance Initiatives (PFIs) and Public-Private Partnerships (PPPs).

For each attribute below, indicate your opinion of the effect level of this statement. "The following attributes are likely to have a significant risk that impacts on the performance of infrastructure projects in Australia".

Q	Attributes	(1)Strongly Disagree	(2)Disagree	(3)Neutral	(4)Agree	(5)Strongly Agree
23	**PS1:** Design meets the contracting requirement					
24	**PS2:** Choose the appropriate procurement strategy					
25	**PS3:** Selection of contractors					
26	**PS4:** The size of the project in terms of selecting appropriate procurement strategies					

Weather (WE)

For each attribute below, indicate your opinion of the effect level of this statement. “The following attributes are likely to have a significant risk that impacts on the performance of infrastructure projects in Australia”.

Q	Attributes	(1)Strongly Disagree	(2)Disagree	(3)Neutral	(4)Agree	(5)Strongly Agree
27	**WE1:** Extreme weather such as heavy raining and flood					
28	**WE2:** Extreme weather such as low, and high temperature					
29	**WE3:** Extreme weather such as storms, and cyclones					
30	**WE4:** Extreme weather such as sea level rise					

Experience of staff (SE)

For each attribute below, indicate your opinion of the effect level of this statement. “The following attributes are likely to have a significant risk that impacts on the performance of infrastructure projects in Australia”.

Q	Attributes	(1)Strongly Disagree	(2)Disagree	(3)Neutral	(4)Agree	(5)Strongly Agree
31	**SE1:** Commitment level of staff					

32	**SE2:** Skills level of staff					
33	**SE3:** Level of education and Training of staff					
34	**SE4:** Experience of staff management					

Site condition (SC)

For each attribute below, indicate your opinion of the effect level of this statement "The following attributes are likely to have a significant risk that impacts on the performance of infrastructure projects in Australia".

Q	Attribute	(1)Strongly Disagree	(2)Disagree	(3)Neutral	(4)Agree	(5)Strongly Agree
35	**SC1:** Soil geotechnical investigation					
36	**SC2:** Earth works					
37	**SC3:** Ground condition (old building foundations, archaeological find, and water table level)					
38	**SC4:**Site access on time (possession in time)					

Design issues (DI)

For each attribute below, indicate your opinion of the effect level of this statement. “The following attributes are likely to have a significant risk that impacts on the performance of infrastructure projects in Australia”.

Q	Attribute	(1)Strongly Disagree	(2)Disagree	(3)Neutral	(4)Agree	(5)Strongly Agree
39	**DI1:** Poor and inefficient design (mistakes in design)					
40	**DI2:** Inadequate and Insufficient design (lack of details, information and specifications)					
41	**DI3:** Lack of designer's experience					
42	**DI4:** Major designs change					

Financial risk (FR)

For each attribute below, indicate your opinion of the effect level of this statement. “The following attributes are likely to have a significant risk that impacts on the performance of infrastructure projects in Australia”.

Q	Attributes	(1)Strongly Disagree	(2)Disagree	(3)Neutral	(4)Agree	(5)Strongly Agree
43	**FR1:** Fluctuation of an inflation rate					
44	**FR2:** Fluctuation of					

	an exchange rate					
45	**FR3:** Fluctuation of an interest rate					
46	**FR3:** Funding issues (payments delay)					

Subcontractor (CO)

For each attribute below, indicate your opinion of the effect level of this statement. "The following attributes are likely to have a significant risk that impacts on the performance of infrastructure projects in Australia".

Q	**Attributes**	**(1)Strongly Disagree**	**(2)Disagree**	**(3)Neutral**	**(4)Agree**	**(5)Strongly Agree**
47	**CO1:** Subcontractors' performance					
48	**CO2:** Subcontractors availability					
49	**CO3:** Subcontractors experience and skills					
50	**CO4:** Relationship between general contractor and subcontractors					

Government requirements (GR)

For each attribute below, indicate your opinion of the effect level of this statement.

"The following attributes are likely to have a significant risk that impacts on the performance of infrastructure projects in Australia".

Q	Attributes	(1)Strongly Disagree	(2)Disagree	(3)Neutral	(4)Agree	(5)Strongly Agree
51	**GR1:** Change in government policy					
52	**GR2:** Political decisions					
53	**GR3:** Safety quality requirements					
54	**GR4:** Sovereign government intervention					

Materials (MR)

For each attribute below, indicate your opinion of the effect level of this statement. "The following attributes are likely to have a significant risk that impacts on the performance of infrastructure projects in Australia".

Q	Attributes	(1)Strongly Disagree	(2)Disagree	(3)Neutral	(4)Agree	(5)Strongly Agree
55	**MR1:** Material procurement					
56	**MR2:** Availability of material					
57	**MR3:** Lack of standards in					

	terms of materials					
58	**MR4:** Inexperienced with material (poor material handling on site)					

Part 4

The Fourth part contains the **one question** about complementary weights.

Q59: For each period of infrastructure project could you provide a simple proportional breakdown of the complementary weight of cost performance index (CPI), schedule performance index (SPI), and risk performance index (RPI), (the sum of these proportions must be 100%)

Period of the project life	**Complementary weight of CPI**	**Complementary weight of SPI**	**Complementary weight of RPI**
0% to 25%			
26% to 50%			
51% to 75%			
76% to 100%			

Part 5

Pilot study

1- Can you please rate the survey questions, on the following points?

Q	points	(1)Strongly Disagree	(2)Disagree	(3)Neutral	(4)Agree	(5)Strongly Agree
Q60	The survey was easy to use					
Q61	The survey was easy to understand					
Q62	The survey questions were relevant to the topic					
Q63	This survey will take approximately 20 minutes to complete					
Q64	The survey parts are clear					
Q65	Use definition of the factor before questions very important					
Q66	Use definition of the factor before questions very					

	clear and enough					
Q67	The attributes of each factor are not ambiguous					
Q68	The attributes listed for each factor reflect the aspects of the measurement of factor effect					
Q69	The language used is clear and uncomplicated					

2-

Q70: If you have any other comments on the survey, please enter them in the box below:

Appendix B3:-Invitation Letter of Questionnaire survey

Invitation letter of questionnaire survey

Dear Sir / Madam

My name is Maan Nihad Ibrahim. I am a PhD student at the University of Southern Queensland (USQ) in Faculty of Health, Engineering and Sciences. One of the requirements of my research is to conduct a questionnaire survey with experienced construction managers and engineers to investigate the related risk factors affecting the Performance of infrastructure projects in Australia. In this context, I am seeking your help to complete this survey. This questionnaire survey will take approximately 15 minutes to complete.

Please, complete this questionnaire, the link is

http://eresearch-surveys.usq.edu.au/index.php/678881?lang=en

Your time, your experience, thoughts and opinions are very much appreciated.

All the information that you provide us with is confidential and will be used only for the purposes of this research.

If you have any concerns or complaints about the ethical conduct of the project(ethics approval No.H16REA261) you may contact Manager of Research Integrity and Ethics at the University of Southern Queensland on +61 7 4631 2214 or email researchintegrity@usq.edu.au or contact

Ethics Officer
Office of Research - University of Southern Queensland
Toowoomba - Queensland - 4350 - Australia
Ph: +61 7 4687 5703 I Fax: +61 7 4631 1995 I Email: human.ethics@usq.edu.au

I would be most grateful if you could forward the survey to your fellow colleagues

Thank you

Regards

Maan Nihad Ibrahim

PhD Student University of Southern Queensland (USQ)

M.Sc. (Construction Management Engineering)

B.Sc. (Civil Eng.)

Email: Maannihad.Ibrahim@usq.edu.au

Apendixe B4:- Sample of Questionnaire Survey

Questionnaire Survey

Dear Sir / Madam

Thank you for your interest in participating in this Questionnaire.

My name is Maan Ibrahim, I am a PhD student at the University of Southern Queensland (USQ). My research topic is "Evaluation of assessment of infrastructure construction project in Australia using a modified concept of earned value management".

The questionnaire survey is expected to last approximately 15 -minutes. Please answer the questions as best as you can; there are no right or wrong answers. It is your views and experiences that are important.

All the information that you provide us with is confidential and will be used only for the purposes of this research.

If you have any concerns or complaints about the ethical conduct of the project (ethics approval No.H16REA261), you may contact Manager of Research Integrity and Ethics at the University of Southern Queensland on +61 7 4631 2214 or email researchintegrity@usq.edu.au or contact

Ethics Officer
Office of Research I University of Southern Queensland
Toowoomba - Queensland - 4350 - Australia
Ph: +61 7 4687 5703 I Fax: +61 7 4631 1995 I Email: human.ethics@usq.edu.au

Part 1

Q1: How many years of experience you have in infrastructure construction projects?

- ☐ 0-10
- ☐ 10-15
- ☐ 15-20
- ☐ 20-30
- ☐ More than 30

Q2: What is the highest degree you have completed? (if currently enrolled, highest degree received) (Choose only one)?

- ☐ Diploma
- ☐ Bachelor's degree
- ☐ Master's degree
- ☐ Doctorate
- ☐ Other certificate

Q3: From which State (territory) are you?

- ☐ Western Australia
- ☐ Northern Territory
- ☐ South Australia
- ☐ Queensland
- ☐ New South Wales
- ☐ Australian Capital Territory
- ☐ Victoria
- ☐ Tasmania

Q4: What roles have you had during the years of work in infrastructure projects? (Choose as many as appropriate)

- ☐ Site engineer
- ☐ Senior project manager

- ☐ Project manager
- ☐ Design engineer
- ☐ Senior engineer
- ☐ Operation manager
- ☐ Construction engineer
- ☐ Planning engineer
- ☐ Estimating engineer
- ☐ Management engineer
- ☐ Others

Q5: Please, select the type of project(s) you are experienced in? (Choose as many as appropriate)

- ☐ Roads
- ☐ Tunnels
- ☐ Bridges
- ☐ Airports
- ☐ Railroads
- ☐ Dams
- ☐ Infrastructure maintenance
- ☐ Harbours
- ☐ Pipeline construction
- ☐ Water Supply
- ☐ Wastewater
- ☐ Others

Q6: Please, select the appropriate sector you are represented in? (Choose only one)

- ☐ Public sector
- ☐ Private sector
- ☐ Mixed sector (quasi-government sectors.)

Q7: How do you describe the category of your current organization? (Choose only one)

- ☐ Client representative
- ☐ Consultant
- ☐ Contractor
- ☐ Others

Part 2

Earned value management (EVM).

Earned value management (EVM) concept is used in monitoring and controlling projects to predict the final results of the project through the analysis of the project variables and project environment and the study of their relations.

Q8: EVM concept is likely to use widely in infrastructure projects in Australia?

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Undecided (neutral)
- ☐ Agree
- ☐ Strongly agree

Q9: Why do you think this is the case?

Part 3

Related risk factors impact on the infrastructure projects

Sustainability (SS)

Sustainability is becoming an increasingly important factor in modern infrastructure projects. Sustainable Infrastructure can be defined as "Infrastructure that is designed, constructed and operated to optimize environmental, social and economic outcomes in the long term".

For each attribute below, indicate your opinion of the effect level of this statement "The following attributes are likely to have a significant risk that impacts on the performance of infrastructure projects in Australia".

Q	Attributes	(1)Strongly Disagree	(2)Disagree	(3)Neutral	(4)Agree	(5)Strongly Agree
10	**SS1:** Design does not incorporate sustainability requirements					
11	**SS2:** Fluctuating current market price in terms of sustainability material					
12	**SS3:** Unavailability of materials					

	supply and resources of sustainability					
13	**SS4:** Government legislation of sustainability requirements					
14	**SS5:** Understanding the principle of sustainability					

Stakeholders' requirements (SH)

When considering stakeholders' requirements and communication, most literature sources divide stakeholders into three main groups; **clients, consultants, and contractors.**

For each attribute below, indicate your opinion of the effect level of this statement "The following attributes are likely to have a significant risk that impacts on the performance of infrastructure projects in Australia".

Q	Attributes	(1)Strongly Disagree	(2)Disagree	(3)Neutral	(4)Agree	(5)Strongly Agree
15	**SH1:** Government requirements of stakeholder					
16	**SH2:** Diverse requirements of stakeholders					
17	**SH3** Requested					

	changes by clients					
18	**SH4:** Type of contract in terms of stakeholders' requirement					

Communication (CM)

For each attribute below, indicate your opinion of the effect level of this statement "The following attributes are likely to have a significant risk that impacts on the performance of infrastructure projects in Australia".

Q	**Attributes**	**(1)Strongly Disagree**	**(2)Disagree**	**(3)Neutral**	**(4)Agree**	**(5)Strongly Agree**
19	**CM1:** Do not use the appropriate communications strategy					
20	**CM2:** Stakeholder experience in terms of communications					
21	**CM3:** Delay of change orders approved by the client					
22	**CM4:** Relationship between stakeholders in					

	terms of communications					

Procurement strategy (PS)

Procurement strategies used in infrastructure project delivery, generally include: Traditional contracting, Design and Construct, Alliance contracting, Private Finance Initiatives (PFIs) and Public-Private Partnerships (PPPs).

For each attribute below, indicate your opinion of the effect level of this statement. “The following attributes are likely to have a significant risk that impacts on the performance of infrastructure projects in Australia”.

Q	**Attributes**	**(1)Strongly Disagree**	**(2)Disagree**	**(3)Neutral**	**(4)Agree**	**(5)Strongly Agree**
23	**PS1:** Design meets the contracting requirement					
24	**PS2:** Choose the appropriate procurement strategy					
25	**PS3:** Selection of contractors					
26	**PS4:** The size of the project in terms of selecting appropriate procurement strategies					

Weather (WE)

For each attribute below, indicate your opinion of the effect level of this statement. “The following attributes are likely to have a significant risk that impacts on the performance of infrastructure projects in Australia”.

Q	Attributes	(1)Strongly Disagree	(2)Disagree	(3)Neutral	(4)Agree	(5)Strongly Agree
27	**WE1:** Extreme weather such as heavy raining and flood					
28	**WE2:** Extreme weather such as low, and high temperature					
29	**WE3:** Extreme weather such as storms, and cyclones					
30	**WE4:** Extreme weather such as sea level rise					

Experience of staff (SE)

For each attribute below, indicate your opinion of the effect level of this statement. “The following attributes are likely to have a significant risk that impacts on the performance of infrastructure projects in Australia”.

Q	Attributes	(1)Strongly	(2)Disagree	(3)Neutral	(4)Agree	(5)Strongly

		Disagree				Agree
31	**SE1:** Commitment level of staff					
32	**SE2:** Skills level of staff					
33	**SE3:** Level of education and Training of staff					
34	**SE4:** Experience of staff management					

Site condition (SC)

For each attribute below, indicate your opinion of the effect level of this statement. "The following attributes are likely to have a significant risk that impacts on the performance of infrastructure projects in Australia".

Q	Attribute	(1)Strongly Disagree	(2)Disagree	(3)Neutral	(4)Agree	(5)Strongly Agree
35	**SC1:** Geotechnical investigation					
36	**SC2:** Earthworks					
37	**SC3:** Ground condition (old building foundations, archaeological find, and water					

	table level)					
38	**SC4:**Site access on time (possession in time)					

Design issues (DI)

For each attribute below, indicate your opinion of the effect level of this statement. “The following attributes are likely to have a significant risk that impacts on the performance of infrastructure projects in Australia”.

Q	**Attribute**	**(1)Strongly Disagree**	**(2)Disagree**	**(3)Neutral**	**(4)Agree**	**(5)Strongly Agree**
39	**DI1:** Poor and inefficient design (mistakes in design)					
40	**DI2:** Inadequate and Insufficient design (lack of details, information and specifications)					
41	**DI3:** Lack of designer's experience					
42	**DI4:** Major designs change					

Financial risk (FR)

For each attribute below, indicate your opinion of the effect level of this statement.

"The following attributes are likely to have a significant risk that impacts on the performance of infrastructure projects in Australia".

Q	Attributes	(1)Strongly Disagree	(2)Disagree	(3)Neutral	(4)Agree	(5)Strongly Agree
43	**FR1:** Fluctuation of an inflation rate					
44	**FR2:** Fluctuation of an exchange rate					
45	**FR3:** Fluctuation of an interest rate					
46	**FR4:** Funding issues (payments delay)					

Subcontractor (CO)

For each attribute below, indicate your opinion of the effect level of this statement. "The following attributes are likely to have a significant risk that impacts on the performance of infrastructure projects in Australia".

Q	Attributes	(1)Strongly Disagree	(2)Disagree	(3)Neutral	(4)Agree	(5)Strongly Agree
47	**CO1:** Subcontractors' performance					
48	**CO2:** Subcontractors' availability					
49	**CO3:** Subcontractors' experience and skills					
50	**CO4:** Relationship between general contractor and					

	subcontractors					

Government requirements (GR)

For each attribute below, indicate your opinion of the effect level of this statement. “The following attributes are likely to have a significant risk that impacts on the performance of infrastructure projects in Australia”.

Q	Attributes	(1)Strongly Disagree	(2)Disagree	(3)Neutral	(4)Agree	(5)Strongly Agree
51	**GR1:** Change in government policy					
52	**GR2:** Political decisions					
53	**GR3:** Safety and quality requirements					
54	**GR4:** Sovereign government intervention					

Materials (MR)

For each attribute below, indicate your opinion of the effect level of this statement.

“The following attributes are likely to have a significant risk that impacts on the performance of infrastructure projects in Australia”.

Q	Attributes	(1)Strongly	(2)Disagree	(3)Neutral	(4)Agree	(5)Strongly

		Disagree				Agree
55	**MR1:** Material procurement					
56	**MR2:** Availability of material					
57	**MR3:** Lack of standards in terms of materials					
58	**MR4:** Inexperienced with material (poor material handling on site)					

Part 4

The Fourth part contains the **one question** about complementary weights (proportional weight or relative weight).

Q59: For each period of infrastructure project life, could you provide a simple proportional breakdown of the complementary weight (proportional weight or relative weight) of

- **Cost performance index (CPI) (CPI=EV/AC)**
- **Schedule performance index (SPI) (SPI=EV/PV)**
- **Risk performance index (RPI) (risk performance index (RPI) which measures the risk of performance of projects through the integrated assessment of the basic elements of performance**

(time and duration), as well as the factors that affect the risk of project performance.

(The sum of these proportions must be 100% for each period)

This complementary weight ($W1, W2, W3$) will be used to modify the concept of Earned Value Management (EVM) by incorporating risk performance via RPI in the estimate at completion (EAC) equation,

$$EAC = \frac{BAC - BCWP}{W1CPI + W2SPI + W3RPI}$$

When,

- EV=BCWP [Earned Value (EV) or the budgeted cost of the work performed (BCWP) is the financial value of the work performed.]
- BAC= budget at completion

Period of the project life	**Complementary weight of CPI**	**Complementary weight of SPI**	**Complementary weight of RPI**
0% to 25%			
26% to 50%			
51% to 75%			
76% to 100%			

Thank you for agreeing to take part in this questionnaire survey - your time, your experience, thoughts and opinions are very much appreciated.

I would be most grateful if you could forward the survey to your fellow colleagues

Regards

Maan