CAUSALITY ANALYSIS OF CONSTRUCTION DELAYS AND VALUE ENGINEERING PROTOCOLS IN MARINE PROJECTS

Hamidreza Karami

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Department of Construction Management
Faculty of Humanities
Curtin University

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DECLARATION

I, Hamidreza KARAMI, to the best of my knowledge and belief, do declare that this PhD thesis entitled “Causality Analysis of Construction Delays and Value Engineering Protocols in Marine Projects” contains no material previously submitted for the award of a degree or diploma in any university or in a scholarly or a fictional publication, in whole or in part, by any other person except where due acknowledgement has been made.

Except where otherwise indicated, this doctoral thesis is my own work.

Signature:

Date: 2 April 2021

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DEDICATION

To my loving parents, Ghodratollah Karami and Esmat Nejadebrahim, my source of encouragement and inspiration, for their unconditional faithful support and understanding in all the situations.

To my very special brother, Hamed Karami, who never stopped supporting me.

SUPPORTING PUBLICATIONS

The normative construction management literature is limited with regard to marine projects; that is, projects built near shore and offshore that involve complex processes around important water bodies and the associated extreme weather elements. Certain unique attributes of this complex environment distinguish marine projects from other projects on land. Knowledge gaps in this area encouraged me to publish three scholarly journal articles and four conference papers. My research activities involved reviewing the literature and exploring how specific characteristics of marine construction projects are pivotal in reaching performance targets such as on-time delivery, cost and quality. At the time of submitting this thesis, the following are my scholarly productions that align with my doctoral thesis.

In scholarly journals

Karami, H. and Olatunji, O.A. (2020). Critical overrun causations in marine projects. *Engineering, Construction & Architectural Management*, 27(7), 1579–1594.

The construction literature is replete with publications on overrun causations. Hundreds of causal factors have been published in relation to various construction project environments. However, the particular relevance of these factors to marine projects is under-researched. The study identified 73 delay factors under 16 themes and analysed 126 responses to a survey. Findings show that all identified factors have probable outcomes in marine projects. This explains why on-time completion is almost impossible in this sector. A key implication of this relates to applying uncertainty to planning tools and theories in line with the uniqueness of the marine project environment.

Karami, H. and Olatunji, O.A. (2020). Key value engineering protocols in marine projects. *Proceedings of the Institution of Civil Engineers on Management, Procurement & Law,* 173(1), 21–31.

Evidence from the literature suggests that marine projects experience a high frequency of issues that value engineering (VE) protocols are designed to prevent: yet cost and schedule overruns are still rife. This study identified key VE protocols in marine construction projects and assessed their relative importance as an approach to preventing issues with schedule performance. The research identified 19 VE variables under four themes and analysed 126 responses to a survey.

The findings from this study verify the importance of implementing VE protocols in unpredictable and dynamic marine environments to avoid scheduling performance issues. The paper also proposes an action model on how to establish a VE protocol using project data and VE variables as inputs, and to perform a functionality analysis.

Olatunji, O.A., Martin, M and Karami, H. (2020). Understanding trust and creditor's interest in the governance of megaprojects, *Construction Management & Economics*, under review.

This study explored the vulnerabilities of relationships of trust between parties in megaprojects when challenged by complex risks and uncertainties in project transactions. This was examined via analysis of the completion reports of 28 major dam projects in Africa, which were financed by up to 10 global development lenders. Findings suggest bureaucratic controls and authenticity issues were the main debacles affecting project success. Findings also declare economic complexities around megaprojects are as if trust is incumbent at the level of zero vision. However, the most appropriate way to manage self-interest and vulnerabilities in the face of 'predators' in megaproject ecosystems is to develop secondary safety nets that help all parties in trust relationships to recover from their vulnerabilities.

At international academic conferences

Karami, H. and Olatunji, O.A. (2018a). Delay causations in marine infrastructures, a review. In Lee, H.S., Ismail, M.A. and Lim, N.G. (Eds.), *Proceedings of the International Conference on Durability of Building & Infrastructures*. Miri, Sarawak, Malaysia, Vol 1, pp 167–170.

The paper won the Best Technical Paper Award at the conference. It provides a critical review of the literature and identifies delay causations in marine infrastructure projects. The knowledge gap highlighted in this paper is around the lack of incorporation of the uniqueness of projects when investigating delay causation. Unless this uniqueness is well understood, new knowledge constructed in regard to delay causation debate, from a theoretical perspective in particular, is unlikely to be useful. A lack of differentiation in domains and change agents will mean that empirical findings remain impracticable and imprecise. One key achievement of the paper is its simplification of the relationships between unique attributes of marine projects and theoretical frameworks on delay causations.

Karami, H. and Olatunji, O.A. (2018b). Contractor selection model for marine projects. In Do, K., Sutrisna, M., Hammad, A and Ramanayaka, C. (Eds.), *Proceedings of the 42nd Australasian Universities Building Education Association (AUBEA) Conference on Educating Building Professionals for the Future in the Globalised World*, Singapore, Curtin University, Vol 2, pp 27–37.

The paper argues that hiring an appropriate contractor is a typical step towards achieving success in a marine project. A key finding of the paper is that the appropriate contractor for a project must have exceptional capabilities and techniques to deal with the risks and uncertainties that define the peculiarity of marine projects, and be able to drive project success in terms of budget, safety and work quality, among others attributes. In its conclusion, the paper points out how and why traditional selection models are inappropriate for marine projects.

Karami, H., and Olatunji, O.A. (2018c). Key success factors in marine infrastructures, a review. In Do, K., Sutrisna, M., Hammad, A and Ramanayaka, C. (Eds.), *Proceedings of the 42nd Australasian Universities Building Education Association (AUBEA) Conference on Educating Building Professionals for the Future in the Globalised World*, Singapore, Curtin University, Vol 2, pp 121–128.

The identification of success agents is a controversial topic among stakeholders involved in construction. Success is often evaluated using definitive indicators such as on-time completion with no budget overrun; quality of work; and safety performance metrics. Nevertheless, the definition of project success in scholarly works is not universally agreed. This paper attempts to articulate current views on success agents in marine infrastructure projects. The findings can be classified under 10 themes: financial integrity, adequate planning, technical soundness, safety and risk-related protocols, implementation protocols, design adequacy, lessons learned, efficient leadership strategies, team ethical commitment and adequate in-house machinery department.

Karami, H., Ahmadi, L., and Olatunji, O.A. (2019). Knowledge management in marine projects through value engineering protocols, a review. In Ahiaga-Dagbui, D. (Ed.), *Proceedings of ARCOM-2019 on Large Infrastructure Projects: Challenges and Opportunities*, Melbourne, Deakin University, Vol 1, pp. 77–85.

The purpose of this paper is to highlight the role of knowledge as a catalyst to facilitate the achievement of the best output from practical approaches developed, particularly protocols of VE. Findings suggest that adopting VE protocols in line with knowledge during the front-end phase of construction projects facilitates information sharing, assists in developing practical ideas, improves project performance and consequently ameliorates the efficiency of marine construction projects. The paper also identifies that knowledge is useful for marine projects when it develops a pathway for consideration of different design options and assists in developing ideas into practical approaches.

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LIST OF ABBREVIATIONS

AGFI	Adjusted Goodness of Fit Index
CFA	Confirmatory factor analysis
CFI	Comparative Fit Index
CPM	Critical path method
EFA	Exploratory factor analysis
EPC	Engineering procurement construction
FAST	Function analysis system technique
GC	Gantt chart
GFI	Goodness of Fit Index
HREC	Human Research Ethics Committee
KMO	Kaiser–Meyer–Olkin (index)
KSP	Karan Sazeh Pasargad (consultants)
PAF	Principal access factoring
PCA	Principal Component analysis
PERT	Program review and evaluation technique
PLS	Partial least squares
PNFI	Parsimony Normed Fit Index
RMR	Root mean square residual
RMSEA	Root mean square error of approximation
SEM	Structural equation modelling
SAVE	Society of American Value Engineers
SIVE	Society of Iranian Value Engineering
SRMR	Standardised root mean square residual
TLI	Tucker–Lewis Index
UK	United Kingdom
USA	United States of America
VE	Value engineering
VM	Value management
WBS	Work breakdown system

ABSTRACT

Causation and causality of overruns in infrastructure projects are well reported in the normative literature. However, the peculiar impact of the project environment has received limited attention in delay analysis. The central argument of this study is that if causation themes are known but are not analysed according to project peculiarities, research outcomes are not likely to deliver clear impacts. Thus, this study aims to examine delay causations, how they apply to marine projects and whether they can be mitigated by specific value engineering (VE) processes. Several authors have argued that delays are preventable, particularly at the planning stage, and that VE processes are useful in this regard. This study builds its scholarship on exploring delay causations and key VE variables that are appropriate for marine projects. In addition, it investigates causalities between schedule performance and VE protocols via structural equation modelling (SEM).

Further to a literature review used to identify VE protocols and delay causations in marine construction projects, and analysis of archival data involving VE reports to establish the validity of the review, data were obtained from 126 responses to a questionnaire survey administered to experienced marine construction professionals. They included subject experts with site or academic experience as agents of project owners, and as contractors, consultants, planners, project managers and engineers. A reductionist methodology was used to identify the statistical significance of each causation factor. In particular, factor analysis was used to identify the relative statistical significance of factors to determine their importance beyond their descriptive rankings. In addition, SEM was utilised to create a graphical path diagram showing the causal relationships between VE and delay causations. Findings suggest the model fits the data, and the requirements for significance were successfully met.

To validate the model, an open-ended questionnaire was used to examine the findings via a qualitative approach. The viewpoints of 10 participants were analysed. They were emphatic regarding how delays are mitigated in megaprojects using VE protocols and how the proposed model fits into this knowledge space. Overall, findings suggest all delay variables analysed in the study have significant impacts in marine projects, and that marine projects will benefit when VE protocols are targeted at robust knowledge management for design and construction, understudying uncertainties in ground and seabed conditions and agility in planning.

These findings will assist stakeholders of marine projects—and the project management community generally—in developing dedicated strategies that are applicable to scheduling, to prevent and correct obstructions in uncertain project environments. In addition, the findings will assist in increasing the practicality of scheduling theories and contract administration practices in marine projects. This is because it is important that planners and project stakeholders are mindful of the severity of overrun causations triggered by the project environment, such that they are able to develop their expectations to tolerate variability rather than trade impracticable blames.

Keywords: delay causality, Iran, marine projects, mitigation strategies, schedule overruns, structural equation modelling (SEM), value engineering.

CHAPTER 1: INTRODUCTION

1.1 Central Theme of the Study

The purpose of this study is to examine delay causations, how they apply to marine projects, and whether they can be mitigated by specific value engineering (VE) processes. An overwhelming majority of relevant studies underline schedule overrun as a prevalent source of dissatisfaction among project stakeholders (Kenny and Vanissorn, 2012; Hamedani et al., 2015; Shebob et al., 2012). Ahiaga-Dagbui (2015) emphasises the stagnancy and repetition of research findings relating to overrun causations. Hampton et al. (2012) highlight the destructive consequences of schedule overruns for the financial security of stakeholders. They find that in delayed construction projects, both clients and contractors incur financial losses, including preliminary and ongoing expenses, inflation and price escalations. Hence, it is critical to prevent schedule overruns at their source (their causal factors) and understand how causal factors are transformed into delay outcomes (causalities and causations). Evidence by Whyte and Cammarano (2012) and Hamedani et al. (2015) suggests delay prevention elevates project value. In addition, a wealth of evidence in the literature suggests that one way to improve project function and value is to deploy VE and value management (VM) protocols (Barton, 2012; Shaw, 2016). These assist in identifying potential problems and enable stakeholders to establish mitigation and corrective strategies prior to any detrimental event occurring.

VE and VM are apparently used by authors in an interchangeable manner. According to Barton (2012), such undifferentiated usage is often inappropriate. Barton argues that VE and VM methodologies focus on elevating a project’s functional value by considering alternative methods and resources without compromising quality. Nuances in outcomes emerge when deploying each method. The outcomes from VE practices are in the form of technical advice relating to alternative design options and construction methods, most of which are measurable; in particular, in terms of time and how such options affect project schedule. VM, conversely, is a functional mechanism of design management that considers the overall view of project development processes by analysing principal purposes to manage value throughout project lifecycle stages. Wong and Vimonsatit (2012) found that cost overruns caused by delays are most prominent in oil and gas projects. They emphasis the constructive effects of early-stage mitigation on schedule performance. Tang and Bittner (2014) identify VE as a strategy with the potential to be implemented in uncertain marine environments to assess issues and develop innovative solutions. A key challenge to be confronted in this study is to specify key VE protocols in marine projects and validate this approach as a preventive and corrective mechanism. Further, this study seeks to develop a valid model that can assist stakeholders in marine projects and the research community with project management, to better understand the uniqueness of marine projects, the delay causatives in this challenging environment and how identified causations can be mitigated using dedicated mechanisms of VE.

1.2 Research Problem

VE is often mistaken as a cost-trimming tool (Wao, 2015). However, the purpose of VE goes beyond reducing project cost. It is also used to visualise and control variables involved in value creation, including on-time completion. Wao argues that while alternative methods and resources may lead to cost reductions, they should indeed be evaluated against preliminary defined durations. Thus, cost reduction strategies should not compromise schedule duration unless the deviation is negligible. Hamedani et al. (2015) articulate deficiencies in guidelines outlining the impact of VE protocols on performance, and against delay causations. These guidelines can be provided by relevant authorities employing various tools including seminars, instructional workshops and training courses on VE and risk management. Hamedani and colleagues recommend these as worth exploring in future scholarly works. Bittner and Schmitt (2011) emphasise the capability of VE practice in addressing issues in marine construction projects. However, despite the peculiarity of marine projects, the same VE protocols are used in this environment as for other types of project. Previous research has identified persistent issues in marine projects that VE protocols are designed to prevent: that is, cost and schedule overruns are still rife. Tang and Bittner (2014) identify current practices as vague and rather superficial, such that the most ideal solution cannot be guaranteed. Tang and Bittner underline the absence of a mechanism to quantitatively assess and verify proposed solutions. Apart from cost, other components need to be considered in the evaluation stage, including safety, risk, quality, scope, environmental challenges and above all, schedule. This research intends to define key VE protocols in marine construction projects and to investigate their potential capability as a technique for preventing problems with schedule performance. To address delay-related issues, preventive and corrective strategies can be developed during VE through function analysis. This will result in establishing proper implementation procedures that mitigate the likelihood of overruns in marine construction projects.

In addition, expert knowledge can be incorporated into the design process by involving contractors in the early stages of projects; particularly through VE workshops. This reduces the time required to rectify possible design errors that are common contributors to construction issues in projects. Diverse variables are considered when seeking alternative methods and resources in VE and VM workshops. Variables such as implementation methods, pilot studies, dynamic timetables, and contractor involvement in VE; and constructability and management strategies in VM, should be analysed against schedule performance. Identifying variables that impact project schedules and add value to a project makes an exceptional contribution to the construction industry.

1.3 Significance of the Research Problem

In the past 20 years, Iran has experienced notable development of investment in the major construction industry; marine projects are no exception. They are pivotal infrastructures that assist Iran in extraction and exportation of a final product to markets across the world. Oil and gas are the two main products accounting for a large proportion of government revenue. Iran, as an energy superpower, has 10% and 15% of the world's oil and gas reserves, respectively (Lynn, 2014). According to the Central Bank of Iran, in 2016, US$135 billion accrued to the government of Iran through oil exports. This underscores the importance of a sustainable transportation industry, including the shipping industry and related infrastructures, which contribute 15% to the Gross Domestic Product. However, as in other countries, marine projects are impacted by overruns during their lifecycle. Considering the massive budgets for these types of

project, implementing a mitigation strategy will be beneficial for both the private and public sector. It will reduce the negative influence imposed on projects by erratic challenges. Based on a recent study by Karan Sazeh Pasargad (KSP) Consultant Engineers (2016), overruns in most marine projects in Iran have led to negative economic situations for investors—both public and private. They have been influenced by late completion, resulting in cost overruns and consequent dissatisfaction among stakeholders. Further, KSP considers that less than 5% of projects in Iran have been of high quality and accomplished ideally. Fallahnejad (2013) presents a considerable evidence on delay causations in marine construction industry proven by an analysis of interim progress reports. Valyani et al. (2019) underline the critical role of marine construction projects in industrial development and national security, highlighting them as the most strategically important projects in Iran recently. The authors attempted to identify, assess, and evaluate the major and common risks that these projects confront. Shirowzhan et al. (2016) adhere to Fallahnejad (2013) in prevalence of overrun causations in port operational areas including near shore projects in Iran. To improve project performance and address potential challenges in this unpredictable environment, the authors advocate forming a VE team.
Thus, analysing the influence of VE protocols in envisioning issues and ameliorating project performance is a fundamental challenge for the Iranian construction industry. The outcomes will include a VE project pattern that is applicable to marine projects undertaken in any geographical location, through results demonstrating the great efficiency of implementing VE in marine projects, to avoid or mitigate overruns.

1.4 Research Questions

In 1989, a VE survey was administered to highway transportation agencies in the United States of America (USA) and Canada. Wilson (2005) describes the general conclusion reached as follows:

> VE can effectively be integrated with or into other technical or management improvement approaches, such as schedule management. It is more effective on the performance, quality and cost of a project when performed in the development of the project schedule.

Similarly, Younker (2003) defines the VE methodology as a robust approach that assists in improving time performance and project quality. Although VE has been implemented in some major projects in Iran, most have not considered the interaction between VE and schedule overrun (Hamedani et al., 2015). Thus, the question this study seeks to answer is: How does value engineering help to improve schedule performance in marine construction projects? The investigation will focus on pointing out the relationships between factors considered during VE processes and causations of schedule overruns during construction. Ultimately, the study will attempt to answer the following question: What model of value engineering can minimise construction delays in marine projects?

1.5 Research Aim and Objectives

This study attempts to add to the existing limited body of knowledge in the scope of marine construction projects by introducing potential VE protocols. The aim is to establish a platform for managing projects and enhancing project schedules via a multidisciplinary team aiming to highlight alternative solutions, define alternative methods and introduce potential opportunities for value creation within the project. In overall, the aim of this study is to investigate and elicit the impact of VE protocols on schedule performance, towards mitigating delay causations. The objectives of the study are to:

1. establish through the analysis and review of relevant literature, VE variables that are appropriate for marine projects
2. establish through the analysis and review of relevant literature, key delay causations in marine projects
3. investigate causality relationships between delay factors and value engineering protocols through a validated structural equation model (SEM).

1.6 Theoretical Framework

Marine infrastructures are assets built near shore and offshore. Common forms of such infrastructures include jetties, breakwaters, ports, wharves, floating oil and gas platforms, bridges and underwater pipelines and tunnels. Their construction requires specialised skills and extremely complex technologies to perform tasks under erratic and unpredictable conditions, mostly in remote areas where logistics support is difficult. What distinguishes them from other projects is their unique attributes, namely complex resources and equipment, dynamic and uncertain work environment and the interdependency of multiple professional disciplines. Tam and Shen (2012) argues that the uniqueness of marine projects is defined by weather considerations and sophisticated design principles. These characteristics render them more exposed to overruns than are on-land projects. The adverse impact of overruns on stakeholders can be defined as altering the operation stage and jeopardising the project's financial viability. Overruns may be mitigated by investigating their drivers in a particular project environment. Precise mitigation strategies suitable for a particular project environment ameliorate project outcomes (Hunter and Kelly, 2002). Hence, non-scope-focused mitigation techniques are highly unlikely to be perfect.

Overruns are common in marine construction projects and are the main cause of dissatisfaction among stakeholders (Ramanathan et al., 2012; Shebob et al., 2012; Ruqaishi and Bashir, 2015; Tankkar and Wanjari, 2015; Shrivas and Singla, 2018). Given the limited research findings on delay causations and mitigation strategies that are related to the environment, this study aims to identify critical overrun causations in marine construction projects and dedicated techniques to minimise the likelihood of undesirable overruns. The knowledge gap addressed in this study relates to a culture of not considering the definitive impact of delay causations that are specific to project domains and exploring specific mitigation approaches.

The essence of marine projects explains the need for efficient management strategies. Hence, the espoused overrun mitigation approach examined in this study involves the VE methodology. This method is characterised as a preventive strategy for exploring problems in uncertain marine environments and for developing preventive mechanisms (Tang and Bittner, 2014). VE involves determining the functions of various design elements; evaluating alternative construction implementation methods and resources; and assessing the probability of replacement, combination, adoption, adjustment, magnification or removal of a task that enhances value (Ilayaraja and Zafar Eqyaabal, 2015). As a result, the outcomes of VE practices might be in the form of technical advice related to substitute design options and construction methods. Most outcomes can be measured, especially in terms of time and how such options actually impact the schedule of projects. Ilayaraja and Zafar Eqyaabal (2015) believe in the capability of this technique to interact with schedule overrun causations, by focusing on visualising delay factors and implementing control strategies.

Understanding the topic, investigating determinant factors in scheduling and exploring the most suitable VE protocols was achieved by reviewing diverse materials, case studies and the literature. The majority of delay theories rely on recirculation of the process and reiteration of existing delay themes without considering scope-specific drivers (Agyekum-Mensah and Knight, 2017). By and large, there is limited differentiation between what triggers schedule overrun, and the project scope. This study posits that the emphasis should be on scope-focused drivers of overruns, allocation of resources, unique attributes, aspects of complexity and incorporating uncertainties in design options and scheduling processes. In terms of uncertainties, it should be noted that qualitative uncertainties in the marine scope of work are more prevalent than quantitative ones and should be planned well in advance. In addition, and more importantly, implementation of probabilistic over deterministic analysis into design options and scheduling theories is of utmost importance. The implications of such observations will help to improve the practicality of scheduling strategies in marine construction projects. Figure 1.1 presents the theoretical framework for this study.

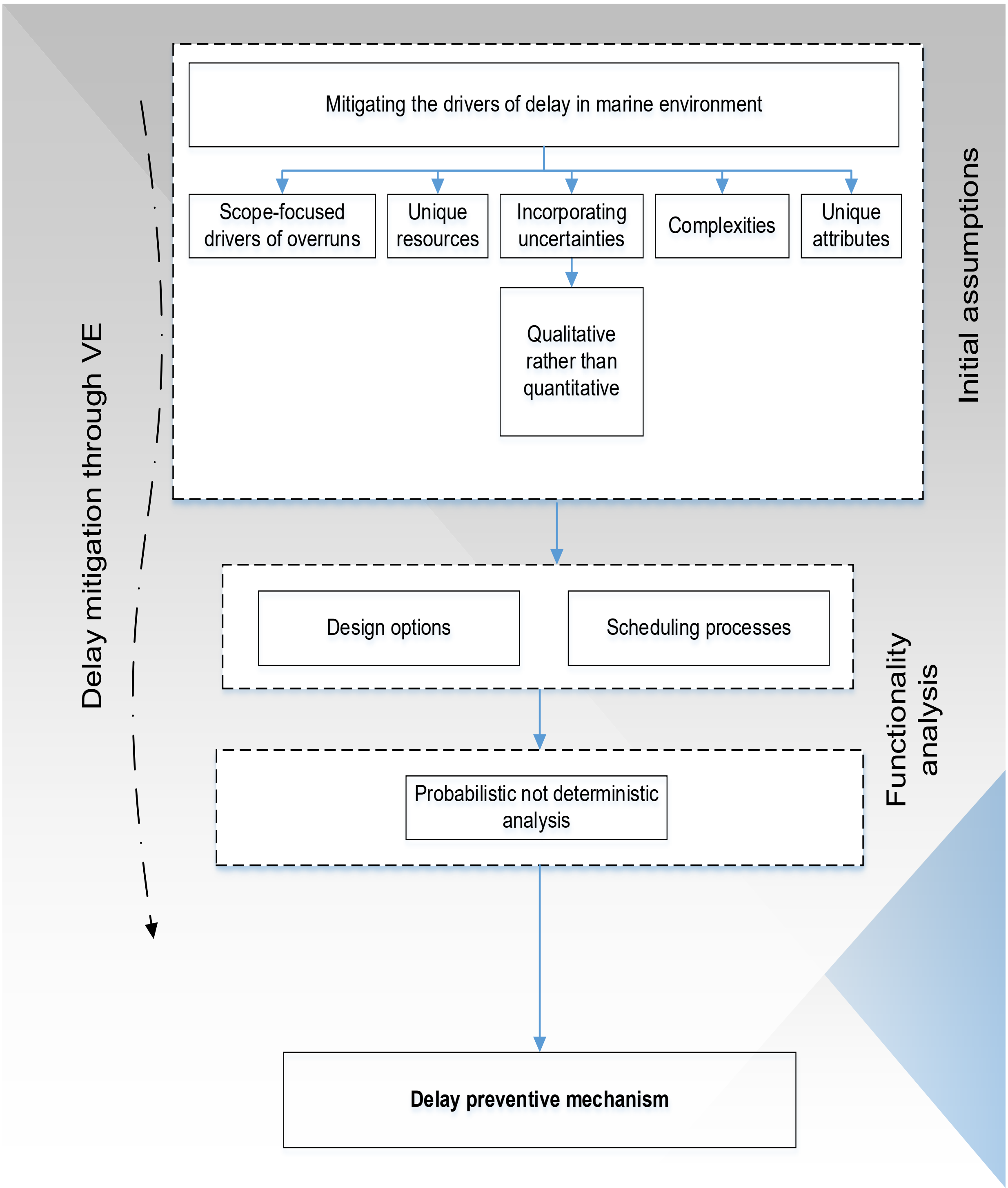


Figure 1.1: Proposed theoretical framework

1.7 Introduction to the Research Methodology

Many research issues have both quantitative and qualitative dimensions (Leedy and Ormrod, 2015). Researchers need to implement methods that are suitable to both paradigms to investigate them thoroughly. A mixed method approach was used in this study for this reason. A review of the literature was undertaken to determine the VE variables to be used in the questionnaire, which was structured so that key marine project stakeholders could offer their views on the importance of each variable. Moreover, an archival analysis of a VE report as a case study was conducted to examine the potential hidden variables and establish the validity of the review. The analysis involved a VE report for a jetty with a 35,000-ton-vessel capacity, located in the Persian Gulf's Kish Island of Iran. The VE variables applied in the project are outlined in the report. In addition, the scholarly literature was reviewed for initial cross-validation. Papers that contribute to the application of VE were reviewed. The review was then filtered to include only papers that discuss the use of VE as a tool in the construction industry to create innovative solutions.

Two criteria further streamlined the review: the use of case studies and marine construction as the scope of work. This helped to assess VE's practicability and functionality through various approaches. This process was complex, given the limited scholarly and empirical literature on the subject. Attempts were made to highlight the importance of this particular context for current and future work.

A questionnaire was distributed to VE experts, carefully selected from a range of positions including clients, consultants, project planners, construction managers, project engineers and technical office engineers. The criteria for inclusion were expertise in completing marine construction projects, extensive management skills and knowledge of VE workshops. Data were retrieved over a 12-month period. The questionnaire's purpose was to identify VE variables that would affect schedule efficiency. Participants were asked to rate 19 variables on a seven-point Likert scale from 1 (strongly agree) to 7 (strongly disagree) in terms of their impact or importance in the formation of marine project mitigation strategies. Iran was considered the primary focus of the research because the majority of data were accumulated from Iran construction projects. Nonetheless, supplementary data were gathered from Australia and several other countries.

Key protocols were developed by grouping the variables using factor analysis. SEM was used to analyse the covariance between observed variables. AMOS software was used in SEM of the obtained VE variables. The internal consistency of the dataset was calculated using Cronbach's alpha. External validity of the findings was investigated through an open-ended questionnaire, which helped in development of a model for ameliorating schedule performance using VE. Saturation point was achieved after 10 responses had been received.

Similar to VE, previous studies and literature reviews were relied upon to identify delay causation and collated into a questionnaire so that key stakeholders in marine projects could share their views on the importance of each variable. The questionnaire survey was administered to respondents and data were obtained. Participants were asked to determine the importance of 73 delay causations reported from the literature using a five-point Likert scale from 1 (extremely important) to 5 (not important at all). Subsequently, data were subjected to a reductionist methodology to explore the most important delay factors among those analysed. Factor analysis also helped to determine the relative statistical significance of the delay variables such that it is possible to assess items that are most important beyond their descriptive rankings. Additionally, the covariances among observed variables were developed into a SEM. AMOS software was used to create a SEM for the obtained delay variables. Internal validity and consistency within the datasets were measured by Cronbach's alpha reliability estimation procedure. As in VE, an open-ended questionnaire was conducted to examine the external validity of the findings, which was concluded after 10 responses.

1.8 Significance of Findings and Contributions to Knowledge

This study revealed a high frequency of delays in marine construction projects. Results of the survey indicated that 89% of participants described delayed completion in marine projects as common, giving the impression that major marine projects cannot be completed satisfactorily. This generates a major challenge for the theories of scheduling applied in analysing project duration in marine construction projects, especially concerning how planning strategies perform in the light of environmental uncertainties. Prescriptive approaches in the early planning stages are recommended by scholars as having potential for improving project schedules in marine construction projects.

This study presented VE as a possible approach to foresee or mitigate delays in marine projects. Participants in this research were experts from both research and industry practice. Four VE themes were retrieved from the experts' perspectives, verifying VE as an efficient method to mitigate delays in marine environments and underlying the importance of some practices. Ensuring accurate design in which knowledge and empirical evidence are integrated has been recommended as a determinant factor. Others include consideration of pilot studies during the design phase; maintaining detailed planning, including for risks and uncertainties; and assessing the practicality of different approaches and resources at the early stages of a project.

Further, the unique achievement of this research is the identification of delay factors important in marine projects, both by theme and by relationship. A reductionist technique was applied to group the factors of delay into 16 underlying themes: client–contractor interruptions; inadequate planning; safety practices; instructions and communications; management approaches; design and construction issues; organisational structure; political and cultural factors; environmental uncertainties; extreme and complex resources; activity estimation errors; owners' stagnant structure; financial issues; delay in approval processes; construction strategies; and marine equipment. Although some of the extracted variables are important in other projects, they relate differently to marine construction projects, and their potential consequences will be significantly different.

Exploring drivers in a particular project environment can alleviate delay causations. This is indeed a useful approach that helps to develop mitigation measures, both preventive and corrective, and supports stakeholders and the project management community in marine construction projects in better evaluating the sources of overruns; and improving scheduling methodologies, decision-making policies and management practices.

1.9 Structure of the Thesis

This thesis contains nine chapters. Chapter 1 begins with a brief introduction to the study's central theme, the purpose of the study and potential approaches that can be adopted based on the project environment. Following this, the research problem and its significance is discussed and research questions initiated. Further, research objectives are outlined, followed by the theoretical framework and the methodology by which the study will achieve the objectives. Finally, the findings and their importance for stakeholders in marine projects and the research community are discussed. The outcomes of this study in the form of conference and journal papers are listed at the beginning of this chapter.

Chapter 2 presents a review on VE and VM methodologies using the wealth of existing knowledge. Key factors in each approach; similarities and differences in their application; and their outcomes and effectiveness in project schedules are discussed.

Chapter 3 provides a precise review of the literature on different aspects of marine projects including unique attributes, significant delay causations and how to justify dedicated mechanisms—in this case VE—to mitigate delay causations.

Chapter 4 describes the research methodology applied in the research; that is, how the study objectives were achieved, the nature of the data used for the study and how they were analysed.

Chapter 5 presents a preliminary data analysis. To cross-check variables that did not emerge from the literature review, establish the validity of the review and further investigate the topic using particular examples, an analysis of archival data was conducted. A case study report that was relevant to the study's topic assisted in reinforcing the variables before proceeding towards the primary data collection.

Chapter 6 presents an analysis of all the results obtained utilising different survey instruments including questionnaires and case studies conducted as part of the data collection process for this study. The chapter also develops a structure for the covariances among the obtained combined variables using SEM and reviews model fit indices. The model obtained from exploratory factor analysis (EFA) was validated using SEM as a particular statistical method to determine to what degree the model obtained matches the data. In other words, through confirmatory factor analysis (CFA), the structure of the observed variables was verified.

Chapter 7 discusses the open-ended questionnaire results to evaluate the external validity of the findings. This is a process of model validation in which findings are assessed and commented on by experts in the field.

Chapter 8 explains the implication of findings from this study and how they might influence scheduling strategies and assist in the establishment of dedicated mechanisms applicable in scheduling theories to mitigate and correct impediments caused by overruns in marine construction projects.

Chapter 9 presents the conclusions from this research and provides guidance for industry practitioners to further develop and improve project performance.

1.10 Summary of the Introduction Chapter

Outcomes from this study in scholarly publications were discussed at the opening of this chapter. This was followed by a brief mention of the significance of the project environment when discussing drivers of overruns and potential mitigation approaches. The general failure to implement these approaches, mainly VE in marine projects, was highlighted in this section. Further, the flow of the study in regard to its objectives and initial findings was briefly explained.

The central theme of this research was summarised in the next section as ‘mitigating delay causations in marine construction projects using VE processes’. This was followed by an introduction to the importance of potential VE processes other than just their cost-trimming capability and how they can impact scheduling performance in marine projects.

The significance of the proposed research problem and how pivotal marine infrastructures can be for both public and private investors was investigated in a later section. This led to posing of the following research question: How does value engineering help to improve schedule performance in marine construction projects?

Based on the research question, the objectives of the study were outlined. The theoretical framework of the study was illustrated in a figure and briefly discussed. Further, an introduction to the methodology applied in this study, including the data collection tools, participants, sample size and statistical analysis used was provided. The frequency of delays in marine projects, challenges involved in scheduling theory, environment-related delay causations and potential of VE as a mitigation mechanism were determined as potentially important findings. Finally, the thesis framework was reviewed at the end of the chapter.

In the next chapter, the focus is on definitions of VE and VM and the capability of each method at different stages of construction projects. With respect to marine construction projects, the practicality of VE in scheduling theories and addressing potential issues throughout the lifecycle of projects is examined.

CHAPTER 2: VALUE ENGINEERING AND MANAGEMENT

2.1 Statement of Purpose

The main intention of this chapter is to introduce VE as a strategy development method applicable to expert collaboration in the achievement of optimal solutions to assist successful completion. The functionality of this methodology in marine construction projects and how VE protocols can help in scheduling processes are investigated. The main focus is on incorporating the uniqueness of this scope of work into design and scheduling options to achieve optimal outcomes. Elements investigated in this chapter are VE and VM, the theory behind each method and differences in outcomes from employing them. In addition, the practicality of applying VE approaches in strategy formulation; detecting and eliminating triggers of schedule and cost overruns; enhancing project implementation; and managing stakeholders are validated through a literature review.

2.2 Value Engineering

The term 'value engineering' was first used to refer to value analysis (Cooke, 2014). The requirement to analyse and engineer project value dates back to World War II when Lawrence Miles was assigned to find alternative ways to overcome material scarcity constraints. His emphasis was on the functions a service was meant to perform. He then developed alternative ways of achieving the same functions without compromising quality. This concept is now adopted broadly in the construction industry, and its effective implementation has been reported in many projects. Cheah and Ting (2005) argue that the generic structure of VE makes it applicable to different forms of project. They also outline how the implementation of VE can result in improvement in the culture of teamwork and effective interaction between stakeholders. Tang and Bittner (2014) adhere to this claim, and believe that 'in collaborative decision making for marine construction projects involving various stakeholders from multiple disciplines, the widely adopted VE approach will facilitate cross-disciplinary teamwork for effective problem solving when facing uncertainties'.

Mousakhani et al. (2017) validate the practicality of VE by presenting a comprehensive framework for implementing VE in road construction projects. Tohidi (2011) goes further and highlights the application of VE in various industries such as 'automotive, information technology, project management, transport (road and traffic), health, chemical industry, food industry and construction management' for over 70 years.

Most studies indicate that the VE process includes the collection of data on alternative options for project components, their expected lifetime efficiency and planned functions. Bínová (2014) explains VE as a tool that can be used to increase project value by monitoring the cash flow and schedule from the early stages to the completion of construction. The author describes this process as the review by a team of experts of project functionality, scope and specifications, tender documents and other dimensions of the project such as risk, contract implementation and policies.

According to the Society of American Value Engineers (SAVE) (2017), VE is a systematic approach used to maximise the value of a project. The ideal outcome can be achieved through the collaboration of a multidisciplinary team with project-relevant skills and expertise. Yan (2012) argues that VE has emerged from a number of technical processes targeted at improving the effectiveness of project costs, such that it is possible to obtain the lowest lifecycle cost without compromising the quality and project schedule. Ilayaraja and Eqyaabal (2015) describe VE as a management technique with substantial potential to solve difficult problems and make decisions aimed at mitigating overruns while meeting the required level of functionality.

Evidence from the literature suggests that VE does not represent a critical review; rather it helps to improve project function and value. This approach can help to predict issues so that stakeholders can formulate attenuation and prevention strategies well before an adverse event occurs (Leung and Wong, 2002; Atabay and Galipogullari, 2013; Tang and Bittner, 2014). Overall, the literature defines VE as a common tool whose parameters apply to all projects, irrespective of their uniqueness. Moreover, it is useful in protecting and optimising predefined budget and performance functions by evaluating alternative methods and resources to achieve project objectives. A conclusive definition for VE operation includes the following:

- The initial inputs for the implementation of the VE method are a description of issues along with the project details.

- Control mechanisms in the VE method determine the conditions under which the efficiency of an alternative should be measured. Moreover, limitations such as schedule, resources or even technical requirements are precisely investigated.
- The structures for the VE procedure define its stages as well as the frameworks required for each stage.
- Ultimately, the outcome is a VE protocol stipulating the improvement of the project with respect to functions required and other benchmarks such as budget, schedule, quality and safety.

Nowadays, VE is focused on collaborative team activities to create and develop the best solution to mitigate issues that may evolve over the life of a project (Cooke, 2014).

2.3 Value Management

According to Qiping-Shen and Yu (2012), VM evolved from a scope expansion and development of approaches to VE. The term was first used in 1974 by the General Services Administration of the USA to illustrate the use of value techniques at the management level. Qiping-Shen and Yu explain that in the 1960s, VM processes were recognised in Australia as a management strategy rather than an engineering method. Ilayaraja and Eqyaabal (2015) describe VM as a project management framework, broad in scope, that applies the results of VE workshops to deliver value throughout the project lifecycle and satisfy stakeholder requirements. Luo et al. (2011) underline the client-level practicality of VM by defining VM as a tool that enables clients to identify and communicate their requirements for the functionality of their project components. Their objective in this is to develop ideas that can facilitate the required level of functionality, such that at a later stage, they are able to evaluate and accentuate practical performance proposals that benefit projects during development.

A similar concept is evident in the work of Othman and Abdelrahim (2019), who explain how VM provides a client with ideas about a project's intended benefits through the implementation of certain procedures that generate and optimise benefits while minimising the use of resources. Similarly, the VM methodology promotes understanding of stakeholders' priorities and their expectations with respect to project achievements. According to Qiping-Shen and Yu (2012), this method serves as a standard language enabling stakeholders to work together to identify development opportunities and discuss potential issues at the very early stages of the project.

VM was recognised officially in Australia in 1977 and 20 years later became a prerequisite for major government contracts in some departments, including the New South Wales Department of Public Works and Services (Spaulding et al., 2005). Although employing VM techniques is not mandatory for all circumstances in Australian Government contracts, contractors are encouraged to apply value creation strategies to capital projects (Daddow and Skitmore, 2005). Based on the findings from a study by Bowen et al. (2011) on the South African manufacturing industry, most project designers still consider VM as a methodology for reducing costs. This erroneous conjecture and lack of guidelines on the practicality of VM in various areas needs to be addressed. This provides a pathway for future studies, especially in the construction industry.

2.4 Elements of Value Engineering and Value Management

The normative literature seems to agree with the popularity of VE for major construction projects. Elias (1998) defines the overarching purpose of VE as a methodical approach to maximise the functional value of a proposed project by ingraining the ideals of value for money and quality performance. Employing VE will ameliorate stakeholder satisfaction through improving project performance (Gayani and Kosala, 2017). According to Yan (2012), the process requires a team of experts to interact and generate new ideas regarding optimum solutions that can promote maximum value. Along with the experts, having a goal-oriented strategy driven within the project governance structure is not least important. The wealth of literature regarding VE indicates that most researchers believe in a similar approach involving five stages aimed at reducing overruns and improving functional value of projects (Table 2.1). The initial stages consist of knowledge sharing on risk domains and design options followed by an analysis of functions. Further steps are the evaluation of probable alternatives, development of the final outcome and the conclusion of optimum implementation plans (Ilayaraja and Eqyaabal, 2015; Wao, 2015).

Table 2.1: Stages in VE workshops (Ilayaraja and Eqyaabal, 2015; Wao, 2015)

Stage	Description
1	Information sharing on risk domains and design options
2	Analysis of functions
3	Evaluation of probable substitutions
4	Developing the final outcome
5	Eliciting optimum implementation plan

Similarly, Barton (2012) argues that the same stages of VE are involved in VM. However, VM protocols are intended to create value through evaluating constructability and profitability of a proposed project. A group of stakeholders with diverse expertise from multiple departments form the team. They represent relevant government agencies, clients, contractors, consultants, economic and law organisations, and are more in number compared with VE protocols. The intention is to assess the principal purposes, to form the conceptual design needs. Barton identifies the different stages of the VM process as knowledge sharing and idea generation, evaluating ideas, developing ideal options, making final proposals and providing a job plan; a similar process to that of VE. Othman and Abdelrahim (2019) argue that VM provides the opportunity for a team of experts to develop effective and innovative alternatives and decisions. They present a five-stage VM strategy (see Table 2.2) similar to those of Norton and McElligott (1995) and Barton (2012).

Table 2.2: Value management workshop stages

Stage	Description	Objective
1	Information input	Recognising the project, its functions, and design and operation elements
2	Creativity phase	Brainstorming to generate alternative ideas considering the basic requirements
3	Evaluation of potentials	Evaluating ideas generated in the last phase from different perspectives
4	Development	Developing the idea selected in the evaluation phase and looking into it in more detail
5	Optimum solution	Summarising the optimum solution and proposing the final outcome

2.5 The Difference between Value Engineering and Value Management

Based on Barton (2012), differences between VE and VM are not accepted universally among scholars, and both can be utilised to achieve optimal value in projects. In the view of the author, in addition to cost reduction, VM often considers other drivers such as economic, environmental and political factors, that could affect value generation. In other words, while VE focuses primarily on the short-term context, the VM methodology explores the broader perspective by analysing the main purposes for evaluating a project's constructability and profitability.

The Australian Standard Committee (2007) suggests that a workshop is still mandatory, regardless of the definition utilised. The emphasis is constantly on enhancement of project value. VE and VM have evolved over time. Cheah and Ting (2005) and Qiping-Shen and Yu (2012) state that VE was first used in the manufacturing sector before its adoption in 1959 in the construction industry. They also state that VM was first used in 1974 by the USA General Services Administration to demonstrate how value strategies can be used at an organisational management level.

Bínová (2014) articulates that VE protocols should be regarded in the initial stages of a project, including design and construction, to better assist project implementation plans. Others hold different opinions, concluding VE can be implemented effectively in various ways throughout the lifecycle of a project (Ilayaraja and Zafar Eqyaabal, 2015). Conversely, VM is typically applied at the feasibility stage of a project, although Whyte and Cammarano (2012) argue that VM is applicable at all stages of the lifecycle upon a client’s request. Scholars have listed VE's objectives as eliminating or reducing the propensity for overruns; exploring alternate methods of implementation and resource optimisation; and evaluating the potential for substitution, combining, adjusting and increasing functions that enhance a project’s value (Zhang et al., 2009; Fard et al., 2013; Bínová, 2014; Wao, 2015). However, Whyte and Cammarano (2012) consider that VM’s principal purpose is to determine the constructability and financial viability of a project for shareholders by evaluating various proposals that match their needs, to achieve maximum value.

Generally, VE and VM are ideal for projects where there is a significant financial investment, including complex projects where multiple risks are recurring, and intense projects where operations are repetitive, designed and built to unique specifications with budget and schedule constraints (Qiping-Shen and Yu, 2012; Ilayaraja and Eqyaabal, 2015).

Shaw (2016) provides a precise definition regarding VE and VM in an article presented on a website that outlines both methodologies as essential functions of value for money in construction. Shaw identifies VM as a method that underlines the potential for value creation within a project and manages value delivery. It embraces all phases of the project and is applicable from a feasibility study to the operation phase, and even after. The procedure seeks to achieve an optimum balance between cost, schedule and project performance. Shaw also highlights the main advantage of VM as providing a clear pathway to improve each project by recognising stakeholder needs and objectives.

Similar to VM, Shaw believes in the applicability of the VE technique throughout all stages of a project; not only following cost elimination but also aiming at value improvement. With collaboration among experts in different disciplines, VE analyses alternative solutions to eliminate unpleasant overruns, cost and time; in particular, without compromising functionality and quality.

It is a subject of some debate among professionals in the construction community whether VE is simply a cost-cutting tool. Shaw argues that the purpose of the VE approach goes beyond mere cost reduction. It underlines diverse solutions and provides a project with efficient methods that enhance value and improve project performance. Like most critics, Shaw believes in early implementation of both VE and VM, although projects can profit at any stage with different levels of effectiveness. Both methodologies pursue the same objective and ideal accomplishment—by means of managing and developing ideas (VM) and utilising alternative methods and resources (VE). A functional comparison of VE and VM from different perspectives is illustrated in Table 2.3 by reference to scholarly works.

Table 2.3: Functional comparison between value engineering and value management

	Value engineering	Value management
Where/ Lifecycle stage	➢ Basic and detailed design ➢ Construction ➢ Completion and operation in special circumstances See Bínová (2014); Ilayaraja and Zafar Eqyaabal (2015)	➢ Mainly briefing stage and feasibility study ➢ All stages in case of any problem or upon client's request See Qiping-Shen and Yu (2012); Whyte and Cammarano (2012)
Why/Purpose	➢ Reducing overruns without affecting quality ➢ Improving project performance ➢ Maximising functional value See Zhang et al. (2009); Fard et al. (2013), Bínová (2014); Wao (2015)	➢ Obtaining maximum value for the project ➢ Evaluating diverse proposals matching client's requirements considering economic, environmental, political and other factors ➢ Identifying constructability and profitability of the project See Whyte and Cammarano (2012); Bínová (2014)
Type of Project	Applicable in all industries' projects with the following characteristics: ➢ High cost ➢ High complexity ➢ Recurring tasks ➢ Special specification ➢ Tight budget ➢ Tight schedule See Ilayaraja and Zafar Eqyaabal (2015)	Like the VE methodology, VM can be utilised in different industries to determine the constructability of projects See Qiping-Shen and Yu (2012)
Any change in practice over time	➢ First application was in the manufacturing industry by Lawrence Miles ➢ Became popular and efficient in other industries, particularly construction ➢ First applied in a construction by Dell 'Isola in 1959 See Cheah and Ting (2005); Qiping-Shen and Yu (2012)	➢ VM evolved from scope expansion and development of approaches to VE ➢ The term VM was first used in 1974 by the General Services Administration of the USA to show use of value techniques at the management level as well See Cheah and Ting (2005); Qiping-Shen and Yu (2012); Whyte and Cammarano (2012)

<table>
<tr><th></th><th>Value engineering</th><th>Value management</th></tr>
<tr><td>What people do during the process</td><td>Searching for alternative methods to reduce overruns and add value following the below stages:
➢ Information compilation
➢ Functional analysis
➢ Generation of ideas
➢ Evaluation
➢ Development and conclusion
See Ilayaraja and Zafar Eqyaabal (2015); Wao (2015)</td><td>The same stages as VE are involved to evaluate constructability and profitability of the project
A group of stakeholders and experts, larger than that for VE, assesses the principal purposes to form the conceptual design needs
See Barton (2012)</td></tr>
<tr><td>How VE/VM impact strategies to prevent delays/Variables</td><td>➢ Alternative resources:
• Easy to access and provide
• Saving time for procurement
• Schedule performance
➢ Implementation methods:
• Less confusion in construction
• Having step-by-step work breakdown
• Ability to allocate resources easily
➢ Pilot study about ground conditions; near shore projects in particular:
• Preventing unpredictable issues and delays
➢ Flexible timetable:
• Ability to compensate for lost time due to severe weather conditions
➢ Involving contractors:
• Integrating expert knowledge into design options
• Reducing design errors
• Reducing time overrun
➢ Monitor/optimise resource allocations:
• No overrun due to lack of resources or over-allocation
➢ Having appropriate procedures to deal with repetitive tasks and mass production; e.g. pre-cast and pile preparation in marine works:
• Saving time in construction and execution by using practical methods from similar projects
• No time overrun due to lack of resources
See Elias (1998); Cheah and Ting (2005); Whyte and Cammarano (2012); Wong and Vimonsatit (2012); Aje et al. (2017)</td><td>➢ Developing the most practical and efficient option to feed design stage:
• Less time-consuming design phase
• No need to redesign
➢ Considering all factors affecting the project such as environmental and political consequences:
• No limitation or restriction during the construction or operation phase to stop the project which causes delay
➢ Determining the most constructible and profit-making project during VM workshop:
• Less time and cost overrun in project lifecycle
• No need to spend time to redesign
See Whyte and Cammarano (2012)</td></tr>
</table>

2.6 Value Engineering and Function Analysis System Technique Diagram

Charles W. Bytheway developed the function analysis system technique (FAST) diagram and presented it in a paper introduced at the 1965 SAVE national conference in Boston. Since then, FAST has been widely used by government agencies, private enterprises and VE consultants. FAST refers to a complete plan, system or process that involves interrelated steps or a sequence of actions (Mandelbaum and Reed, 2006). There are three types of FAST diagram: customer-oriented, technical and classical. Bytheway (2012) describes all diagrams as ‘creative thinking processes that focus on the determination of the technical functions of a product and the technical solutions connected with these different functions’. The last two types of diagram apply to construction-oriented projects. Despite differences in the diagrams, the structure and underlying theories applied by VE experts follow similar approaches. The basic steps in FAST are (Fowler, 1990):

- defining the task function
- identifying the key fundamental functions
- describing the key supporting functions
- expanding the FAST diagram to the right
- verifying the FAST diagram.

A generic FAST diagram is shown in Figure 2.1.

In FAST diagrams, a function description is defined as an active verb and a measurable noun using a two-word format (Borza, 2011): for example, ‘decrease voltage’, ‘generate income’ and ‘increase cost’. In limiting the explanation to just two words, participants are required to describe clearly and succinctly what task needs to be undertaken, not how it is conducted. This removes the product's physical constraints from planners’ thoughts and allows them to explore alternatives more easily. The structure of a FAST begins with use of the two-word format and expansion of the diagram from the left-hand side using the function that best explains the main objective of the project.

In essence, FAST allows the researcher to objectively think about issues. The technique helps by revealing conceptual relationships among components to define the scope of a project. In addition, a FAST diagram can be used to evaluate whether a proposed solution meets the project's needs and to define irrelevant, duplicated or incomplete functions (Value Analysis Canada, 2019). Beneficial impacts of FAST for projects include risk mitigation, improved efficiency and well-managed scope (Shiimi, 2018).

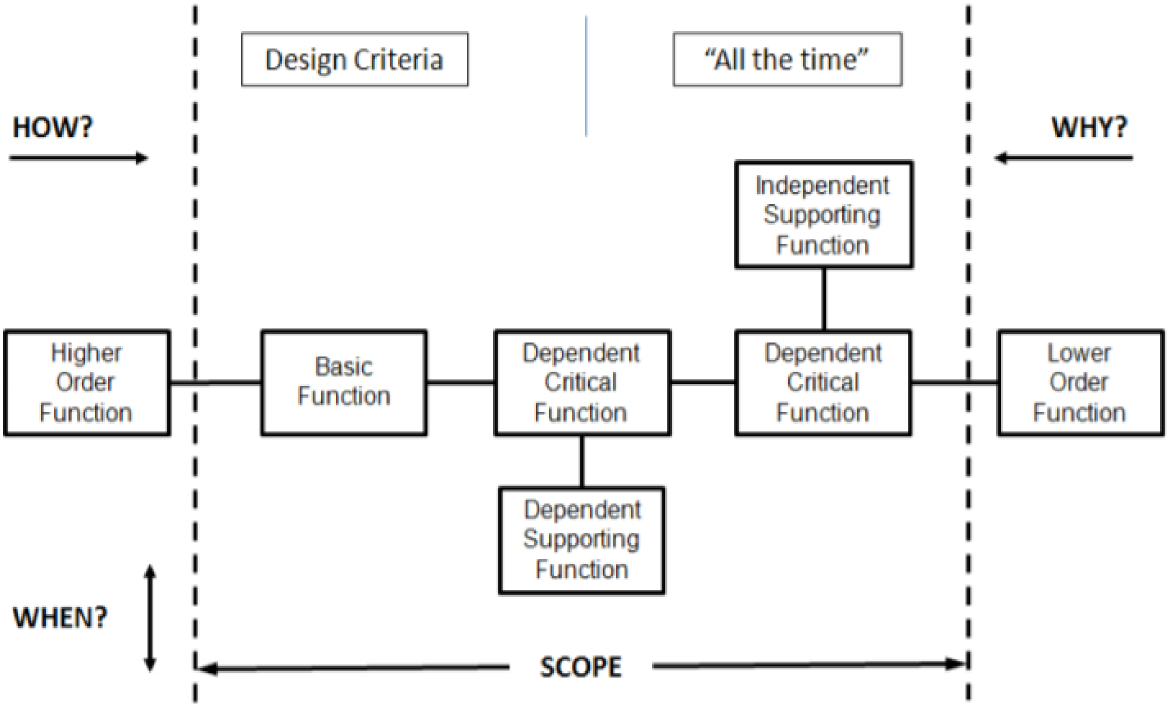


Figure 2.1: Generic FAST diagram (Source: Borza, 2011)

2.6.1 Benefits of the Function Analysis System Technique

A FAST diagram is a creative thought process that facilitates team interaction. Value Analysis Canada (2019) lists some of the benefits of FAST diagram as including:

- Using a FAST diagram helps build a mutual understanding among a project's team members.
- Incomplete functions of the project/service can be identified through a FAST diagram.
- A FAST diagram helps to identify and clearly observe issues related to the functions.
- Functional relationships can be arranged and recognised through a FAST

diagram.

- FAST is useful in identifying a task, method or product's basic purpose.
- Using FAST enhances interactions among disciplines.
- Creativity in a team can be encouraged through the use of the FAST technique.

2.6.2 Steps in Construction of a Function Analysis System Technique Diagram

Value Analysis Canada (2019) recommends following a flowchart beginning with functions identified using a function analysis, as shown in Figure 2.2.

The process begins by developing the functions in the 'How' and 'Why' orders. Starting with the 'How' direction, the effort should be in developing an answer in a two-word form to the question 'how is the function achieved?'. Further, the reasoning for the 'Why' path should be checked. This is achieved by asking 'why is this function performed?'. When the logic is not working, the order for any incomplete or incompatible functions should be defined or modified. There might be some tasks in a project that occur at the same time. Classifying concurrent tasks and developing the diagram is achieved by asking questions such as 'When this function is done, what else is performed or triggered by the function?'. The higher order functions (see Figure 2.1) explain what is being performed and the lower order functions clarify how they are going to be completed. It should be noted that 'When' in the FAST diagram does not apply to time as determined by a clock, but to processes that occur with or as a result of each other.

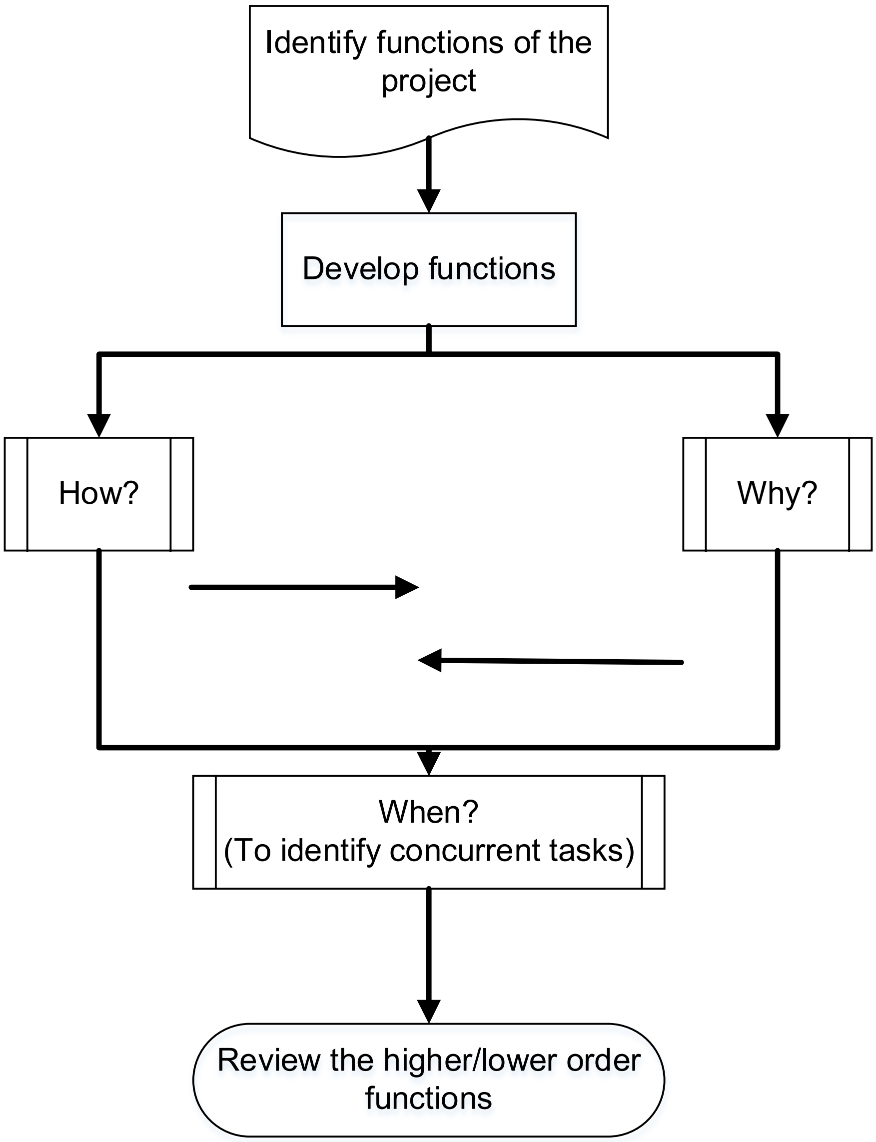


Figure 2.2: Steps in construction of a FAST diagram

This method concludes with a diagram in which the logic of the functions can be illustrated and examined (Kaufman and Woodhead, 2006; Jay and Bowen, 2015). In the view of Mousakhani et al. (2017), this structural diagram displays how functions are linked and the path to the accomplishment of the project. This is similar to the view of Nayebvali et al. (2014), who consider that FAST, in its diagrammatic form, responds to 'why', 'how' and 'when' questions by illustrating the logical relationships between existing functions. In other words, the diagram examines questions such as why a feature exists, how it delivers its potential, and when it performs in structural dependency (Watson and Spiridonova, 2019).

Scholars are in agreement regarding FAST's practicality as a problem-solving tool that facilitates the recognition of functions and their relationship (Nayebvali et al., 2014; Shiimi, 2018). Creating a comprehensive FAST diagram highlights potential problem areas and helps better understand the requirements related to those unique constraints. This assists in reducing potential interruptions during the implementation phase and improves a project's schedule.

2.7 History of Value Engineering Application in Iran

VE implementation in Iran dates back to 1975, but there has since been no development and it has remained silent for many years. Finally, after a long suspension in its use, all executives and construction companies were asked by the government to review their projects by applying the VE technique. This requirement was based on paragraph C of Article 61 of the *Third Development Plan* for the country. This accelerated movement towards the re-application of VE strategies and the establishment of VE in 2001 (Ghamarnia et al., 2008).

Nowadays, the Society of Iranian Value Engineering (SIVE) is the authority that develops and implements standard VE protocols in Iran. SIVE adheres to global VE practices by conducting VE workshops and using this technique to review project activities from the initial stages to commissioning and operation. The aim is always to satisfy the predefined time and schedule without compromising quality. SIVE also seeks to stay up to date with global VE standards by determining and adopting improvement plans, including:

- Running conferences and seminars for the advancement of VE at the national and international level
- providing scholarly content to members and keeping them up to date on the effective adoption of VE in various industry sectors
- publishing monthly newsletters and enhancing a knowledge and value culture
- facilitating interaction with other associations at an international level.

Nevertheless, every year the region suffers an enormous amount of damage caused by incomplete construction projects (Khademi and Beheshti, 2014). It is observed in most projects that the initial estimated cost and time are substantially overrun and that in some circumstances the implemented projects are not economically justified because of the absence of a rigorous management strategy. This is evident in a report prepared by the Office of Monitoring and Evaluation of Plans in Strategic Management and Supervisory Organization of President (formerly, the Management and Planning Organization). The authors conclude that inappropriate cash flow and excessive costs of project functions are the key drivers of such failures. From the authors' point of view, VE is the only strategy capable of cost reduction that can enhance a project's qualitative requirements. In this technique, innovative ideas can be developed to improve the project's schedule, quality and budget.

A study conducted by Kalani et al. (2017) also shows a significant increase in predefined time and cost of projects in Iran between 1995 and 2002. The authors believe in VE's practicality for overcoming these issues and outline obstacles that hinder the implementation of VE in the construction industry in Iran. The main hindrance factors include lack of familiarity with VE and its benefits, unsupportive investors and owners, lack of robust legislation by the authorities and skill shortage in this field.

Fard et al. (2013) identify additional hindrance factors for employing VE protocols in the Iran construction industry. The authors define the scope change enforced by clients; obsolete standards and regulations; lack of positive attitude; lack of local instructions and information; and inexperienced people involved in projects as important factors. Fard and colleagues highlight a knowledge gap as the unfamiliarity of clients/owners who overlook VE as a necessary clause in contract documents; and outdated organisational standards.

Overall, there is evidence that the design phase lacks innovation (Shahhosseini et al., 2018). These authors verify this with a case study on a gas refinery's water transmission system at Reno Mountain in Iran. Similarly, Khademi and Beheshti (2014) underline the deficiency of the design process in their investigation of a case study involving an underpass in Gachsaran, Iran. To this end, one of the best tools is the VE technique. Technically, this is the way in which an undesirable phenomenon can be pre-assessed and alternative solutions developed.

Iran has recently experienced a substantial increase in investment in the construction industry, including marine works, which plays a major role in facilitating the extraction and export of products to regions around the world. However, unpredictable challenges can affect such projects. Despite their uniqueness, they have similar VE protocols to those used in other projects. Previous research shows that issues that can be resolved with VE procedures, including cost and time overruns, are still prevalent in marine projects. This study aims to define key VE protocols for marine projects and their relative importance in avoiding scheduling issues.

2.8 Practical Applications of Value Engineering and Value Management

Given the wealth of literature on VE and VM, both approaches apparently follow similar procedures, yet each yields a different outcome (Barton, 2012; Whyte and Cammarano, 2012). For example, both methods involve knowledge sharing; idea generation; evaluation and development of alternative solutions; and articulation of implementation plans (Yan, 2012; Ilayaraja and Zafar Eqyaabal, 2015; Karunasena and Rajagalgoda Gamage, 2017). However, nuances in outcomes emerge when deploying each method.

2.8.1 The Potential of Value Engineering and the Nature of Outcomes

VE is used when it is essential to measure the functions of particular design elements; analyse alternative options in terms of construction/implementation methods and resources; evaluate the likelihood of substitution; and combine, adopt, modify, magnify or eliminate a task to improve value (Barton, 2012; Ilayaraja and Zafar Eqyaabal, 2015). As a result, outcomes from VE processes could be in the form of technical advice relating to alternative design options and construction methods, most of which are measurable; in particular, in terms of time and how such options affect the project schedule. An example is considering steel piles as an alternative to concrete soldier piles in a quay wall jetty, which requires a robust evaluation of changes. A group of VE experts will be involved in a VE workshop to analyse these alternative options.

Using a function analysis, for example, they will develop diverse ideas and reach a conclusion that satisfies the project requirements. Modifications aimed at project value improvement will be analysed against the primary schedule to prevent any imposed time overruns on the project. Such changes will require re-strategising of resourcing (e.g. whether different equipment and materials could be used to improve speed, safety, quality, cost and function of the element being built); revising the assumptions upon which design considerations have been made (e.g. geotechnical); and working out ways or approaches (e.g. cash flow and construction methods) that best support project implementation plans; among other actions.

To summarise, factors that may affect schedule performance can be analysed through VE processes, and their value/impact for the project can be engineered by eliciting alternative options that may help reduce the likelihood of overruns at different stages of the project lifecycle. This is the single most important reason why VE has been selected for this study: theoretically, it is appropriate; and technically, it is the best approach to pre-assessing delay causations while alternative solutions are being developed.

2.8.2 The Potential of Value Management and the Nature of Outcomes

VM is a functional design management mechanism with the potential to examine the bigger picture of project development processes. It can be employed where there is a requirement for the evaluation of the principal purposes to manage value throughout project lifecycle stages. According to the Australian Standard on Value Management (2007), the term VM embraces VE. Qiping-Shen and Yu (2012) argue that VM maximises the functional value of a project by managing its development from the concept to the operation phase. In other words, VM supervises the outcome of a VE workshop to improve the project's performance. This is confirmed by Shaw (2016). In the above example involving the jetty project, underlining the possible alternatives (steel piles *v.* concrete piles) and eventually managing the development of the solution is part of the VM process aimed at improving value. Factors affecting value improvement and practical methods to obtain the best functional value as identified during a VE workshop are monitored and controlled by means of VM. Barton (2012) emphasises this very emphatically. He argues that measurements used in the VM process are qualitative, which requires implementing non-build solutions; whereas VE focuses on technical recommendations regarding the actual building process. An example cited by Barton involves the issue of traffic congestion at a main road intersection, as a VM team responsibility. Considering the many potential solutions, this problem is highly complicated. Solutions include applying alternatives such as a demand management strategy, improving the public transport system, developing travel habits of road users and considering flyover/underpass bridges. These options can be combined to improve consequences. Measurements implemented in this process are likely to be qualitative (greater than or less than; better than or worse than). There is no single customer and many people are potentially affected by the decision.

On the whole, the functions of the component parts of a project can be measured and quantified against the schedule in VE processes. This approach is theoretically appropriate. From a technical point of view, it is effective in uncovering underlying issues while alternative strategies are being evaluated. However, because of the qualitative nature of the VM mechanism, it is not suitable for the purpose of definitively measuring and managing schedule performance. Barton (2012) accentuates elevating a project's functional value as the main focus of both methodologies.

2.9 Further Analysis of Value Engineering Parameters in Marine Construction Projects

Johnson and Tatum (1993) classify marine construction projects as those involving high-risk activities, intense investment and diverse fabrications, including jetties, ports, underwater pipelines, wharves, oil and gas platforms, breakwaters and bridges. Factors such as high-technology equipment, the technical soundness of project procedures and practical implementation methods are considered to improve efficiency and minimise risk in the marine construction industry. These authors identify a strong teamwork culture, technical efficiency and empirical experience from similar projects as specific variables in marine projects that can potentially be discussed in VE workshops and that may improve the organisational efficiency of future contractors.

After reviewing the literature, Duy Nguyen et al. (2004) identifies key indicators of success in marine construction projects as project manager proficiency; financial stability; a broad range of disciplines within teams; accountability and commitment of team members; and appropriate resource allocation. Precise protocols are required for the recruitment of contractors because of the pivotal role of humans in the abovementioned factors. Hiring appropriate individuals with expertise in the unique and multidisciplinary environment of marine projects is challenging. This justifies the need for the precise resource allocation involved in VE procedures. Likewise, Walker (1995) underlines the competency of the construction team as an important variable influencing on-time completion. Moreover, the author identifies schedule performance in line with cost and quality as a crucial factor in construction projects. According to Walker, competent management, project complexity and especially project scope all have a direct influence on schedule performance in the construction industry.

Marine construction projects are affected by a diverse range of impediments that can complicate their design and estimates, and affect construction activities (Johnson and Tatum, 1993). Each individual project requires a specific treatment based on its unique characteristics. Risky environments can endanger equipment and crews, while geotechnical variables can affect productivity. Accessibility and support are limited with respect to the outlying geographic areas in which marine construction projects are typically situated. It is vital to have precise mechanisms to foresee and prevent likely issues. Karami and Olatunji (2018c) argue that flexible timetables, pilot studies, plan-ahead techniques and special implementation methods can help improve the performance of marine construction projects.

The multidisciplinary nature of marine projects means that they are highly dependent on personnel. According to Johnson and Tatum (1993), the proficiency of the workforce at various levels is a determinant in marine construction projects. In this multidisciplinary environment, objectives can only be achieved through the commitment of crew members who follow precise instructions aimed at attaining predefined goals. Efficient management strategies are of utmost importance for the effective coordination of projects. According to Sun (2010), ‘Marine construction projects rely on higher level equipment’. These projects represent massive investments, lengthy time commitments and a dynamic construction atmosphere. They have a significant influence both domestically and overseas. Marine contractors must hire or purchase specialised machinery and equipment for the construction phase. Sun points out that the high-end equipment required for marine construction is often booked up years in advance, presenting a challenge to planning. The author recommends that companies have in-house machinery departments so that contractors can plan in advance according to project specifications. It may even be possible to develop and customise the required equipment for project needs (Johnson and Tatum, 1993). The inability to allocate specialised resources according to scheduling can result in immense schedule and budget overruns.

Tam (2012) concurs with Gudmestad (2002) regarding risk management strategies as the path towards on-time completion of marine projects. The author outlines geotechnical uncertainties as the most common factor affecting design and scheduling in marine construction projects. This justifies the need for accurate pilot studies at the early stages of a project, prior to construction. Similar to other researchers, Tam believes in the practicality of this approach in improving project performance.

The challenging marine construction environment necessitates a systematic approach to address uncertainties and fulfil project requirements to a desirable level, safely and without compromising quality. Tang and Bittner (2014) identify VE as a systematic mechanism with the potential to evaluate issues and create innovative solutions suitable for the uncertain marine environment. In other words, having a VE team comprising experts who are experienced and familiar with marine construction at different stages can improve performance and increase the likelihood of the successful completion of projects on time and within budget. Samie (2016) emphasises the appropriate collaboration of different disciplines as a key factor in the multidisciplinary environment of marine infrastructure. Based on a case study at the Abuzar oilfield in the Persian Gulf, Younesi et al. (2017) explored risk assessment during the oil platform construction phase. The authors find that risk management as a predictive approach is capable of foreseeing uncertainties in construction activities and resolving likely issues. This could be discussed in VE workshops to prevent possible issues arising during the construction phase.

According to Abhishek and Kumar (2017), integrating expert knowledge into the construction phase of marine projects leads to improved performance and successful completion, and reduces the likelihood of overruns. Selecting the most appropriate contractors through an adequate selection model will prevent inaccuracies during the construction phase of a marine project and result in optimal project completion (Karami and Olatunji, 2018b). This would be more important when outsourcing activities to ameliorate schedule performance in marine projects. Hui et al. (2008) suggest that outsourcing leads to poor project outcomes if contractors are not adequately managed and organised. Conversely, Mahmoudi et al. (2020) propose a conceptual model for recruiting contractors when outsourcing tasks. They define the cost plus award fee contract as the most applicable alternative when outsourcing is required.

Based on a study of large projects in Vietnam, Nguyen et al. (2004) identifies comfort, competence, commitment and communication as four focal areas for successful completion. The inherent complexity and uncertainty in large construction projects, especially marine projects, demands specific management skills and dedicated mechanisms.

After reviewing the wealth of scholarly studies regarding engineering and construction issues in the marine environment, Tang and Bittner (2014) identify two primary factors—dynamic conditions and uncertainty—that hinder marine construction projects at different phases. The authors consider VE a problem-solving tool for evaluating key variables based on a solid understanding of a project’s domain and specifications. Gunduz and Yahya (2018) highlight the central role of project managers and management tools at the early stages of a project lifecycle, particularly the planning and design stages, to successfully deliver a project.

Variables that ameliorate performance can be defined and implemented at various levels. These variables can take on different forms according to project characteristics and requirements: for example, they may be in the form of technical instructions (e.g. construction methods) to improve the functionality of components or part of a strategy aimed at improving project performance and reducing probable risks (e.g. plan-ahead techniques). Some variables are unique to marine projects and should be considered when undertaking specific tasks in the erratic marine environment (e.g. dynamic timetables). Moreover, certain factors in marine construction (e.g. an in-house machinery department) may be considered a privilege for contractors during construction and even at the pre-qualification stage.

In the present study, in accordance with the literature and empirical evidence, 19 variables pertaining to marine construction projects were identified that could be investigated during VE workshops (see Table 2.4). These variables were reviewed to establish a strategy for the purpose of mitigating delays and improving value.

Table 2.4: Value engineering variables

Variable	Description
1	Implementing methods for major tasks
2	Contractor involvement in integrating expert knowledge into design options
3	Analysing alternative resources
4	Analysing alternative methods
5	Addressing activities that can be affected by weather conditions
6	Establishing a flexible schedule for activities that can be affected by weather conditions
7	Having a detailed work breakdown structure for critical activities
8	Specifying a budget for a pilot study to prevent unpredictable delays
9	Considering a pilot study in relation to ground conditions
10	Monitoring/optimising resource allocation
11	Having appropriate procedures for repetitive tasks and mass production (e.g. pre-cast and pile preparation)
12	Using practical methods from similar projects
13	Outsourcing mass productions (e.g. pre-casts) to save time
14	Monitoring weather conditions daily to plan ahead for severe weather conditions
15	Using up-to-date technology in design options if possible
16	Considering previous studies on similar projects in the region
17	Using plan-ahead packages to deal with inclement weather conditions
18	Involving industry experts in the creativity phase of VE workshops
19	Using expert knowledge to analyse the duration of initial tasks on major activities to ensure accuracy

2.10 Summary of Value Engineering and Management

In this chapter, VE and VM strategies were discussed. Both approaches seek to improve value and function throughout the lifecycle of a project without compromising quality. Most scholars agree on the similarity of workshop stages, with the presence of experts in diverse disciplines related to the project's scope. Both include information compilation, function analysis, idea generation, final evaluation and presenting of conclusions. With early-stage implementation, the most benefit can be obtained, though the application is still helpful in other stages.

A comparison between VE and VM in terms of application processes and outcomes, based on the wealth of literature, was provided in this chapter. Table 2.3 provides a detailed functional comparison between VE and VM in this regard. Based on the wealth of literature and viewpoints of experts, probable influencing VE factors were identified. Most importantly, the practical application of both methods with a focus on different outcomes was outlined at the end of this chapter. In addition, the theoretical and technical choice of VE over VM in terms of minimising the probability of delay was justified and explained using some examples from a construction point of view.

Finally, the FAST diagram as a useful tool applicable in VE collaboration workshops was introduced. It is helpful in building a mutual understanding among participants, identifying issues related to different functions, facilitating the interaction between disciplines and encouraging creativity in the team.

The focus of the next chapter is different aspects of marine projects including unique attributes, significant delay causations and how to justify dedicated mechanisms—VE and its relevant techniques in this case—to mitigate delay causations.

CHAPTER 3: DELAY FACTORS IN MARINE PROJECTS

3.1 Introduction to Delay Causations in Marine Projects

Marine construction projects are among the most significant human alterations to the environment. They are a specialised division of the construction sector with a high degree of risk and vast expenditure (Johnson and Tatum, 1993). Examples of this segment of the construction industry include wharves, jetties, breakwaters, ports, tunnels and bridges. In the view of Bugnot et al. (2020), investigation of their intensive impact on aspects such as the economy has gained less attention than on-land projects, which has resulted in huge cost overruns. Bugnot et al. identify that in 2018, marine construction affected on average 1.5% (0.7–2.4%) of the 'global Exclusive Economic Zones', compared with 0.02–1.7% of urban areas being affected. Therefore, satisfactory completion in marine construction projects is paramount. Failure occurs when such projects do not meet their critical objectives, such as initial targets relating to cost, on-time completion, safety and quality, stakeholder engagement, environmental impact (sustainability), strategic outcomes (e.g. macro-economic targets), lifecycle functionality/performance and aesthetics (Pinto and Slevin, 1988; Flyvbjerg et al., 2004; Flyvbjerg, 2007). The overarching purpose of this chapter is to review global causations of delays, their point of relevance to marine construction projects and how drivers of delay could be mitigated in this scope of work by observing aspects such as unique characteristics. Because of the extent of budget required in both the public and private sector for marine projects, it is vital to understand how best to ameliorate schedule performance; measure the variables thereof; and determine how they interact to promote on-time completion. One way to facilitate this is by integrating marine-specific delay drivers and unique attributes into design options and scheduling strategies. The recent literature indicates limited differentiation between delay trigger factors and project domains. In other words, the project environment, as a quite nuanced and unique component of the construction industry, should be recognised and considered. Unless this uniqueness is thoroughly recognised, it is doubtful that new insights in delay causation debates will make much sense, particularly from a theoretical point of view.

Unique features of marine engineering projects include the complex equipment and services they require. The environment in which they operate is uncooperative for basic conventional processes. Such projects are inherently risky and unpredictable. In addition, they involve intensive cooperation from a variety of technical disciplines. According to Tam (2012), the uniqueness of marine projects is characterised by weather constraints and specific design concepts. These factors increase vulnerability to delays more than in other project contexts. Strategies used in earlier studies to alleviate project delays that were not unique to the specific project environment were unlikely to be ideal solutions for all project environments. Performance indicators including on-time completion for construction projects have been widely documented in the literature (Porter and Parker, 1993; Larsen et al., 2016; Peetawan and Suthiwartnarueput, 2018). However, most research in the area is not specific to the project environment and rarely addresses the unique characteristics of projects, especially those of marine construction projects. Improvement in project outcomes is likely to be substantial when mitigation measures are suitable for specific project contexts (Hunter and Kelly, 2002).

The path to successful completion of marine projects is likely to differ from that for conventional projects. However, there is limited research on this aspect in the literature. A review of the literature is necessary to explore views on marine construction projects and empirical evidence on delay agents, and to investigate how they impact marine projects. Overall, a key objective of the study is to identify the critical delay causations that are most prominent in marine projects.

3.2 Unique Attributes Associated with Marine Projects

Karami and Olatunji (2018a) categorise marine projects according to a complex spectrum. They identify that such projects are associated with ambiguity and uncertainty, interdependency, non-linearity, unique local conditions, autonomy, emergent behaviours and unfixed boundaries (Bakhshi et al., 2016). He et al. (2015) add technological, organisational, goal, environmental, cultural and information complexity to this list. A brief introduction to the common types of marine construction project is provided in Section 1.6. Over 33% of the earth’s land mass is surrounded by water. This aquatic environment provides ways for transport, helps industries with energy production, supplies food for people and intensively impacts the economy of most countries. Multinational corporations in this market typically build 'ports, underwater pipelines, cofferdams, docks, piers, outfalls, terminals, breakwaters, and bridges' (Johnson and Tatum, 1993). According to these authors, there is a need for detailed technical evaluation of project processes and construction strategies. Because of the competitive nature of the bidding stage, a low-cost competitive edge is required for construction firms in this industry. Moreover, particular functionalities are needed to gain a strategic advantage through differentiation, and marine construction projects require innovation and application of new technologies for successful completion. This can be accomplished through the constructive and systematic implementation of value creation strategies.

Uncertain environmental conditions and difficult access to construction sites make it challenging to achieve project goals in the marine scope of work; in particular, schedule and budget. The abovementioned attributes influence design, estimation and construction phase of these projects. Each marine project appears to offer its own distinct conditions in terms of weather uncertainties, geotechnical variation, design criteria and remoteness. Working within this unpredictable scope is extremely risky. Weather uncertainties can put equipment and resources at risk. Tidal currents are likely to restrict efficient operating times. Geotechnical assumptions are not quite deterministic; rather they are probabilistic, which leads to estimation errors and reduced productivity. Logistic support for remote project sites is problematic and challenges the scheduling process. Project efficiency can be affected by the performance of high-end marine equipment. Such equipment is not widely available and its performance is not easily predictable. Marine projects are more perilous than land-based projects and require robust mechanisms to manage the complex activities undertaken in this unpredictable environment (Bugnot et al., 2020). They must be evaluated according to their uniqueness and a wide range of variables. This demand is further intensified by interdependency in project activities. For example, a road construction project can still be completed and used section by section; this is not the case for marine projects. Tasks are highly interdependent and must occur consecutively in a certain sequence to achieve the main goal and reach the operation phase. Karami and Olatunji (2018a) believe that these attributes make marine projects sensitive to cost, scheduling, resourcing, safety and quality issues, concluding that 'the impact they trigger on outlined expectations can be chaotic, and the dynamism underlying the problems they elicit could be more frequent and more sensitive than in other complex projects on land' (P168).

According to Tam (2012), unique attributes of marine projects include their complexity (resources, material and equipment), multidisciplinary environment, perilous working conditions, specialised design principles and inclement weather conditions. A concise definition of each feature follows:

- Complexity:
  Vidal et al. (2008) define complexity in marine projects as 'the property which makes it difficult to understand, foresee and keep under control its overall behaviour, even when given reasonably complete information about the project system'. Underestimating of complexity in any megaproject can lead to time and cost overruns; marine construction is no exception (Bosch-Rekveldt, et al., 2011). Construction in complex and extremely unstable circumstances of marine scope of work requires a problem-solving tool to address the wide variety of technical issues (Tang and Bittner, 2014).
- Multidisciplinary environment:
  According to Halpern, et al. (2008), what distinguishes marine construction from other types of project is the interdependency of multiple technical disciplines. Assessing complicated engineering issues concerning key dimensions (e.g. schedule, budget, safety, efficiency and environmental impact) and multiple disciplines (e.g. design and construction) requires a wide range of expertise (Tang and Bittner, 2014). A fit-for-scope strategy promotes a 'crowdsourcing process' of combining expertise and diverse disciplines.
- Perilous working conditions:
  The environment in which marine projects is being implemented is unfriendly to basic conventional processes. This makes these projects highly vulnerable to risks. They may intensify the inclement weather, and the environment within which they operate is not least challenging. As a consequence, they require extremely complex designs and construction strategies that are not commonly employed. Cox and Cheyne (2000) and Haukelid (2008) describe safety

problems in the marine construction scope of work, agreeing that marine construction projects are several times higher risk of disaster than construction projects in any other industry.

- Specialised design principles:
  Marine projects are exceptional in their sophisticated design concept. Design errors can reflect fundamental flaws, which can lead to harm or destruction of the structure (Gudmestad, 2002). In view of the importance of this industry and the extent to which it has an economic effect, failure has unacceptable implications. This is confirmed by the Norwegian Petroleum Directorate in 1979 (Pate-Cornell, 1990). An additional safety margin must be regarded to allow for design errors or failures in the process of marine operation. As recommended by Pate-Cornell (1990), a third party review and design risk analysis is an efficient way to mitigate potential risks. Samie (2016) concurs, highlighting the importance of incorporating potential risks from various disciplines when designing an offshore platform. Samie provides the example that the structural discipline requires 'cooperation of structural, geotechnical, corrosion and naval architectural specialists in addition to drafting and modelling engineers. In a broad sense, topside design requires interface between several engineering disciplines'. This illustrates how data from one discipline can have an impact on the design process of other disciplines in marine construction projects.
- Inclement weather conditions:
  Anastasiou and Tsekos (1996) explain how severe weather conditions frequently cause overruns in marine projects, and how such phenomena are not always foreseeable. The construction phase in marine projects may be interrupted by weather conditions (Tam, 2012). Tam introduces inclement weather as a major source of risk for contractors that may disrupt critical tasks in a project. Inclement weather usually has more of an effect on marine projects than on-land projects. Such weather includes strong winds, tidal waves and wet weather during which the whole site may be inoperative; whereas for on-land projects, indoor work can continue whenever the weather is unpleasant.

Tang and Bittner (2014) conclude that lessons learned from similar projects are crucial sources of information that should be taken into consideration. However, because of nuanced differences between projects, such lessons are not always transferable. Ruqaishi and Bashir (2015) argue that the use of advanced technology in marine projects separates them from other types of project. Further, technical efficiency and unique high-end equipment is required to respond to the distinctive characteristics of marine construction projects in both the construction and design phases. This may be achieved by identifying the key specifics and most applicable strategies during a project's lifecycle. Since both the uncertainty and unpredictable nature of work are lined up against the schedule performance in marine projects, a practical strategy to overcome various obstacles is of utmost importance. This is discussed more in further sections.

3.3 Common Adopted Contributing Factors of Success

Project success may be measured according to criteria such as on-time delivery, budget expenditure, quality and safety (Omoush, 2020). According to Sanvido et al. (1992), a success-oriented strategy requires a set of essential conditions and components that must be implemented for ideal accomplishment. However, Chan et al. (2004) point out that the concept of success is still complicated. Ashley et al. (1987) define success in terms of timely completion, quality, safety and stakeholder satisfaction. Similarly, Tuman (1986) proposes a general definition of success as the optimal accomplishment of projects in a timely manner. de Wit (1986) points to technical performance and stakeholder satisfaction as measures of success. However, the importance of scheduling performance should not be ignored. Karami and Olatunji (2018c) highlight domain-based and environmental criteria as the most valuable elements by which an efficient strategy can be implemented to guard against likely issues and determine the risk of the potential success or failure of projects. It is widely acknowledged in the literature that preventive approaches are the primary means of managing unexpected issues. Even with all possible forms of control, projects continue to be subject to schedule and cost overruns and quality and safety issues. It is more effective to evaluate the success of an approach based on an understanding of the effect of the project's unique characteristics on overruns and levels of satisfaction. It is imperative to develop a mechanism to identify the key variables in the various phases of a project to address different challenges in construction projects. In this way, solutions will be capable of improving project efficiency, minimising the likelihood of overruns and elevating project value.

Walker (1995) identifies project scope evaluation as a determinant variable that can improve schedule performance. Sanvido et al. (1992) believe that the analysis of determinant factors in evaluating project success is advantageous to stakeholders. This may be done by creating mechanisms to better recognise the constructability and profitability of projects and applying corrective measures to resolve identified issues. Sanvido and colleagues identify the essential criteria for success according to various stakeholders: for owners, these include the avoidance of schedule or cost overruns and ensuring functionality and high quality; for designers, success is determined via client satisfaction, constructible designs and projects meeting their schedules and budgets; and for contractors, success criteria include meeting schedules, being under budget and owner satisfaction. For all stakeholders, two important factors are time and cost, meaning that there is a high correlation between these factors and project success.

Academics and industry experts have recently made considerable efforts to address issues specific to large-scale projects, namely their uncertain, dynamic and complex nature. The challenge in establishing a specific strategy for successful completion has become the subject of debate among researchers and those involved in the construction industry, particularly industry practitioners (Duy Nguyen et al., 2004). Although stakeholders and project contributors have made efforts to develop universal approaches to the successful delivery of large-scale construction projects, they continue to struggle. According to Davis (2014), because of the absence of a universal agreement on a definitive pathway to successful completion, further research is warranted.

Gunduz and Yahya (2018) argue for practical methods to improve schedule performance and avoid cost overruns. Similar to other researchers, they believe there is a need to evaluate methods based on three criteria: quality, schedule and budget. Sanvido et al. (1992) assert that the successful completion of a project depends on thoroughly and meticulously satisfying a set of factors, mainly schedule and budget. In other words, extracting and fulfilling these criteria is highly correlated with project success.

de Wit (1986) highlights the fulfilment of project aims and objectives, including the predefined schedule, as the best measure of project success. After conducting a pilot study on successful projects, the author identified six criteria by which to evaluate project success: financial performance, time performance, stakeholder satisfaction, serviceability, contractor fulfilment and project team satisfaction.

Many studies have measured project success using metrics such as on-time and on-budget completion with satisfactory quality. The question is how to identify and fulfil success variables to guarantee optimal outcomes. Sanvido et al. (1992) argue that this is achievable by assessing projects individually and considering their unique attributes, enabling the project team to implement predictive and corrective strategies.

3.4 Overruns and Existing Scheduling Theories

Schedule overruns are common in construction projects. Many studies have found that schedule overruns are a key source of dissatisfaction among stakeholders (Ramanathan et al., 2012; Shebob et al., 2012; Ruqaishi and Bashir, 2015; Tankkar and Wanjari, 2015; Shrivas and Singla, 2018). In particular, Hampton et al. (2012) outlines the destructive influence of schedule overruns on the financial security of stakeholders, concluding that completion delays affect clients, contractors, consultants and the public sector. For instance, the inability to generate income from a delayed enterprise leads to economic difficulties for clients. Likewise, contractors lose money to inflation, delayed resources and ongoing preliminaries. Hence, project stakeholders will benefit from identifying causes of delays and strategies to cope with the effects of schedule overruns. A study by KSP Consultant Engineers (2015) reveals that overruns, which occur in the majority of marine projects, severely affect the finances of public and private investors, and delayed completions result in cost overruns and stakeholder dissatisfaction.

The causes of overruns are well documented in the construction literature. Ahiaga-Dagbui et al. (2015) believe that the subject has been over-researched and that the findings have become stagnant, repetitive and superficial because overruns are still rife, with research findings being inconclusive. Most studies are limited to descriptive statistics, and many fail to recognise the nuanced elements of the construction industry, such as the project environment. In addition, scholars have identified a long list of factors that is impossible to clearly consolidate because they apply to project domains differently. Further, how these factors interrelate in specific and complex projects is difficult to determine. The purpose of the current study is to identify the uniqueness of marine projects; highlight the effect of an uncertain work scope on scheduling processes; and determine the most prominent causes of delay among the identified factors.

Implementation of project scheduling procedures requires a broad variety of approaches and resources. It is clear from the evolution and convergence of project management theory with modern scheduling techniques that the views of professionals on the impact of these tools and techniques still vary. This condition can be partially attributed to a lack of insight on the most adequate basis for the application of these approaches.

The proper implementation of scheduling strategies in construction projects is impossible without knowledge of fundamental concepts (Bertelsen et al., 2007). Al-Nasseri and Aulin (2015) identify scheduling theories that have been commonly used in construction projects, including the critical path method (CPM), the Gantt chart (GC) and the program review and evaluation technique (PERT). Methodologies implemented in practice have evolved from traditional deterministic scheduling theories into more advanced scheduling theories based on probabilistic techniques (Al-Nasseri et al., 2016). The wealth of literature on the topic suggests that conventional approaches are those initially implemented for the visualisation and optimisation of overall project length, rather than for monitoring schedule uncertainties or resource limitations. Examples of the conventional approaches identified by Al-Nasseri and his team include the GC, CPM, PERT and the line of balance. They introduce critical chain project management and the primarily last planner as two modern approaches capable of addressing the limitations of traditional methods.

The major difference between CPM and PERT is that the former is based on a deterministic technique while the latter implements a probabilistic approach to integrate the uncertainty related to activity duration (Zhu and Heady, 1994). In other words, 'PERT has converted CPM's computational approach of a single time estimate into three-point estimates based on a probabilistic distribution of the observed mean of completion time' (Hegazy and Menesi, 2010, P6).

In summary, GC is an effective method for specifically visualising the progress of scheduled work, but pays no attention to human resources and correlations between time and budget. This limitation has been partly addressed by incorporating GCs into a method that theoretically manages significant uncertainties and thus quantifies and monitors the relationships or interactions between tasks. CPM and PERT can be combined as one approach, particularly in large construction projects with a multitude of activities.

Liu (2013) concurs with this approach and believes in the practicality of 'combining a CPM-based deterministic network with a PERT probabilistic' estimation technique to manage mega projects. The focus here is not on scheduling theories. Because of the qualitative nature of uncertainties in marine construction projects, the emphasis should be on probabilistic analysis while incorporating uncertainties into scheduling processes and design options. This study seeks to investigate the effectiveness of integrating VE into scheduling processes by highlighting the qualitative nature of uncertainties and benefiting from probabilistic approaches in marine construction projects.

3.5 Review of the Overall Severity of Delays in Construction Projects

Delays are common in construction projects and thus are a concern shared by project stakeholders because they affect stakeholder expectations. Sambasivan and Soon (2007) argue that delays in construction projects are a worldwide issue. Global surveys have revealed the frequency of delays in various types of projects, including in 70% of major infrastructure projects in the Kingdom of Saudi Arabia (Assaf and Al-Hejji, 2006), 97% of public and private construction projects in Libya (Shebob et al., 2012) and 40%

of construction projects in India (Iyer and Jha, 2006). Perera (2006) claims that 80% of road projects in Sri Lanka are subject to schedule overruns, rendering them costly, time consuming and risky. Similarly, Odeyinka and Yusif (1997) found that almost 70% of construction projects in Nigeria had been delayed during implementation. Major delay factors included inclement weather conditions, inadequate resource allocation and poor cash flow management.

Based on a case study in Chile, Ballesteros-Pérez et al. (2015) found that a significant number of construction projects were not completed on time, leading to lower efficiencies, which eventually manifested as cost overruns and an enormous waste of natural resources and materials. The authors identified extreme weather conditions as one of the most persistent delay factors.

Construction delays are a pervasive and universal issue (Ahmed et al., 2003). Globally, almost 40% of construction projects experience schedule overruns (Sambasivan and Soon, 2007; Agyekum-Mensah et al., 2012). A 1997 review by Conlin and Retik found that 52% of projects in the United Kingdom (UK) had been delayed, and Graves and Rowe (1999) found that 70% of public projects in the UK had delayed. Sambasivan and Soon (2007) reported that 17.3% of similar projects in Malaysia had been delayed, with key factors including unresponsive equipment during construction, inappropriate resource allocation, management issues, insufficient training of personnel, inexperienced contractors, poor cash flow management, payment issues, inadequate communication between disciplines and poor construction methods.

Mpofu et al. (2017) found that delay issues appeared more prevalent in regions with higher development pressures. The authors identified the key construction delay factors in the United Arab Emirates, which included overoptimistic scheduling and lack of workforce productivity; they argue that timely completion cannot occur unless all three major parties in construction projects (contractor, client and consultant) modify their practices. Koushki et al. (2005) enumerate three significant delay factors in the Kuwaiti construction industry, namely inadequate contractors, poor cash flow control and extensive scope changes during the construction phase. Contrary to Mpofu et al.'s view, delays are not always limited to developing countries. For example, in the UK, a

National Audit Office investigation reported that approximately seven of every ten projects in the public sector were delayed (Bourn, 2001).

According to Assaf and Al-Hejji (2006), a 10–30% deviation from the initial time schedule is not unusual for 70% of construction projects. Shahsavand et al. (2018) identifies 78 delay agents, which they group into seven categories: client-related issues, equipment and labour issues, contractor-related issues, problems with materials and resources, design-related issues, external causes and consultant-related issues. The authors argue that delays are almost inevitable in construction projects and their magnitude varies greatly from project to project.

Wang et al. (2018) and Lo et al. (2006) investigated the causes of delays during the construction phase of building projects in China. They identified client-directed scope changes and low-bidding policies, payment issues, inadequate communication and inefficient subcontractors as the main drivers of delayed completion. Lo et al. (2006) add environmental issues, poor site management and unforeseen geotechnical conditions for the Hong Kong construction industry.

3.5.1 Construction Delay Classification

To determine liabilities, it is necessary to identify categories of delay in construction projects (Menesi, 2007). Scholars have described types of delay in various ways. Schedule overruns can be classified according to the responsible party (client, consultant or contractor) (Ekanayake and Perera, 2016). Conlin and Retik (1997) and Menesi (2007) classify delays as excusable, non-excusable or concurrent. Enshassi et al. (2009) further divide excusable and non-excusable schedule overruns into two categories: compensable and non-compensable. Trauner et al. (2009) identify four fundamental categories of delay that embrace the earlier views: critical/non-critical, excusable/non-excusable, compensable/non-compensable and concurrent/non-concurrent. Trauner et al. underline knowledge of delay types as a success factor in developing appropriate mitigation strategies. To assess the impact of a delay factor on a project, it is necessary to determine its criticality and concurrency. All identified delays can be categorised as either excusable or non-excusable. Delays may also be classified as compensable or non-compensable (Trauner et al., 2009). Adopted from Trauner et al. (2009), Table 3.1 shows categories of construction project delays. The different categories are explained below the table.

Table 3.1: Construction project delay categories

No.	Delay type	Description
1	Critical	Affects project/milestone completion date (referring to CPM)
	Non-critical	Does not affect project/milestone completion date (referring to CPM)
2	Excusable	Caused by an unexpected occurrence beyond control (e.g. fire, flood)
	Non-excusable	Foreseeable and within control (e.g. poor performance, inexperienced workers)
3	Compensable	Contractor entitled to reimbursement of time and cost (e.g. scope change by the client)
	Non-compensable	Contractor not entitled to compensation (e.g. strikes)
4	Concurrent	Delays that are separate but simultaneously affect critical paths (referring to CPM)
	Non-concurrent	Delays that are separate and influence critical paths at different times (referring to CPM)

- Critical/non-critical:
  In any type of delay assessment in construction projects, the key concern is the factors that hinder the entire project's progress or those that are crucial to the completion of the project. However, there are also delay factors that do not postpone the project deadline or the milestone completion date. Factors that affect the target date for project completion or, in some circumstances, the milestone completion date are known to be critical; those that do not affect the predefined completion date for the project or the milestone date are non-critical. The theory of critical/non-critical delays emerges from CPM scheduling theory. Although the evaluation of essential activities is a key component of CPM theory, the majority of projects, irrespective of the type of scheduling theory applied, have critical operations. If these operations are extended, the date of completion of the project or the milestone completion date may be deferred. In certain contracts, the words 'controlling item of work' may be used instead. Generally, this applies to critical tasks or jobs. Irrespective of the type of scheduling theory used, there is a critical path in all types of construction project that, if prolonged, would extend the date of completion.

- Excusable/non-excusable:

  An excusable schedule overrun is, in general, due to an unexpected occurrence outside the control of the contractor/subcontractor. Examples include exceptionally inclement weather, scope changes imposed by the client/owner, floods, acts of God, fires, and strikes by the labour force. These circumstances can be relatively unpredictable and not subject to the control of the contractor. It should also be noted that contract documentation should be considered and decisions made within the criteria specified in the context. For instance, certain contracts will not accept any time losses caused by inclement weather, irrespective of how rare, unpredictable or extreme they may be.

  Conversely, non-excusable schedule overruns are generally predictable and within the control of the contractor/subcontractor. Examples include performance issues, failure to provide appropriate equipment, and mismanagement. Similar to excusable delays, contract specifications must be straightforward and easy to understand in terms and conditions.

- Compensable/non-compensable:

  A compensable schedule overrun gives the contractor a time extension and extra entitlements. It should be noted that only excusable schedule overruns are entitled to compensation. In contrast, non-compensable time overrun does not guarantee any compensation for the contractor even if an excusable time overrun occurs. Hence, it is very important to investigate the nature of delay and identify whether or not it is compensable. In addition, there would not be any extension of time or compensation if the schedule overrun is deemed non-excusable. It is best if contracts clearly state the types of time overrun that are non-compensable and thus where the contractor would not be entitled to any compensation but may be permitted an extension of time.

- Concurrent/non-concurrent:

  Investigation into concurrent delays should focus not only on the detection of critical delays, but also on the assessment of liability for delay-related losses. Owners commonly consider concurrent time overruns as a justification for allowing an extension but no extra compensation for contractors. Similarly, contractors typically challenge owners as to why payment-associated damages cannot be compensation for their delays. Even worse, not all contractual arrangements account for the ‘concurrent delay’ provision and how they affect the contractor’s right to additional compensation in contract specification. There is a lack of awareness in the construction industry regarding the principle of concurrent delay. Simply put, separate delays occurring at the same time along the critical path of the project are called concurrent delays.

3.5.2 Causes of Schedule Overruns

Construction projects are typically subject to schedule overruns. The literature highlights the frequency and the effects of schedule overruns on stakeholders (Kenny and Vanissorn, 2012; Shebob et al., 2012). Further, there is a vast literature on overrun variables (Kenny and Vanissorn, 2012; Tankkar and Wanjari, 2015; Alsuliman, 2019). Most studies on the subject have used questionnaire surveys, implying that causations are ‘hard’ variables with definitive boundaries (Chan and Kumaraswamy, 1997; Odeh and Battaineh, 2002; Long et al., 2004; Sambasivan and Soon, 2007; Kaliba et al., 2009). Findings have been based on qualitative studies and validated by quantitative instruments. In particular, outcomes have been reported from questionnaire surveys, expert opinions explored through interviews, case studies and construction practices. Overall, schedule overruns have been identified as a major issue in the construction industry. The relative importance of their causations has also been reported (Shebob et al., 2012).

The various causes of overruns have been reported in the literature (Cantarelli et al., 2012; Ansar et al., 2014; Love et al., 2016). While authors frequently agree on the causes of causations, they sometimes disagree about what constitutes overruns and how specific factors affect project outcomes. For example, Flyvbjerg (2011) and Love et al. (2015) differ in their views on how overruns should be measured. They also fail to explain how the causes of overruns affect specific sectors of the construction industry or project types. An analysis by Adam et al. (2017) of 40 scholarly studies shows management issues are the main drivers of construction delays. Other studies disregard the role of environmental factors in overruns. Habibi and Kermanshachi (2018) highlight discrepancies in research outcomes. Ansah and Sorooshian (2018) believe there is a lack of a comprehensive structure in systemic reviews and delay clustering. Factors such as inconsistences and omissions in design and project estimates are identified by Ahiaga-Dagbui et al. (2015), who argue that future studies should improve on the precision of their findings (i.e. the actual effect of causes in relation to the project environment) and expand their coverage to factors that address project uniqueness. According to Karami and Olatunji (2018a), the causes of delays differ according to project type. For example, most authors agree that inclement weather causes delays. However, the effect of weather on marine projects is more significant than it is on land-based projects: heavy winds, tidal waves and wet weather can make entire sites inoperable in marine projects, while in land-based projects, it is possible to complete indoor work in poor weather conditions. Thus, it is insufficient to simply identify the causes of delays; rather, their impact should be assessed according to the project environment. Taking project uniqueness into consideration will assist in the understanding of different causes, how they might be mitigated and how this process can add value to construction projects (Whyte and Cammarano, 2012).

Kenny and Vanissorn (2012) used a questionnaire survey to identify 10 delay factors in Western Australia's construction industry: skill and labour shortages, financial difficulties, overoptimistic deadlines, unforeseen circumstances, poor organisation of stakeholders, lack of communication, planning errors, inappropriate decision-making processes and design and construction errors. Based on professionals' perspectives, Agyekum-Mensah and Knight (2017) report unexpected circumstances, inadequate resource management and inefficient construction methods as the main reasons for construction delays. Yap et al. (2020) highlight issues such as improper planning and scheduling, inefficiency in site management, finance-related problems, change orders imposed by clients and inadequate contractor selection models as common factors.

Motaleb and Kishk (2010) and Prasad et al. (2019) add change orders and finance-related issues to the list of overrun factors. Sepasgozar et al. (2015) found that the implementation of obsolete technologies in construction is a key cause of schedule overruns. Zidane and Andersen (2018) found that the most common universal delay factors are design issues, financial instability, inadequate scheduling, poor management approaches and construction methods, and a shortage of resources. Although these factors affect all forms of construction projects, their effects may differ for marine projects. Tam (2012) found that unreliable geotechnical assumptions are a common cause of overruns in marine projects. This highlights the necessity for pilot studies in the early stages to prevent problems in the construction phase. In addition, Hampton et al. (2012) reports on the relationship between cost and schedule overruns, concluding that cash flow constraints often trigger schedule constraints.

Ruqaishi and Bashir (2015) reviewed oil and gas projects in Oman and identify seven causes of delay in the marine environment: inefficient structural management by contractors; problems with subcontractor job delivery; poor planning and work breakdown structures by contractors; poor site control by contractors; political conditions causing delays in importing materials; poor communication among project stakeholders at different stages; and inadequate procurement resulting from ineffective interactions with vendors. Shrivas and Singla (2018) found that schedule overruns in marine projects are frequent and universal. However, they underline the lack of scholarly and empirical materials on the subject. Consistent with the above, Ramanathan et al.'s (2012) review of 41 studies enumerates a range of factors including finance, project attributes and design complexity. Younesi et al. (2017) add issues pertaining to the project environment, finance and people. Other studies, including those by Samie (2016), Alsulimani (2019) and Mpofu et al. (2017), identify inefficiencies in communication across critical disciplines, inappropriate contractor selection methods and unrealistic contract durations. In addition, findings by Tang and Bittner (2014) suggest that marine projects require extensive remote support and crew protection, and delays are often exacerbated by their isolation from support infrastructures, issues with temporary structures and inclement weather.

In their survey on oil and gas construction projects in Vietnam, Van Thuyet et al. (2007) identify five major causes of schedule overruns: excessive bureaucracy in terms of project approvals from clients; lack of efficient design; lack of competency in different parties; inadequacies in contract constructs; and delays in internal approval processes. The latter include delays in land deliveries or site handovers, work approvals, drawing and document approvals, and delivery of test results. The effect of these factors on marine construction projects can be severe.

Tam (2012) reports a prominent risk factor affecting marine construction projects; that is, the contradiction between tender documents and actual project circumstances. The study identifies a range of design- and construction-related factors, including design errors, estimation errors, inexperience in the design team, construction errors and the consultant's inability to deal with severe uncertainties. Tam highlights that lessons learned from previous projects are a crucial source of information and confidence.

Researchers have also found organisational structure to be a prominent factor in delays. Conflicts and errors are minimal when organisational structure is well established. Samie (2016) concludes that ineffective communication between engineering and construction teams involved in offshore projects is a significant cause of overruns and design errors, suggesting that this may be prevented through dedicated strategies. Tang and Bittner (2014) introduce VE as a systematic problem-solving approach with the potential to develop design solutions and address various challenges in the marine construction industry.

Ramanathan et al. (2012) used a questionnaire to investigate factors contributing to the timely completion of construction projects globally. They reviewed studies by Assaf et al. (1995), Chan and Kumaraswamy (1997), Odeh and Battaineh (2002), Long et al. (2004), Frimpong et al. (2003) and Alaghbari et al. (2007) and identify a number of factors responsible for delays, including water table levels; intrusion by neighbours; the lack of financial incentives for contractors; outdated technologies; unrealistic contract durations enforced by clients; unreliable data; and failure to involve contractors in the early design phase, consider alternative resources or adopt flexible timetables. Other variables include the lack of on-site quality assurance systems, the absence of planning for mass production, the lack of safety training, damage and accidents, insufficient inspection procedures, social and cultural factors, uncooperative owners and inappropriate construction methods.

Marine projects are critical economic assets, and their failure can lead to deterioration in a country's economy. It is critical that they are not only completed on time, but that they achieve their intended quality, function and purpose. Overruns are a major cause of dissatisfaction among stakeholders (Ramanathan et al., 2012; Shebob et al., 2012; Ruqaishi and Bashir, 2015; Tankkar and Wanjari, 2015; Shrivas and Singla, 2018) because they delay operations and consequently jeopardise the financial viability of projects. Thus, it is important to consider the effect of factors contributing to overruns in marine projects, which are unique and complex in terms of their high-risk environments, sophisticated technologies, large budgets and dynamic nature. One way to understand and consider factors leading to overruns is to identify their criticality and interrelationships.

Based on the literature on construction project delays, 73 overrun factors were identified. Table 3.2 summarises the literature from which variables were derived, and Table 3.3 presents the 73 identified factors.

Identified overrun factors through the review of the literature may be thematically classified into different groupings. These include factors related to credibility of planning techniques, environmental constraints, and documentation and approval processes. Others include availability of appropriate technologies, resources and equipment, interruptions between client and contractor, inappropriate instructions/communications, safety problems and socio-political factors.

There are also factors related to owner attributes, organisational structure, management approaches and issues originating from the design and construction stages. Also important are factors related to estimation activities, financial stability of different parties, construction strategies and construction equipment.

Table 3.2: Summary of delay factors

Source	Highlighted delay factors
Tam, 2012 Alsulimani, 2019	Weather considerations, complex design principles, unreliable geotechnical assumptions, lack of pilot studies, contradictions between tender documents and project circumstances, design errors, estimation errors, inexperience among design teams, construction errors, consultant inability to deal with severe uncertainties, lack of lessons learned from previous projects
Adam et al., 2017	Management issues
Ahiaga-Dagbui et al., 2015 Yap et al., 2020	Inconsistences and omissions in design, estimation issues, environmental factors
Odeyinka & Yusuf, 1997 Tang & Bittner, 2014 Karami & Olatunji, 2018a	Weather considerations, high and low tides, lack of VE
Kenny & Vanissorn, 2012	Skills and labour shortages, financial difficulties, overoptimistic deadlines, unforeseen circumstances, stakeholders' poor organisation, lack of communication, planning errors, inappropriate decision-making processes, design and construction errors
Odeyinka & Yusuf, 1997 Agyekum-Mensah & Knight, 2017	Unexpected circumstances, inadequate resource management, inefficient construction methods
Koushki et al., 2005 Motaleb, 2010 Prasad et al., 2019	Order changes, finance-related issues
Sepasgozar et al., 2015	Obsolete technologies
Zidane & Andersen, 2018	Design issues, financial instability, inadequate scheduling, management approaches, construction methods, resource shortages
Odeyinka & Yusuf, 1997 Koushki, et al., 2005 Hampton et al., 2012	Cash flow constraints
Koushki et al., 2005 Ruqaishi & Bashir, 2015	Inefficient structural management by contractors, issues with subcontractor job delivery, poor planning and work breakdown structures by contractors, poor site control by contractors, political conditions causing delays in

Source	Highlighted delay factors
	imported materials, poor communication between project stakeholders at different stages, inadequate procurement caused by ineffective interactions with vendors
Ramanathan et al., 2012 Ansah & Sorooshian, 2018 Ahmad et al., 2019	Finance, project attributes, design complexity, water table levels, intrusion by neighbours, lack of financial incentives for contractors, outdated technologies, unrealistic contract duration enforced by clients, unreliable data, failure to involve contractors in the early design phase, failure to consider alternative resources, failure to adopt flexible timetables, lack of site quality assurance systems, lack of planning for mass production, lack of safety training, damage and accidents, insufficient inspection procedures, social and cultural factors, uncooperative owners, improper construction methods
Younesi et al., 2017	Project environment, finance and people
Samie, 2016 Mpofu et al., 2017 Karami & Olatunji, 2018a	Inefficiencies in communication across critical disciplines, inappropriate contractor selection methods, unrealistic contract durations, lack of workforce productivity
Tang & Bittner, 2014	Extensive remote support and crew protection
Van Thuyet et al., 2007 Ahmad et al., 2019	Excessive bureaucracy in terms of project approvals from clients, lack of efficient design, lack of competency in different parties, inadequacies in contract constructs, delays in internal approval processes (e.g. delays in land delivery or site handovers, late work approvals, delays in drawing/document approvals and delays in the approval and delivery of test results)

Table 3.3: Identified delay factors

1	Delays in land delivery	20	Social and cultural factors	39	Poor site control by contractors	58	Lack of financial incentives for contractors to finish ahead of schedule
2	Inappropriate decision processes	21	Lack of efficient design	40	Lack of liabilities for different parties	59	Uncooperative owners
3	Delays in subcontractors' job delivery	22	Lack of database to estimate activity duration and resources	41	Failure to utilise lessons learned from similar projects	60	Insufficient communication between owner and design team in design phase
4	Low speed in job site transfer	23	Lack of proper cooperation between consultant and contractor	42	Neighbour interference	61	Extreme bureaucracy in client's organisation
5	Inefficient information stream	24	Lack of cooperation between client and consultant	43	Delays in importing materials due to political conditions	62	Owner financial security
6	Order changes imposed by clients	25	Inadequate contracts	44	Weather considerations	63	Contractor financial difficulties
7	Failure to optimise/monitor resource allocation	26	Construction methods	45	High and low tides	64	Escalation in resource prices
8	Failure to involve contractor in early design phase	27	Unstable management structure and style of contractor	46	Conditions of water table on construction site	65	Price fluctuations
9	Lack of consideration for alternative resources	28	Unavailability of professional construction management	47	Unreliable geological assumptions	66	Late work approvals
10	Lack of appropriate quality assurance systems on site	29	Inexperienced personnel	48	Skill shortages	67	Delays in test result approvals
11	Lack of planning for mass production	30	Lack of consultant's practical experience	49	Inappropriate contractors	68	Delays in document/drawing approvals
12	Lack of safety training and meetings prior to commencing construction	31	Inadequate design team experience	50	Delayed resources	69	Shop drawing preparation and approval

13	Safety issues	32	Lack of pilot study prior to construction	51	Procurement and resource allocation	70	Lack of execution methods for major tasks
14	Damaging marine equipment during execution due to lack of safety	33	Impractical design	52	Labour productivity	71	Inappropriate work breakdown structure by contractor
15	Inspection procedures employed at construction site	34	Unforeseen ground conditions	53	Overoptimistic scheduling	72	Unresponsive marine equipment
16	Accidents during construction	35	Outdated technology	54	Estimation errors in early design phase	73	Skill shortage for high-end marine equipment
17	Improper site instructions imposed on contractors	36	Lack of VE department in organisation	55	Impractical contract duration imposed by client		
18	Contradictions between tender documents and actual situation	37	Inappropriate communications	56	Poor judgment and experience in estimation processes		
19	Poor consultant auditing system	38	Inefficient coordination among critical disciplines	57	Failure to adopt a flexible timetable for certain tasks		

3.5.3 Causations and Causalities

What is more important than identifying delay factors is how they trigger into causations and causalities? Causation is about how factors transform into delays, while causality refers to how they interact and maintain a delay situation.

The intention here is not to explain every potential situation in which a factor contributes to schedule overrun or interacts with another factor in a project. Rather, some of the most common factors contributing to schedule overruns and the potential of interaction with other factors are discussed to provide a better understanding of these concepts.

During the construction phase of projects, there are specific times of year in which productivity may decrease because of inclement weather conditions. Decreased productivity may be compensated for by either additional resources or an extension of the schedule, both of which lead to a deviation from predefined benchmarks. It is necessary to schedule activities in such a way that they will not be impacted by weather conditions. Delays from any source might interrupt activity sequences and push the schedule to an inoperational season. This means that activities sensitive to weather conditions will be slowed down, which influences the schedule. Weather uncertainties can have adverse impacts on marine construction projects. This common type of delay factor in the marine scope of work can slow down productivity, impose risks for different activities, cause accidents, fully or partially stop the workflow, and damage equipment and personnel, all leading to schedule overrun. Another example of interaction between delay factors is not using up-to-date weather prediction technology and damaging high-end marine equipment. Since this equipment is not easily accessible/replaceable, the consequence would be schedule and budget overrun.

As discussed in the reviewed literature, inadequate resource management as a common delay factor can influence the project schedule. Unavailability of resources such as materials, equipment and personnel can lead to delays at different stages of a project. Interdependency of activities in marine construction projects requires continuous contribution and availability of resources where and when needed. Any interruption to workflow caused by resource unavailability leads to schedule issues and extension of the predefined time and budget. Since marine construction is highly dependent on unique resources, this should be precisely planned for during the initial stages of a project, and plan-ahead strategies must be considered.

As explained before, some high-end marine equipment is booked years in advanced. The unavailability of such equipment because of inefficient management of resources may move certain operations to a season during which the project decelerates because of unpleasant weather conditions. This might originate from financial difficulties of the contractor and/or late payments by the owner.

Another delay factor investigated in the literature examined is lack of expertise. This factor can turn into a delay if contractors do not prepare to employ the necessary staff well in advance and postpone hiring staff to seasons when the workload is high, making it difficult to recruit qualified personnel. Lack of experienced workers can reduce productivity and pose risks to the various activities undertaken in a project. The result will be a deviation from the timetable. This aspect is more common given the nature of marine environment and pre-existing shortage of expertise in this scope of work. Unskilled staff may cause issues at different stages of a project. An unqualified design team can create schedule overrun through inadequate/impractical design and the necessity for redesign and rework. Similarly, unskilled operators may damage equipment, create safety issues and fully or partially stop the workflow.

One major delay factor that is common in construction projects is approval processes. Depending on the size, environment and complexity of a project, this factor can lead to extensive schedule overruns. As is well known, approval procedures involve defining the steps to be followed for a completed task to be accepted. Under no circumstances can a contractor commence work without approvals. Since marine projects are highly dependent on weather conditions and the interdependency of their activities, there should be a straightforward approval process so that there are no implications for operation sequences. As an example, tests, documentation and processes related to driven piles are important prerequisites for construction of suspended-deck jetties. Late approvals impede project progress and delay on-time completion. As another example and, in regard to causalities, late work approvals may delay a project in various ways. Based on intensity, they may push some activities into inoperable seasons with inclement weather conditions, create financial difficulties due to price fluctuations and interrupt resource allocation processes.

Inappropriate equipment allocation is another factor that can delay construction projects. Due to the particular characteristics of marine projects, selection of the most suitable equipment is paramount. Marine machinery should be selected in accordance with project requirements. Unresponsive marine equipment can contribute to risk, accidents and, consequently, time losses. Financial issues and a low budget allocated to a project are likely explanations for contractors not using fit-for-purpose equipment. This makes them hesitate to use the appropriate machinery, so as to increase their profits. In terms of causalities, precise budget estimates at the initial stage and the recruitment of a qualified/capable contractor through an appropriate pre-qualification method will eliminate the problem.

Overall, any delay factors examined can contribute to a schedule overrun by turning into an overrun or interaction, and exacerbating the delay situation. Both situations create dissatisfaction for stakeholders. Industry professionals have examined various scheduling techniques to overcome this issue. Unfortunately, schedule overruns are still rife in the construction industry. This study aims to focus on scope-related techniques and to incorporate this approach as the most practical delay mitigation technique. The next chapter assesses potential strategies in marine construction projects.

3.6 Marine Construction Projects and the Need for Specific Mechanisms

Karami and Olatunji (2018a) refer to marine construction projects as requiring exceptional capabilities and techniques to deal with risks and uncertainties. They classify marine construction work as complex projects that require specific considerations beyond the common superficial approaches. According to Johnson and Tatum (1993), working in a marine environment is extremely challenging. The optimal completion of multiple tasks in this highly risky and uncertain environment requires a high level of technical knowledge compatible with a project's unique attributes (Tang and Bittner, 2014; Karami and Olatunji, 2018c). Johnson and Tatum (1993) conclude that the marine construction industry is distinguished by the high-frequency use of developed technologies, including pile driving, offshore installations and steel fabrication. Johnson and Tatum's work also underscores the high potential of this industry to adopt new technical knowledge. Tang and Bittner (2014) emphasise the need for an approach capable of determining factors in the uncertain marine environment that will be effective in ensuring the success of projects. In other words, to improve efficiency, it is imperative to investigate and develop approaches beyond the generic project management approaches suggested in traditional scholarly works. Findings from Karami and Olatunji (2018c) highlight the usefulness of VE protocols in marine construction projects for integrating science and empirical knowledge into design alternatives. Although VE is often mistaken as a cost-trimming tool (Wao, 2015), future work must consider other useful aspects of this systematic approach.

3.7 Mitigation

Complying with predefined schedules can eliminate overruns in construction projects, and the marine sector is no exception. Deviations from the basic timetable by any party can financially affect stakeholders. Considerable practical evidence shows that schedule overruns in the execution phase have an immediate impact on project costs. Accordingly, applying a practical mechanism aimed at minimising, preventing or correcting delay factors will add value to the project and improve efficiency. Depending on factors such as type, size and budget, cutbacks will become more obvious. Considering the uncertain environment, repetitive processes, complexity and high budgets of marine projects, they will benefit substantially from mitigation mechanisms. Establishing predictive strategies during the initial and planning stages of projects can help achieve positive outcomes.

Given the significant impact of marine projects on the economic development of many countries, their unique attributes must be considered when analysing causes of delay. Park et al. (2006) recommend dedicated approaches such as dynamic planning, pilot testing, plan-ahead procedures and specific implementation methods as potential mechanisms that can mitigate overruns and improve performance if considered in the early stages of projects. The unique characteristics of marine projects should be considered at this stage to achieve optimal outcomes. However, there has been a lack of research with respect to the role these strategies play in the complex and uncertain marine environment. Baccarini (1996) argues that the successful management of projects, including marine projects, is highly dependent on recognising their unique characteristics. Robust mitigation approaches are needed to meet the diverse challenges arising from unique attributes. Similarly, Chai et al. (2015) argue that the optimal accomplishment of projects requires dedicated techniques and processes that have the potential to identify conflict and causes of delays, and provide preventive approaches. The authors conclude that although diverse mitigation methods have not been successful in completely eliminating delays, they are still crucial for diminishing the negative effects of overruns. After reviewing the literature on project success factors, Abedi et al. (2011) identify 30 delay mitigation mechanisms; however, they do not consider the unique attributes of projects as essential factors in selecting mitigation approaches.

Olawale and Sun (2010) categorise delay mitigation techniques into four groups: predictive, preventive, corrective and organisational. They argue that the predictive approach is applicable at the early stages of a project, even before construction commences. Recommendations and proposals based on the characteristics of a project should be considered at this stage. Proposals will be improved by having experts provide preventive methods through a knowledge-sharing process. In the case of an overrun, regardless of the project phase, corrective mechanisms may be implemented after identifying the cause. Olawale and Sun also emphasise the influence of organisations as a potential cause of delays, which may be addressed through improved communication and understanding of the needs of all stakeholders to elevate the functional value of the project. VE embraces all four of the abovementioned approaches and may be implemented in construction projects, particularly marine projects, for the purpose of mitigating delays. The next section provides more detail about the practicality of VE in keeping projects to schedule by minimising the likelihood of overruns.

3.8 Justifying Value Engineering

According to Karami and Olatunji (2018c), project success is often determined through the evaluation of key variables in VE, namely scheduling, budgeting, quality and safety. The highly challenging environment of marine construction projects requires a mechanism that can evaluate alternative methods in terms of scheduling, safety, quality and environmental impact (Tang and Bittner, 2014). Tang and Bittner argue that VE is an effective approach for addressing the problems resulting from diverse barriers in the uncertain marine environment. Preventive strategies such as VE are considered effective in the successful management of projects and improvement of project performance. Empirical evidence and scholarly works suggest that some overrun causative factors may be controlled, particularly at the planning stage prior to commencing construction (Elias, 1998; Kenny and Vanissorn, 2012). The highest returns can be expected in the early stages of the project lifecycle. However, some authors argue for the practicality of using VE at different stages of the project lifecycle (Ilayaraja and Eqyaabal, 2015). Likewise, Shaw (2016) outlines the effectiveness of utilising VE for eliminating cost overruns and improving performance over the life of the project. VE may assist project stakeholders and practitioners in planning and improving project performance. As stated in the previous section, VE can identify the risk of overruns and reduce their likelihood in major construction projects; however, little has been reported about its applications in marine infrastructure. Elias (1998) identifies the complexity and size of projects as factors affecting the scope of work in VE workshops. Apart from budget, these two phenomena are significant in marine projects and may trigger overruns if not well managed. Key VE factors, particularly in the form of technical advice (protocols) associated with alternative methods, can be implemented to mitigate causes of delays and eliminate consequent cost overruns. Fortunately, most alternatives are measurable in terms of time and how they may affect the project schedule. In other words, functions of the diverse elements of a project can be evaluated and quantified against the schedule using this mechanism. VE is an appropriate theoretical approach and is technically the most practical way to evaluate the causes of schedule overruns and develop alternate solutions. VE includes the integration of information with respect to different project components, their expected lifetime performance and their designated purposes (Shen and Liu, 2003; Park et al., 2012). Figure 3.1 illustrates how VE can be validated in marine construction projects by focusing on their unique attributes to filter out the prominent causes of delays. Considering the scope, complexity, uncertainty and economic significance of marine projects, VE is anticipated to be the most effective approach. More effort is required to establish overrun predictive strategies in the early stages of VE by analysing delay variables.

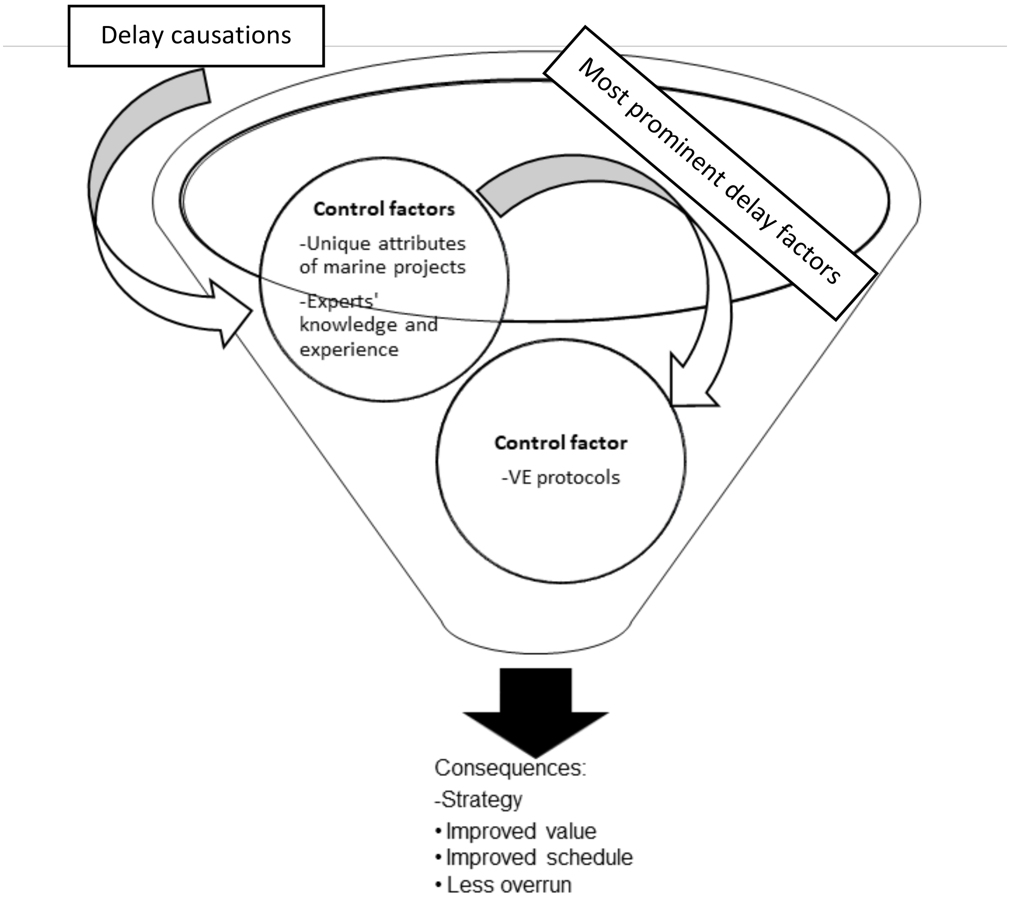


Figure 3.1: Strategy creation process through VE protocols

3.9 Summary

The overarching purpose of this review chapter and an interpretation of the terminologies used were briefly explained in an introduction section. Global causations of delays and their relevance to marine construction projects were critically reviewed with a focus on highlighting the lack of literature relating to differentiation between delay trigger factors in project domains. The high propensity of marine construction projects to suffer delays was discussed and justified by considering specific attributes and established constraints in this dynamic and uncertain environment.

The significance of this study was further clarified by highlighting the essence of this form of project and its implications for the economy, development, technology, practice, research, transport and society.

Specific characteristics associated with marine construction projects and how distinctly they affect activities compared with on-land projects were explored and explained using some examples. Interdependency in project activities as a unique attribute in this work scope—which demands careful consideration at the scheduling and design stage—was underlined. In addition, satisfying a predefined schedule as a common criterion for success was reviewed using the literature. This was followed by a brief discussion on scheduling theories, a review on global severity of delays and their origin in construction projects, and classification of delay types. The necessity of considering probabilistic approaches while scheduling in marine construction projects was also explained.

The review of the literature in this chapter identified delay factors both thematically and topically. The way they trigger into causations and causalities was described using some examples. Finally, VE as a potential approach appropriate to be integrated into scheduling and design options in marine construction projects was justified. The validity of this methodology as a useful theoretical and technical approach to evaluating the functions of the diverse elements of a project and quantifying them against the schedule was confirmed.

This study adds to the limited body of knowledge on the scope of marine construction projects by pointing out the necessity of introducing scope-related delay drivers. The study also highlights the nature of uncertainties, appropriateness of probabilistic approaches in scheduling and design options and, finally, the practicality of VE protocols and how they can assist in scheduling theories.

Factors extracted through the reviews were utilised to design a survey questionnaire. The next chapter explains the research methodology applied in the research; that is, how the objectives of the study were achieved, the essence of the data used for the study, and how they were analysed.

CHAPTER 4: RESEARCH METHODOLOGY

4.1 Introduction to Research Design

The purpose of this chapter is to outline the methodology used for this study and to clarify the data collection approach and the mechanisms by which the data have been analysed. According to Salkind and Rainwater (2006), research is a process in which a subject is investigated and new facts or knowledge are discovered. The method includes a systematic structure called the research design, which is the key component of any scientific investigation. It uses relevant methodologies with the purpose of objectively verifying a hypothesis or addressing a research question.

Myers (2009) states that the conduct of research is driven by processes aimed at generating and interpreting statements with respect to knowledge related to the subject being explored. Moreover, this methodical approach separates scientific knowledge from non-scientific knowledge. Rather than relying on sense experience and faith, scientific knowledge is based on evidence and verification (Taylor, 2005; Wray, 2007). Longino (2002) suggests that the rationality of science is a feature of the structure of the research community. This verifies the necessity for a methodological approach in constructing scientific knowledge.

The rationale for selecting the designated method for this research—which covers all stages including issue clarification, the approach to address the objectives, how the data would be gathered and how the elicited findings would help the related community—is explained throughout the chapter.

The chapter begins by explaining the philosophical stance of the study. This philosophic description is accompanied by an exploration of an effective research approach for this specific study. Having determined these two main factors, the chapter outlines how the present investigation could be facilitated by implementing a mixed method approach that would fulfil all requirements of the study. The chapter proceeds by clarifying how the research was performed in the sense of data gathering, interpretation and synthesis specific to this research study.

This chapter concludes with an explanation of the ethics and confidentiality considerations required to undertake the research, based on Curtin University Human Research Ethics Committee (HREC) criteria.

4.2 Research Paradigm

The philosophy of research has been described in numerous ways. Ryan (2018) identifies research philosophy as ‘what the researcher perceives to be truth, reality and knowledge’. In Ryan’s view, a research philosophy highlights ‘the beliefs and values that guide the design of and the collection and analysis of data in a research study’. Lemaire and Paquin (2019) believe that ‘the definitions of philosophy are neither unanimous nor constant in time’. These authors argue that each research philosophy embraces the basic principles on which the researcher relies on as a foundation for their approach to study. Barney (2001) and Priem and Butler (2001, cited in Parnell, 2005) argue that the concept of philosophy ‘implies the existence of competing ideals and multiple perspectives on an issue’. In the view of Gliner et al. (2011), philosophy drives the conduct of research. They believe that a philosophy defines the types of legitimate question, how they are to be answered and in what manner they are to be perceived.

Before they commence, researchers should consider the philosophy underlying their work (Saunders and Tosey, 2013); in other words, the philosophical belief adopted needs to be clearly addressed. This can be done by assessing different paradigms and validating the most appropriate one based on the nature of the research. Considering appropriate paradigms comprehensively in the initial stages of the research design is a top priority. According to Lincoln et al. (2011), ‘questions of method are secondary to questions of paradigm’. To clarify this perspective, some explanations are provided below on the definition a paradigm.

In the view of Fellows and Liu (2015), paradigms are theoretical settings and systems that facilitate the process of viewing events. Their function is not limited to the perspectives adopted; rather, they provide different pathways for queries and identification (Fellows and Liu, 2015). Each specific paradigm, as Grant and Giddings

(2002) state, promotes commitment. Paradigms may assist researchers in directing their focus in the most appropriate and suitable manner. Grant and Giddings believe that selecting the most adequate paradigm is of the utmost importance for approaching scientific inquiries and eliminates potential issues for the researcher.

Wahyuni (2012) and Guba and Lincoln (1994) stress the importance of paradigms in a research study: ‘Research paradigms address the philosophic dimensions of the social sciences’ (Wahyuni, 2012). A research paradigm is a collection of essential assumptions and beliefs that provides an envisioning framework and directs the researcher throughout the research (Jonker and Pennink, 2010).

Grant and Giddings (2002) emphasise the importance of philosophical issues in different types of research. Similarly, Creswell (2009) articulates that initially it is important to question the research paradigm to be implemented in the conduct of research, because it significantly influences the way in which social studies are developed, understood and carried out.

Some researchers distinguish paradigms by applying common criteria, entitled metaphysics, including ontology, epistemology and methodology as three fundamental beliefs. These metaphysics criteria lead researchers in conducting a scientific exploration (Saliya, 2009). Wahyuni (2012) represents them as ‘philosophical dimensions to distinguish existing research paradigms’. According to Wahyuni, ontology and epistemology ‘relate to the nature of knowledge and the development of that knowledge, respectively’.

Wahyuni (2012) adhere to Grant and Giddings (2002) regarding the role of ontology in representing the nature of knowledge to be explored: ‘Ontology is the view of how one perceives a reality’ (Wahyuni, 2012).

Epistemology illustrates the connection between a researcher and a knowledge discipline (Guba and Lincoln, 2005). It is used to create, recognise and apply knowledge that is considered adequate and legitimate (Wahyuni, 2012). The level of impact a researcher can have on the investigation process is normally defined as the ‘amount of objectivity or subjectivity introduced to the study’ (Saliya, 2009). The third metaphysics criterion, methodology, refers to a framework for conducting a research process in the area of a specific paradigm (Wahyuni, 2012). In other words, it outlines the approach adopted by the researcher to explore the knowledge.

This study reviewed all paradigms under each of the three metaphysics criteria and examined the most suitable paradigms individually. The eventual outcomes of examining each of these three criteria were combined to assess the consistency between them. Four paradigms were considered in the current research: positivism, post-positivism, interpretivism and critical theory.

The following section explains the abovementioned paradigms examined in this study under the three metaphysics criteria.

4.2.1 Ontology: The Nature of Knowledge to be Discovered

Ontology explains the characteristics of the knowledge to be discovered. Four types of ontological position determined are naïve realism, critical realism, relativism and historical relativism. According to Golafshani (2003), positivism can be utilised to examine facts related to naïve realism. Guba and Lincoln (2005) describe these facts as natural law-driven facts.

Saliya (2009) and Wahyuni (2012) believe that there is no artificial nature in the knowledge related to positivism. For instance, because of the uniqueness of gravitational acceleration, it is seen as a global reality; however, is uniqueness and being natural associated with the ontological status of the current investigation?

In contrast, the positivist's view of naïve realism is disproved by the other three paradigms. As post-positivism contends, universal truth does not exist; rather, there are different views of scientific knowledge because of multiple realities. Post-positivism 'introduces critical realism into research disciplines as opposed to naïve realism' (Bailey, 2007). Interpretivism argues that knowledge is a local and especially formulated reality; therefore, interpretivism is understood as relativism. Critical theory identifies that knowledge is practically formed over time by cultural, social and racial values; this is considered historical realism (Grant and Giddings, 2002).

By using the articulation of the essence of a criminal investigation, Guba and Lincoln (1994) distinguish knowledge related to positivism and interpretivism: a positivist evaluates crime utilising quantitative techniques, and correspondingly the researcher intends to discover patterns and connections between causes and effects. The counterviews of the interpretivist are views such as categorisation of crimes and assessing the potential of becoming a criminal in a society.

In the view of Guba and Lincoln (2005), the positivist considers everything as quantifiable, while the interpretivist argues that knowledge is an 'intangible mental construction'. The paradigm of critical theory adheres to interpretivism in the intangibility of social constructs (Saliya, 2009). This author believes that there is much more flexibility in post-positivism in regard to tangibility.

Post-positivism contradicts interpretivism in regard to the intangibility of abstract measures (Grant and Giddings, 2002). Nevertheless, post-positivists assume that reality cannot be fully understood given the lack of a rational mechanism and the inflexible attributes of phenomena (Guba and Lincoln, 1994). Consequently, post-positivism seems different from positivism: 'Researchers can still move towards the perfect reality related to abstract measures in post-positivism by using accumulated efforts' (Bailey, 2007; Wahyuni, 2012). There is still a need for inquiries to be critically assessed, to be as close to reality as possible (Letourneau and Allen, 1999).

In view of the abovementioned ontological positions of post-positivism, knowledge related to post-positivism is believed to be critical realism between naïve positivism and post-structuralism (Guba and Lincoln, 2005).

Advantages and disadvantages related to the explained ontological positions are viewed in the context of this research study in further sections.

4.2.2 Epistemology: Interaction between Researcher and the Knowledge to be Identified

Epistemology explains the philosophical status associated with the interaction between the knowledge to be identified and the researcher. In the view of Guba and Lincoln (1994), three types of position can be associated with epistemology: pure objectivity, pure subjectivity and ideal objectivity.

As explained above, positivists believe in truth being real and natural; hence, the researcher should not impact or be impacted by the reality (Golafshani, 2003; Saliya, 2009; Wahyuni, 2012). Positivism, consequently, requires pure objectivity—but can there be pure objectivity? This has been widely debated at the philosophical level by scholars such as Fellows and Liu (2003) and Grant and Giddings (2002).

Even in experimental measurements, the influence of researchers is evident (Grant and Giddings, 2002). This can be seen in the variable selection process. Further, machine and human error in analysis can negatively affect pure objectivity.

The interpretivist paradigm and critical theory act together in relation to their epistemological status. These two paradigms underscore the investigator's subjectivity in a research project. Guba (1990) argues that both interpretivism and critical theory can be considered 'the other extreme of positivism'. Moreover, Guba states the role of the researcher in both paradigms as a listener and interpreter, which represents a higher position for the researcher than for research participants.

From the post-positivist point of view on epistemology, ideal objectivity is placed between pure objectivity and pure subjectivity (Grant and Giddings, 2002). Post-positivism seems to be more adaptable because of ideal objectivity (Guba and Lincoln, 2005). Grant and Giddings (2002) concur, articulating that the ideal objectivity in post-positivism can be seen as an opportunity to benefit from both subjectivity and objectivity in a research study.

The epistemological positions explained above were considered in the context of this study to establish the most appropriate technique. The selection process is described in following sections.

4.2.3 Methodology: a Framework for Conducting a Research Process in the Area of a Specific Paradigm

The final metaphysics criterion relating to research paradigms and explained in this study is the methodology. This is a framework through which the researcher can conduct the research process and explore knowledge.

Verifying a theory is the positivist attitude in an investigation. The verification procedure is considered a controlled practice under which slightly ambiguous circumstances should be strictly monitored, to achieve validity in an investigation process (Guba and Lincoln, 1994). For instance, other influencing factors such as temperature change need to be observed in a pressure-to-volume relationship. Letourneau and Allen (1999) state that this methodological status is feasible where universal laws exist. Theory verification through a post-positivism methodology requires the heavy involvement of quantitative techniques (Guba and Lincoln, 1994). This is not necessary in all circumstances (Golafshani, 2003).

Fellows and Liu (2003) concur with Letourneau and Allen (1999) in rejecting that knowledge can be possibly confirmed by a positivist methodology. Knowledge can only be substantiated or contradicted; it cannot be authenticated (Fellows and Liu, 2003). These authors describe that numerous facts are required to substantiate a theory; however, just one fact would be sufficient for contradicting the same theory. Post-positivism is the most appropriate methodology in investigations associated with scientific knowledge, in which multiple methods are suggested for exploring the as-close-as-possible reality. This post-positivism paradigm does not follow intractability when selecting and fully controlling circumstances; rather, post-positivism seeks to achieve credibility by selecting diverse techniques from among qualitative and quantitative methods, referred to as ‘critical multiplism’ (Letourneau and Allen, 1999).

Interpretivism and critical theory promote the use of mainly qualitative methods in the context of research investigations. Denzin and Lincoln (2003) demonstrate the inductive implementation of the quantitative method in research investigations in the interpretivist paradigm. This is referred to as hermeneutical/dialectical methodology in the authors' conclusion on interpretivism.

A dialectical approach is used in the critical theory paradigm, where qualitative conversational information is assessed in a reasonable manner to identify the negative consequences of constructs (Bailey, 2007).

Based on the methodological concepts discussed for the four paradigms chosen, the appropriateness of each was evaluated and compared in the context of the current study to identify the most effective philosophy. This is described in the following section.

4.2.4 Determining the Best Paradigm for the Current Research

This section compares the philosophies of positivism, post-positivism, interpretivism and critical theory within the context of this study to select the most suitable paradigm.

4.2.4.1 Ontology

The ontological status associated with each of the paradigms was explained in Section 4.2.1. This section connects the knowledge and each of the paradigms associated with this research investigation.

Knowledge related to positivism is distinctive across the world and is therefore seen as a global reality. The question here is, are all these attributes relevant to the knowledge explored in the current study?

Based on the literature reviewed, VE strategies and scheduling theories are both human made and not natural. Successful completion of construction projects is influenced significantly by the attributes and contributions of stakeholders. A wealth of literature suggests there is no unique approach or scheduling theory relating to delay mitigation in construction projects. In addition, reality is highly dependent on the diverse opinions of respondents in scheduling of construction projects. This indicates the controversial position of naïve realism, referred to as the ontological position of positivism, in the current research.

One of the objectives in the current research is to investigate the usefulness of VE strategies in delay mitigation. The causes and effects in this objective must be quantifiable (tangible) in relation to both concrete and abstract indicators. This necessitates the use of interpretivism and critical theory in this investigation. Interpretivism and critical theory consider abstract knowledge under unquantifiable mental constructs.

Post-positivism is founded on critical realism that also—because of this study's scope—can make the investigation much more flexible. In view of post-positivism, concrete and abstract measures are both quantifiable (tangible). In addition to technical knowledge and mathematical formulations, as construction project settings are formed by human perspectives and their understandings, tacit knowledge is also associated with the current study. Socially constructed knowledge can be investigated through critical realism (Danermark et al., 2002).

Investigating reality accurately through multiple methods can be promoted by implementing critical realism as the optimum ontological position in this investigation. This is explained further in Section 4.2.4.3.

4.2.4.2 Epistemology

Three epistemological positions, namely pure objectivity, pure subjectivity and ideal objectivity, were introduced in Section 4.2.2.

Variables relevant to this research may include types of contracts, resources and methods. The selection of possible variables for this study based on these circumstances would be subjective. Further, potential errors in responses are inevitable, even in relation to satisfying schedule and budget targets. For instance, in regard to evaluation of schedule overruns, an investigator may or may not measure the effect of certain variations on final achievements. Is there any way to measure the impact of strategies in projects? What is the potential scale to be implemented? Since these measures may be subjective, pure objectivity—on which positivism is founded—is therefore not appropriate for this research study.

As discussed earlier, the investigator is weighted more highly than research participants in the field of interpretivism and critical theory. This is a different situation form that in the current study. The aim of this study is to evaluate potential VE protocols and their influence on delay mitigation using the insights of industry professionals. Since the participants may have more influence than the investigator within the context of the study, interpretivism and critical theory are not applicable here. As discussed earlier, they require pure objectivity, which is not possible here.

In light of the abovementioned criticisms, this study aims to utilise a position between pure objectivity and subjectivity. This is post-positivism under an epistemological status. Post-positivism is therefore considered the most accountable based on epistemological and ontological grounds.

4.2.4.3 Methodology

Owing to the ontological status of this research, it was strongly advised that various methods be used for this research investigation.

The complex circumstances that are applicable to the nature of the knowledge in this study cannot be controlled entirely, unlike the conditions in an experiment. This makes the validity of the positivist approach debatable. For instance, the study concludes there are no definite boundaries between uncertainty, uniqueness and complexity. It is quite difficult to measure complexity by separating uniqueness or other attributes in a project environment. Further, participants could not be anticipated to evaluate these measures in a completely accurate manner. In these scenarios, post-positivism is the correct methodology; therefore various methods need to be utilised to uncover reality as much as possible (Shadish, 1993). Therefore, both quantitative and qualitative techniques are used to accurately investigate knowledge relevant to this research study. As per this methodological status, this research investigation considers methodological concerns in relation to positivism, interpretivism and critical theory.

In this section, post-positivism is considered the most suitable philosophic status for the three metaphysics criteria, namely ontology, epistemology and methodology.

Associated with ontological position, the knowledge related to this research investigation could not be regarded as global legislation; thus, this scientific investigation encompasses numerous realities and views regarding on-time completion in construction projects and VE approaches. As discussed above, ideal objectivity is located between pure subjectivity and pure objectivity. By employing both qualitative and quantitative approaches, this philosophical approach increases flexibility to achieve the objectives of this research study. Hence, post-positivism is considered a philosophic position that varies across positivism and interpretivism/critical theory. Positivism is regarded as one extreme on this spectral range, while interpretivism and critical theory appear next to each other at the other extreme. The post-positivist position in this research study may remain between the two aforementioned extremes depending on the nature of the research inquiry. Research philosophies can no longer be viewed as widely valid rules or abstractions (Denzin and Lincoln, 2003). Consequently, paradigms regarded as conflicting in the old days are now closely interrelated under new theoretical frameworks.

Having identified the most suitable paradigm for the current research design, the selection of the most appropriate strategy for this research is now discussed.

4.3 Research Strategy

Saliya (2009) lists some of the commonly used strategies in research studies as case study, action research, survey, experiments and ethnography. Two categorisation mechanisms are widely utilised in research studies to identify the most adequate strategy for the research. The first is Bell's categorisation, as mentioned by Fellows and Liu (2003) and the second is introduced as Yin's categorisation (Yin, 2003). Both categorisations are explained individually in the following subsections to support determination of the most suitable research strategy. The conclusion in regard to the most suitable research strategy is therefore based on each categorisation with a rationale associated with the other.

4.3.1 Research Strategies Based on Bell's Categorisation

According to Fellows and Liu (2003), the five strategies considered under Bell's categorisation are case study, action research, experiments, ethnography and survey. Considering the nature of the current research study, three of these can be instantly omitted from the list: experiments, action research and ethnography. The choice of the most suitable strategy is described further below.

4.3.1.1 Initially Eliminated Strategies (Ethnography, Experiments and Action Research)

An action research strategy is designed to recognise issues and thus facilitate alternatives through the participation of researchers (Fellows and Liu, 2003). The aim of this research study is to develop a model that can assist in delay mitigation in marine projects using the views of industry professionals. Hence, the stakeholder influence is greater than that of the investigator in this research (see Section 4.2.4). This eliminates the action research strategy from among the applicable strategies. It should also be noted that trial strategies and conceptual models introduced in scholarly works should not be considered for implementation before rigorous investigation in the context of construction projects.

In the view of Fellows and Liu (2003), an experimental strategy is carried out under controlled circumstances when factors are well known. In the context of this investigation, and as explained under the ontological status of this research, there were no specific controllable circumstances. This adds the experiments strategy into the inapplicable list.

Finally, the ethnographic strategy is associated with scientific studies of cultures and races in which the behaviour of subjects is measured by a research as part of the subjects' community (Fellows and Liu, 2003). Based on the attributes of the current study, this categorisation does not apply. This leaves two strategies, namely survey and case study, for further review.

4.3.1.2 Comparison between Survey and Case Study for the Current Research Investigation

Fellows and Liu (2003) identify various ways in which surveys and case studies can be conducted. The survey strategy may utilise interviews or survey questionnaires for the purpose of data collection, while multiple techniques such as interviewing major stakeholders and archival research can be employed when conducting a case study. Considering the essence of the current study, both techniques were applicable for collecting the data. Qualitative data can be obtained for both methods using interviews. In terms of quantitative data collection, questionnaires may be utilised for the survey method, while archival data may be employed in case study.

Optimisation between breadth and depth, following Fellows and Liu (2003; see Figure 4.1) was used as the criterion in the current study for choosing the most suitable research method between the two strategies.

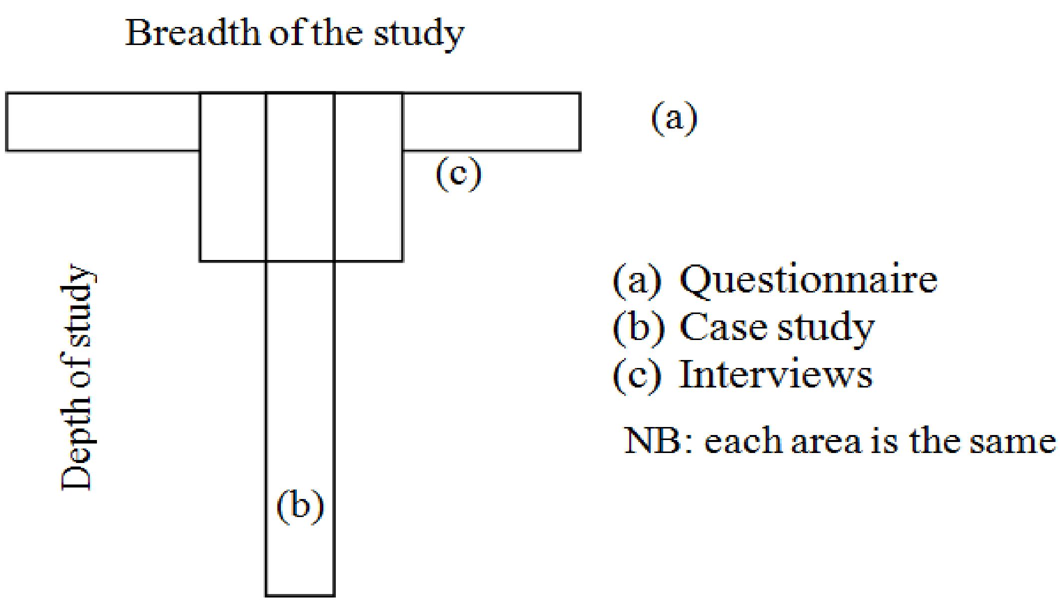


Figure 4.1: Depth and breadth of a research study (adopted from Fellows and Liu, 2003)

Figure 4.1 provides a graphical comparison of the three research methods. Breadth is associated with the proportion of data or the number of projects under study. In the same way, depth specifies how detailed an investigator can be in terms of the specific features or number of projects. The size of the area in each of the boxes in Figure 4.1 is the same. As illustrated, the widest breadth and shallowest depth among the strategies are associated with the questionnaire. Conversely, the deepest is case study; although this is also the narrowest when it comes to width. The status of interview is almost intermediate.

As reviewed in Chapters 2 and 3, the normative construction management literature on marine projects is limited, although the construction literature is replete with publications on overrun causations. Hundreds of causal factors have been published in relation to various construction project environments. However, the particular relevance of these factors to marine projects is under-researched. Therefore, this investigation involved reviewing the literature and exploring how specific characteristics of marine construction projects are pivotal to achieving performance targets such as on-time delivery with minimal cost and high quality via a dedicated mechanism. This was the rationale for choosing breadth rather than depth in this specific situation. Consequently, the questionnaire strategy weighs more and is preferable over the case study.

The potential for findings generalisation is another selection criterion for identifying the most suitable research strategy. According to Rodríguez et al. (2010), both strategies can be employed with the purpose of generalisation, but the process may differ for each. These authors believe that, like experiments, theoretical generalisation can be employed in generalising findings of case studies. The generalisation process can utilise software packages or strong theoretical justifications with empirical interactions (Fellows and Liu, 2003). Nevertheless, because of the nature of the current research study, it was not possible to develop such theoretical formulations for the purpose of generalisation.

Survey as a research strategy requires the use of quantitative analysis for statistical generalisation (Fellows and Liu, 2015). Information gathered from a sample from a population provides the basis for generalisation from that population. Statistical generalisation seemed applicable in the current research study. Consequently, as per the potential for generalisation, the survey strategy was considered the only effective method for the current investigation.

Considering the definition and extent of this investigation, combined with the generalisation requirements, the survey research strategy was regarded as the most adequate method of inquiry for this investigation.

4.3.1.3 Research Strategies under Yin's (2003) Categorisation

A further classification of research strategies is provided by Yin (2003). This strategy offers a more specialised assessment of the best appropriate strategy for the current investigation than is possible with Bell's categorisation. In Yin's (2003) view, there are five applicable strategies, namely case study, experiment, archival review, survey and history. Yin argues that three areas of concern that must be evaluated before identifying the most appropriate research strategy are the nature of the questions raised, the researcher's authority regarding the events and whether the emphasis on the events is contemporaneous or historic. Adopted from Yin (2003), Table 4.1 shows the relevance of the five research strategies based on the abovementioned criteria.

Table 4.1: Research strategies based on the nature of an inquiry (adopted from Yin, 2003)

Strategy	Type of question	Control on behavioural events needed	Contemporary events focused
Experiment	How, why	Yes	Yes
Survey	Who, what, where, how many, how much?	No	Yes
Archival analysis	Who, what, where, how many, how much?	No	Yes/No
History	How, why	No	No
Case study	How, why	No	Yes

Based on Table 4.1, experiments may be utilised if the type of questions raised by a research study is how or why. While experiments must be governed by the investigator, there is no need for any direct control over history and case study. Besides, in regard to the timeframe, case studies and experiments are contemporary events focused, while history is utilised for investigation of previous events. Thus, experiments, history and case study were considered unsuitable for the current study.

The two remaining research strategies, namely archival review and survey, can be utilised to examine other types of question including where, who, what, how much and how many. It should be noted that these strategies are not applicable for addressing why and how questions. Survey and archival review do not require any form of researcher control. The main criterion for choosing between these two research strategies is therefore the timeframe—historic or contemporaneous. An archival research strategy is applicable for exploring both previous and contemporary events while a survey research strategy is focused only on contemporary events. In Yin's (2003) explanation, the essence of an event is concluded as contemporaneous or historic in terms of the ability to obtain statistics, but the timeframe of real events is still in progress. In terms of the current research study, data could be obtained from stakeholders and industry experts even for construction projects carried out in the past. Hence, the events (projects) could be regarded as contemporary. Yin’s (2003) categorisation was used for in-depth examination of the research inquiries relevant to this study. Some of the relevant questions in the current research investigation are shown in Table 4.2.

Some research queries in the primary data examination are shown in the first column of Table 4.2. Yin’s (2003) categorisation and the most appropriate research strategy in regard to the three criteria of question type, control and timeframe are described in the following six columns. Finally, the most suitable strategy with a view to each research inquiry is displayed in the last column of the table.

Table 4.2: Research strategies in comparison to the current investigation (adopted from Yin, 2003)

Research query and description	Question		Control		Timeframe		Suitable strategy based on the three criteria
	Type of question	Appropriate strategy	Researcher's control	Appropriate strategy	Contemporaneous/historic	Research strategy	
To what extent/how much can the following variables be considered in a VE workshop to establish a delay mitigation strategy for marine projects?	How much/how many impacts on delay mitigation?	Survey	No	Any strategy except experiment	Contemporary	Any strategy except history	Survey/archive
What level of importance can the following factors have in delaying marine projects?	What/ who/when?	Survey/ archive	No	Any strategy except experiment	Contemporary	Any strategy except history	Survey/ archive
How much do VE protocols contribute to improving schedule performance in marine construction projects?	How much/how many?	Survey	No	Any strategy except experiment	Contemporary	Any strategy except history	Survey/archive

It should be noted that some queries in Table 4.2 could be classified into several question types. For instance, the third research question identifies the contribution of VE protocols to the schedule performance of marine construction projects. This query may be raised in several forms, including why VE protocols are used, what is the reason behind selecting this strategy, where exactly can these strategies be implemented or in which circumstances may they be more effective. Each form can address the query. Thus, where multiple potential forms were possible, this study examined two dimensions of queries, namely the breadth and depth of the research inquiry corresponding to Bell's categorisation. What, where and when strategies were considered for the purpose of obtaining reasons solely as factual information. No detailed explanations are needed for the way something has occurred. However, in the case of a why form of inquiry, the focus of an investigation would be on in-depth data collection to provide extra definition for the inquiry. For instance, why does this happen; who is mainly accountable; how are environmental impacts ameliorated via strategies? Asking subsequent questions may contribute more context to an investigation. Reasons in the current research investigation were considered facts only.

As shown in Table 4.2, the first and third research queries are in the form of how much/how many. This type of query can be addressed through either archival review or survey under Yin's (2003) categorisation. Particularly for the first and third query, it would have been difficult to obtain the required information for this study through archival review. For instance, the research study required determination of the extent to which VE protocols might contribute to schedule performance. The answer was unlikely to be obtained via an archival review. Thus, despite the theoretical potential of implementing an archival review, the final approach of survey strategy was considered on the basis of Yin's (2003) categorisation.

The extent of the researcher's control and the timeframe as the remaining criteria in Table 4.2 were clear concerns in the context of the current investigation. Considering that no control was required by the investigator, any research strategy (excluding experiments) could be used in the current research study. Equally, any research strategy with the exception of history could be employed since contemporary events were investigated.

Survey as the only research strategy for addressing all the research queries in this study is represented in the last column of Table 4.2. Consequently, both Bell's and Yin's categorisations provide equal outcomes in relation to the most suitable research strategy to be employed in the current research study. Having investigated the paradigms and survey strategies, potential research methods are now reviewed.

4.4 Qualitative Research

Labaree (2009, P4) considers that the term qualitative 'implies an emphasis on the qualities of entities and on processes and meanings that are not experimentally examined or measured in terms of quantity, amount, intensity or frequency'.

Fellows and Liu (2015) describe the qualitative approach as an instrument for obtaining people's viewpoints about a targeted situation either individually or as a group. Consequently, the validity of qualitative data is frequently challenged, especially by scholars with quantitative expertise. According to Fellows and Liu, the analysis of such data is considerably more difficult than analysis of quantitative data, often involving a lot of 'monitoring, filtering and other manipulations' to render methods justifiable as analytical techniques. Through qualitative research, people's beliefs and viewpoints are investigated and the data obtained may be indefinite; however, it will continue to be comprehensive and thus enhanced in content and meaning through a qualitative approach to improve the quantitative perspective.

In the view of Kumar (2019), qualitative study offers the researcher full versatility in all dimensions including aims, structure and methodology. Kumar states that qualitative study is rooted in the theory of epistemology; promotes an accessible, versatile and 'unstructured approach' to investigation; aims at investigating 'diversity rather than quantifying'; underlines the explanation and interpretation of thoughts, beliefs and experiences rather than measuring them; and presents results in a detailed and concise manner rather than analytical form, with less focus on generalisation.

Creswell (2018) concurs with Fellows and Liu (2015) in regard to the capability of a qualitative method as a tool to analyse and acquire the definition ascribed by people or groups in regard to a social problem. According to Creswell, the process includes evolving questions and techniques. Data captured from a participant are analysed using an inductive approach, developing from specific to general themes, with the researcher interpreting the significance of the data. Finally, there is a flexible framework in the ultimate detailed report.

The role of the researcher is highlighted in a wealth of literature. According to Neuman (2014a), a qualitative researcher authenticates the study by reorganising, evaluating and explaining descriptive or graphical data in a way that provides a convincing voice to the initial perception of individuals and the circumstances examined. Rather than relying on charts and numbers, qualitative study puts a stronger focus on data interpretation that is eventually richer and more meaningful. The qualitative researcher describes originally obtained data for readers in a persuasive manner (Neuman, 2014a; Kumar, 2019).

A qualitative research study passes through three phases, as shown in Table 4.3.

Table 4.3: Process of qualitative interpretation (adapted from Neuman, 2014a)

Stage	Description
1	Obtaining specific explanations and viewpoints of the individuals being examined
2	Eliciting underlying consistency in the data
3	Connecting the insights achieved to generalisations of wider concepts or theories

4.4.1 Advantages of Qualitative Research

The ability to generate comprehensive and rich data is stated by Labaree (2009) as the key strength of a qualitative method. This keeps the 'participants' perspectives intact' and offers 'multiple contexts' to explain the phenomenon being studied. The benefits of a qualitative approach for a researcher, according to Labaree, are that it:

- offers the potential to acquire a better understanding of the surrounding environment, which cannot be recognised or obtained through standard numerical and statistical analysis
- provides the opportunity for direct interaction with the participants and immersion in a situation

- enables the researcher to explain current phenomena and circumstances
- establishes flexible forms to gather, analyse and interpret the collected data
- generates outcomes that can help to develop new perceptions
- reacts to variations occurring during the course of the study and provides an alternative research focus
- offers a ‘holistic’ perspective of the phenomenon under study
- reacts to respondents’ local situations, conditions and demands
- enables interactive communication with the ‘research subjects’
- uses initial and unstructured data to ‘create a descriptive capability’.

The main strength of a qualitative approach as presented in the work of Eriksson and Kovalainen (2015) is its capacity to provide nuanced textual content regarding how individuals experience a specific research problem. Similar to this, Bakalis (2001) defines that this method allows for detailed study of specific problems by the researcher. It is ideal for smaller populations and complex subjects (Mitchell, 2007). The scope of this method is wide ranging, which provides participants the opportunity to discuss topics that they consider important (Yauch and Steudel, 2003).

4.4.2 Limitations/Disadvantages of Qualitative Research

Labaree (2009) describes the limitations in the use of qualitative approaches as a means to ‘reflect their inherent strengths’. For example, thorough analysis of the subject under research can be facilitated using a small sample size. However, downsized samples ‘undermine opportunities to draw useful generalisations from the findings’. Labaree discusses the following significant limitations related to the use of qualitative approaches to perform a research study:

- distraction from the initial goals of the study as a reaction to the shifting nature of the research domain
- probable diverse findings using the same data because of the researcher's personal characteristics
- difficulty in replication of the study
- greater chance of ethical issues that compromise the study’s overall validity
- inefficiency in studying causal relationships across various research

phenomena

- complexity in describing differences in the quality and quantity of data obtained from various participants and drawing different, incoherent conclusions
- the collection and processing of data is often tedious and/or costly
- needs a high level of expertise to acquire the required information
- techniques utilised by the researcher and attributes of respondents may threaten consistency and reliability
- inability to facilitate data analysis by splitting the large volume of data into manageable elements.

According to Yauch and Steudel (2003), a qualitative approach is time consuming. They add ambiguity in research questions for some participants as another limitation of this approach. Fellows and Liu (2015) consider that qualitative data analysis is substantially more difficult than quantitative data analysis. In addition, this method has always been the focus of a discussion on generalisability (De Vaus, 2002). Polit and Beck (2010) consider small sample size as the major issue in not being able to generalise findings obtained via this approach.

4.5 Quantitative Research

The quantitative method is used to examine relationships between evidence and data collected in line with a hypothesis, research question and results of previous research. In the view of Neuman (2006, cited by Choy, 2014), the process of quantitative research commences with the consideration of a topic by a researcher. By conducting a thorough review of literature, an issue in a common field of study becomes the focus for development of a research question that can be addressed in the study. Choy identifies the characteristic of this method as a structured questionnaire administered to a target group. In a similar way, in this approach, Babbie (2013) describes structured instruments as the means for data collection. Amaratunga et al. (2002) state that the quantitative method derives from a robust academic background that has immense trust in statistics reflecting views or concepts.

Kumar (2019) states that the quantitative method is grounded in the theory of rationalism; embraces a fixed, standardised and predefined set of criteria to be investigated; seeks to measure the degree of variability in a problem; focuses on the estimation of factors and process objectivity; trusts in corroboration based on a large sample size; and assigns priority to the accuracy and reliability of results. This approach reports findings analytically and draws conclusions and assumptions, with the potential to be generalised. Kumar also suggests that in quantitative research, everything shapes the method; the strategic goals, design, sample and questions the researcher intends to present to the participants are preordained. The value of this technique is the capability of discussing and evaluating the interactions among variables, and defining their causalities.

Similarly, Creswell (2018) identifies the quantitative method as 'an approach for testing objective theories by examining the relationship among variables'. These variables, from Creswell's perspective, can be assessed using various research tools, so that statistical techniques for evaluating numbered records can be performed. The overall report is composed of an 'introduction, literature and theory', methodology, findings and discussion structure. Creswell states that as this research methodology is focused on measurement, it relies greatly on the researcher's capability to detect and quantify variables. In the same way, Gomm (2008) believes that quantitative approaches usually require quantitative data processing to describe a predetermined circumstance objectively.

In quantitative research, according to Neuman (2014a), 'cases are usually the same as a unit of analysis, or the unit on which variables are measured'. Quantitative researchers typically assess variables against their hypotheses or research questions. A quantitative researcher authenticates the process by reorganising, assessing and describing statistics using diagrams and data to illustrate how data patterns correspond to the study topic (Neuman, 2014a). Neuman emphasises the importance of the researcher's approach to defining the variables, which strongly supports the accuracy of a study's findings. In the view of Ackermann and Hartman (1999), the reliability of findings with the quantitative method is strongly associated with the instruments adopted to measure the variables.

Quantitative research explores causalities, requires statistical work and typically commences with a notion (Flick, 2015). Bell et al. (2018) underline four characteristics that distinguish quantitative research: ‘measurement, causality, generalisation and replication’. Bell et al. define a quantitative approach as ‘entailing the collection of numerical data and as exhibiting a view of the relationship between theory and research as deductive, a predilection for a natural science approach, and as having an objectivist conception of social reality’ (P164).

The quantitative method stands out by summarising and generalising large amounts of information on the basis of statistical assessments (Arora, 2015). Similarly, Labaree (2009) states that ‘quantitative methods emphasise objective measurements and the statistical, mathematical or numerical analysis of data collected through polls, questionnaires, and surveys or by manipulating pre-existing statistical data using computational techniques’. The key characteristics of this method are as follows (Labaree, 2009; Babbie, 2013):

- Typically, data are obtained using structured research tools.
- Findings are based on large sample sizes that reflect the population.
- Provided high reliability, it is possible to replicate the research process.
- The research question is clearly defined and used to obtain objective responses.
- Before commencing the data collection, all dimensions of the study are considered precisely.
- Data are arranged in the form of statistics and numbers, mostly in tables, graphs, figures and any other form rather than textual.
- The study could be utilised to generalise ideas more broadly and to envision future outcomes.
- Questionnaires and computer software are the appropriate instruments to collect numerical data.

The whole process leads to classified items and developed statistical models that attempt to describe the observations.

4.5.1 Advantages of Quantitative Research

Some benefits of employing quantitative research are as follows (Labaree, 2009):

- Because of the large number of topics allowed for a study, generalisation of the findings is ameliorated.
- It renders outcomes more accurate.
- It is possible for the research to be replicated and cross-checked with other studies as it employs well-established standards.
- Vast information sources can be summarised, and comparisons across groupings and over time can be made.
- By maintaining a 'distance' from the contributing subjects and using a recognised statistical methodology, individual bias can largely be eliminated.

Kumar (2019) credits this approach's objectivity to quantifiable outcomes and the independence of the researcher. In conjunction with other scholars, Neuman (2006) considers the potential for findings to be generalised to a greater population a key advantage of the quantitative method. Graphs and charts as the most common forms of presenting findings provide an easier way to understand results (Walliman, 2006).

4.5.2 Limitations/Disadvantages of Quantitative Research

The results of quantitative research may be statistically significant but are often of little significance to humans (Labaree, 2009). Labaree identifies some significant limitations concerning the use of the quantitative method to conduct a research study:

- Quantitative data are capable of testing assumptions, 'but may miss contextual detail'.
- The main issue with this method is inflexibility due to application of a rigid approach.
- Manipulation of the research question by the researcher will establish 'structural bias'.
- The results offer less detail about 'behaviour, attitudes and motivation.
- There is a risk for the researcher of not obtaining sufficient, in-depth data.
- Since the findings are 'numerical descriptions', they are limited and do not

provide detailed explanations.

- Since the research is not conducted in a natural environment and a control level is applied, findings may not be real-world outcomes.
- Predetermined responses will not accurately represent how respondents actually feel about a specific topic and may simply be the closest approximation to a 'preconceived hypothesis', in some instances.

4.6 Mixed Method

A wealth of literature underscores the significance of the mixed method among research methodologies. This technique makes use of both quantitative and qualitative approach capabilities. Kumar (2019) states that the approach strives to select the best approaches for finding solutions to the research topic, irrespective of the qualitative–quantitative distinction. It integrates two and sometimes more processes of collecting and analysing research-related data. Kumar defines the focus of this technique as justifying and using the best-suited approach in different scenarios. The mixed method methodology has both qualitative and quantitative characteristics. Certain elements of the process may be flexible and some may be entirely lacking, depending on the model to which they contribute (Johnson and Onwuegbuzie, 2004).

Creswell (2018) identifies a similar pathway for the mixed method, determining this technique as an inquiry methodology comprising the collection of both quantitative and qualitative statistics, the incorporation of the two types of data, and the use of different designs that may include methodological hypotheses and theoretical frameworks. In addition, Creswell highlights that the combination of the two data types provides extra insight beyond the data provided by each single type alone.

4.6.1 Advantages of the Mixed Method

The advantages of using mixed approaches in a research project are classified as follows (Kumar, 2019):

- Improves research potential.
- In scenarios with multiple goals to achieve and where there is no chance of

achieving all the objectives by using only one method, the implementation of various techniques provides an opportunity to find answers to research questions.

- Ideally suited to more complicated situations.
- In complicated situations, this method gives the flexibility to use the most appropriate method, regardless of the model.
- Data enrichment.
- There are cases where data are collected using one approach but an additional dataset is needed for its enhancement or enrichment. The second dataset predominantly takes a different viewpoint on the problems. Such triangulation enhances the data and increases the precision of the results, which is only achievable when the research employs a mixed method approach.
- Collecting extra research information.
- In complicated cases, it is reasonable to gather data by employing two approaches, which provides additional evidence to support or refute a point. The additional dataset is used to compare and validate or refute the results obtained from the first approach.

4.6.2 Disadvantages of the Mixed Method

Kumar (2019) describes some disadvantages of employing the mixed method approach:

- Additional data requires more effort and resources.
- Additional data collection requires more processing time, a larger budget and more effort and technical knowledge. The researcher must deal with at least two datasets, doubling the entire collection, analysis and processing flow.
- Requires extra and different expertise.
- Since this technique requires different approaches that belong to both paradigms, the researcher must be highly familiar with all the techniques and protocols they may need to use that involve a broader set of expertise than for single-method research.
- More than one study population is involved.
- In this approach, it is necessary to contact and develop relationships with more

than one study population.

- Fixing the issues of inconsistencies in data.
- The researcher may detect a substantial discrepancy between datasets. How would they determine whether one is reliable?

4.7 Qualitative *v*. Quantitative Research

Leedy and Ormrod (2015) believe in the importance of 'similar processes' in both qualitative and quantitative methods. Commencing with identification of a 'research' problem and following up by exploring the literature and ultimately collecting and analysing data is embedded in both approaches. However, the two approaches suit different data types. From Leedy and Ormrod's point of view, the quantitative method requires 'numerical data' while a qualitative approach utilises 'non-numerical' data at the initial stage. Table 4.4 outlines the common differences between the two methods according to Leedy and Ormrod (2015).

Neuman (2014a) describes the specific characteristics of quantitative and qualitative methods in a different way. Table 4.5 presents Neuman's perspective on these two approaches.

Quantitative and qualitative approaches are ideal for addressing various kinds of questions. However, it is the researcher's responsibility to make an informed decision on the most appropriate method of research to be used in the conduct of their study.

Table 4.4: Differences between qualitative and quantitative methods (source: Leedy and Ormrod, 2015)

Question	Quantitative	Qualitative
What is the purpose of the research?	• To explain and predict • To confirm and validate • To test theory	• To describe and explain • To explore and interpret • To build theory
What is the nature of the research process?	• Focused • Known variables • Established guidelines • Pre-planned methods • Somewhat context free • Detached view	• Holistic • Unknown variables • Flexible guidelines • Emergent methods • Context bound • Personal view
What are the data like, and how are they collected?	• Numerical data • Representative, large sample • Standardised instruments	• Textual and/or image-based data • Informative, small sample • Loosely structured or non-standardised observations and interviews
How are data analysed to determine their meaning?	• Statistical analysis • Stress on objectivity • Primarily deductive reasoning	• Search for themes and categories • Acknowledgement that analysis is subjective and potentially biased • Primarily inductive reasoning
How are the findings communicated?	• Numbers • Statistics, aggregated data • Formal voice, scientific style	• Words • Narratives, individual quotes • Personal voice, literary style (in some disciplines)

Table 4.5: Qualitative *v.* quantitative research (source: Neuman, 2014a)

Quantitative research	Qualitative research
Test a hypothesis with which the researcher begins	Capture and discover meaning once the researcher becomes immersed in the data
Concepts are in the form of distinct variables	Concepts are in the form of themes, motifs, generalisation and taxonomies
Measures are systematically created before data collection and are standardised	Measures are created in an ad hoc manner and are often specific to the individual setting or researcher
Data are in the form of numbers from precise measurements	Data are in the form of words and images from documents, observations and transcripts
Theory is largely causal and is deductive	Theory can be causal or non-causal and is often inductive
Procedures are standard and replication is assumed	Research procedures are specific and replication is very rare
Analysis proceeds by using statistics, tables or charts and discussing how what they show relates to hypotheses	Analysis proceeds by extracting themes or generalisation from evidence and organising data to present a coherent, consistent picture

4.8 Justifying the Method Adopted for This Study

Most research issues have ‘both quantitative and qualitative dimensions’ (Leedy and Ormrod, 2015); thus, researchers need to use both techniques to sufficiently address them. The use of quantitative and qualitative data is inevitable for some research issues; such issues demand the mixed method. This approach involves not just the collection, analysis and interpretation of both types of data, but also the integration of conclusions from those records into a coherent whole (Leedy and Ormrod, 2015).

This study is carried out utilising the mixed method approach. The approach is built upon the descriptions of research strategies in Section 4.3 and the research goals in Chapter 1.

Three objectives of this study were identified in Chapter 1. Identification of crucial VE variables appropriate to be implemented in marine projects, as the first objective of the study, was achieved by a literature review undertaken to establish an initial perception about the phenomenon. The aim was to elicit the most important VE variables applied in projects that have helped minimise the likelihood of overruns and added value. The obtained variables were embedded in an online survey instrument. Experts in a range of positions—including clients, consultants, experienced contractors, project planners, construction managers, project engineers and technical office engineers—were asked to evaluate the 19 identified VE variables and rate the influence/significance of each in establishing a mitigation strategy for marine projects. Key affecting agents were obtained by applying the reductionist method.

By conducting a more technical study and considering the wealth of literature, key delay causations were identified as the second objective. The outlined delay causations were fine tuned into an online survey/questionnaire. The survey was designed based on an appraisal of the importance of each variable to time overruns in marine projects. Most of the data were accumulated from projects implemented in Iran; however, some other countries were considered as complementary sources. The participants rated the relative importance of time overrun agents for marine projects in the survey questionnaire and a record of key delay factors was obtained by applying the reductionist method to the data.

As the third objective of the study, SEM was utilised to illustrate a structure for the covariance among obtained combined variables and to determine the factor structure of the dataset. This was conducted to confirm the results and check for any relationships between the observed variables and their underlying latent construct(s).

A qualitative instrument helped to validate the findings of this study. This included an assessment of the correlation between elicited themes and corresponding variables as well as the potential relationship between variables in each group of delay and VE, through an open-ended questionnaire. Experts from different disciplines meeting two essential criteria—experience in marine projects and familiarity with VE processes—formed the target group. The demography of the participants is described in this chapter. The questionnaire helped to examine the findings and validate the obtained survey variables by using industry experts' opinions. This facilitated a conceptual model on how delays can be mitigated in major marine projects using VE protocols. In other words, the conclusive model revealed how and when VE protocols must be applied to achieve the best outcome for schedule performance.

The open-ended questionnaire utilised is provided in Appendix 1. At the end of the questionnaire, participants were asked to provide their impression about this study and their overall perception of the likelihood of addressing delay issues by implementing VE protocols. Other questions asked were their position/qualification and years of experience in marine projects in either the public or private sector, the frequency of project delays in their organisation and the best lifecycle stage for implementing VE in marine projects for the greatest chance of reducing potential overrun issues.

4.9 Research Instruments for the Purpose of Data Collection

To function effectively, every professional requires specialised instruments. The instruments used by researchers to pursue their research objectives vary significantly based on the adopted methodology and discipline. For the purpose of collecting and interpreting data and ultimately deriving useful conclusions, this study employed the research instruments discussed in the following subsections.

4.9.1 Literature Review

A literature review describes theoretical insights and previous research outcomes. Its purpose is to evaluate what has already been achieved in similar areas of study (Leedy and Ormrod, 2015). Adapted from Leedy and Ormrod (2015), Table 4.6 outlines the advantages of a thorough review of the literature.

Literature reviews are intended to provide a summary of the sources that researchers have reviewed when studying a specific topic, and to show readers how their work fits into a broader area of study. Some key purposes of a literature review as highlighted by Labaree (2009) are as follows:

- assessing and locating a study within the appropriate scope of its ‘contribution to understanding the research problem’
- developing new directions in evaluating previous studies in a similar context
- disclosing any inconsistencies in the literature
- ‘preventing duplication’ when conducting a research study.

Table 4.6 Advantages of an extensive review of the literature (adapted from Leedy and Ormrod, 2015)

No.	Description
1	It can help determine if other researchers have already discussed the whole or part of a research problem
2	It can offer new ideas and approaches that may not have occurred to the researcher
3	It can inform the researcher about other individuals conducting work in this area
4	It can alert the researcher to controversial issues and unresolved gaps in understanding
5	It can show the researcher how others have handled methodological and design issues in studies similar to their own
6	It can reveal sources of data about which the researcher may not have known
7	It can introduce the researcher to measurement tools that other researchers have developed and effectively used
8	It can help the researcher interpret and make sense of their findings and, ultimately, help tie their results to the work of those who have preceded them
9	It can strengthen researcher confidence that their topic is one worth studying, because they will find that others have invested considerable time, effort and resources in studying it

4.9.2 Case Study

A case study enables the researcher to study 'individuals or organisations, simply through complex interventions, interactions, communities or programs' (Yin, 2014). As a strategy, it explores the actual context of a problem. Denzin and Lincoln (2011) define this strategy as a comprehensive tool for research purposes. Kothari (2004) stresses the popularity of case study for exploring a 'social unit' in which the focus is 'in-depth rather than breadth'. In other words, case study is basically an extensive evaluation of the specific unit under review that establishes the validity of the review and facilitates further investigation about the topic in particular instances. The identification of the unit is easy because of clarity in boundaries (Payne and Payne, 2004). Kothari (2004) lists the characteristics of the case study approach as follows:

- There is a possibility for the researcher to consider one or more units to explore.
- In-depth study of the subject facilitates the path towards insightful conclusions.
- With this approach the subject is studied in full, considering all aspects.
- As a qualitative approach, this technique enhances our experience and provides a strong perspective on life.
- The subject of the research is explored directly by rigorous consideration of its profile.

- The case study approach leads to constructive hypotheses, making generalised knowledge more valuable.

According to Thomas (2003), a case study generally involves a ‘description of an entity and the entity's action’. Data from case studies help to identify entity issues and develop solutions. However, a major limitation is the high risk of making misleading generalisations because of the small number of cases under investigation.

In the view of Creswell (2018) and Leedy and Ormrod (2015), a case study is a systematic method in which a case is investigated over a specific period, involving comprehensive collection of data across various sources such as interviews, documents and archival reports. Data collected using the case study process is of great assistance to the researcher in designing an adequate questionnaire (Kothari, 2004).

In this study, key VE variables ideal for marine projects were identified from the literature. To identify variables that did not emerge from the literature review and establish the validity of the review findings, an archival report on a project in which VE had been performed was used as a cross-checking case study. This VE report was in regard to a jetty with a capacity for vessels up to 35,000 ton located in the Persian Gulf, Kish Island, Iran. The aim was to extract hidden VE variables that were not generated or were difficult to obtain via the literature review, but were applied in the project.

4.9.3 Questionnaire

Online questionnaires provide an efficient method for data collection within a short timeframe and with high quality (Mertler, 2002; Smith et al., 2013). The key advantage of online questionnaire surveys is that they improve efficiency by saving time. Data are instantly available and can be loaded into statistical software (Carbonaro and Bainbridge, 2000; Ilieva et al., 2002). In the view of Jones et al. (2008), questionnaires have specific benefits compared with other data collection instruments such as interviews. The process of collecting data is not costly and requires no highly skilled administrative staff. It is possible to reach a larger population and the instrument can be administered in numerous ways including verbally by telephone, email and via web links. Bowling (2014) identifies poor response rates and 'associated bias' as two major weaknesses of using questionnaires. Likewise, Leedy and Ormrod (2015) highlight the potential for a low rate of return as a downside to the use of questionnaires. They state that the only way to generate valuable data is to plan, formulate and distribute questionnaires carefully. To that end, Leedy and Ormrod introduce some useful guidelines that help by motivating participants to engage, to increase response rates. Table 4.7, adapted from Leedy and Ormrod (2015), outlines their protocol.

Table 4.7: Guidelines for efficient questionnaire construction (adapted from Leedy and Ormrod, 2015)

No.	Description
1	Keep it short
2	Keep the respondent's task simple and concrete
3	Provide straightforward, specific instructions
4	Use simple, clear, unambiguous language
5	Give a rationale for any item whose purpose may be unclear
6	Check for unwarranted assumptions implicit in your questions
7	Word your question in ways that don't give clues about preferred or more desirable answers
8	Determine in advance how you will code the responses
9	Check for consistency
10	Make the questionnaire attractive and professional looking

When respondents are from different regions, the online survey questionnaire is the most ideal way to obtain their responses (Leedy and Ormrod, 2015). Because of the diversity and distribution of marine construction projects all over the world, online instruments were considered the best way of approaching and interacting with the professionals involved in this area.

4.9.3.1 Questionnaire Design

At the stage of the primary investigation, a questionnaire was developed to collect data in line with the predefined objectives of this study.

Most of the items were presented as closed-ended questions. Only two open-ended questions were asked to obtain participants' particular perspectives regarding two factors: delay and VE variables. The primary investigation could therefore be viewed as quantitatively dominated. The assumptions on which the questionnaire's design was based are explained below.

Three key criteria for an efficient questionnaire are simplicity, which promotes participation; variety in question format, which motivates participants; and clarity, which mitigates errors in responses (Malhotra et al., 2002). This study follows Malhotra et al.'s (2002) suggestions for effective design of a questionnaire. The initial stage of reviewing the objectives was precisely done to identify which data were required. Approachability and availability of the information were two criteria that then needed to be considered. In designing the survey questionnaire, key inclusion criteria were experience in delivery of marine construction projects, familiarity with the VE methodology and significant technical or management responsibilities. The potential for gathering the required data was assessed by evaluating the questionnaire's length.

The most important consideration regarding questionnaire length is the balance between the amount of data and the participant response rate. Saunders et al. (2007) agree with Malhotra et al. (2002) about the potential negative impacts of a lengthy questionnaire. They consider the response rate to be inadequate with a lengthy questionnaire. However, it should be noted that in-depth data do enrich responses. The influence on response rate of the length of the questionnaire varies among studies, from high to very low (Cook et al., 2000; Walston et al., 2006). This variation is due to various factors determining the survey length, such as the number of questions, pages and screens, as well as the completion time (Cook et al., 2000). The importance of every single question in the questionnaire designed for this study was rated and considered. As a consequence, negative impacts on data enrichment of restricting the questionnaire's length could be mitigated. Thereafter, and following Malhotra et al. (2002), clarity and tendency in answering questions were taken into consideration.

The potential for confusion caused by double-barrelled questions was reviewed, as were biased questions. Further, and to enhance clarity if necessary, appropriate but brief explanations were included for each question. The goal was to include less technical terms, keep the wordings as simple as possible and make the whole process explicit.

Since anonymity generally facilitates the process of responding, the researcher decided to distribute the questionnaire anonymously. In addition, ticking and graphical techniques were utilised in the design of the questionnaire to promote participation. Most questions were brief and simple to answer, requiring either a short description or ticking of a box.

In regard to the layout of the questionnaire, participants were given the chance to contribute their point of view by highlighting possible missing variables in several open-ended questions. The preliminary evaluation of the questionnaire is discussed in the next subsection. Results arising from these responses formed the primary analysis of the data. Statistical data and the proportions of contributions in each area were identified using the Statistical Package for the Social Sciences (SPSS 25).

4.9.3.2 Preliminary Evaluation of the Questionnaire

How to design an unexceptionable questionnaire is a subject of controversy among scholars; however pre-evaluation contributes to developing an efficient one (Barribeau et al., 2012). These authors articulate two types of pretesting for a designed questionnaire: general; and reliability and validity. Barribeau et al. (2012) recommend assessing the layout, degree of difficulty in answering questions, information adequacy, terms and content, statistical significance and sequence, in general pretesting. Accuracy is considered in the second type of pretesting, for reliability and validity.

For pretesting of the questionnaire in this study, eight marine construction professionals from the main categories of contractors, consultants and clients formed the target group in a pilot study. The questionnaire was evaluated against the abovementioned criteria for general pretesting. Actions taken in the process of the questionnaire design (debriefing) were explained with the aim of reliability and validity pretesting. Table 4.8 summarises the procedure conducted for pretesting the designed survey questionnaire in this study.

Table 4.8: Participants in preliminary evaluation of the questionnaire

Participant position	No.	Category	Criteria
			General evaluation
Senior civil engineer	1	Contractor	Layout, difficulty, data adequacy, terms and content, sequence
Project manager	1	Contractor	Layout, difficulty, data adequacy, terms and content, sequence
Civil engineer	1	Consultant	Layout, difficulty, data adequacy, terms and content, sequence
Director with academic experience	1	Consultant	Layout, difficulty, data adequacy, terms and content, sequence, statistical significance
Senior project manager	1	Client	Layout, difficulty, data adequacy, terms and content, sequence
Senior project engineer	1	Client	Layout, difficulty, data adequacy, terms and content, sequence
			Reliability and validity evaluation
Construction manager	2	Contractor	Reliability and validity

The first column in Table 4.8 highlights each participant's current role. Eight participants in the study were requested to provide their point of view regarding the criteria mentioned in the last column. The criteria allocated to each respondent were associated with their expertise. For instance, only the director with the academic background was asked to provide feedback on statistical significance.

All participants agreed on the questionnaire's inclusiveness with respect to study objectives. However, two minor issues pointed out were that the large number of delay variables may require a long time to address and there was a necessity to translate the questionnaire into the Persian language. The first issue highlighted was dealt with by developing the format of the online questionnaire in a way that it could be saved and, if necessary, referred back to by a respondent. The questionnaire was also translated from English to Persian by an accredited translator for better consistency and accuracy, which addressed the second minor issue identified by the target group.

4.9.3.3 Open-ended and Closed-ended Questionnaires

The questionnaire is one of the most common techniques by which data can be collected in a research study (Polgar and Thomas, 1995). It is a research tool designed to collect relevant information from participants. The key success factor is precise structure and design of the questionnaire. Polgar and Thomas consider that the researcher plays a critical role in selecting the most relevant questionnaire from a range of formats that are compatible with the objectives of the study.

In the view of Polgar and Thomas, the two most popular forms of questionnaire are known as open-ended and closed-ended questionnaires. No predetermined answers are provided in open-ended questionnaires; whereas participants are provided with a prepared list of response options from which to choose in a closed-ended questionnaire. Polgar and Thomas (1995) adhere to Foddy and Foddy (1994) in this context. These authors state that closed-ended questionnaires restrict the participant to a range of options. McClelland (1994) names these ‘forced-choice’ questionnaires, suggesting there is a clear downside to them, in that the risk of not considering all potential choices could inadvertently affect the results. In the view of Foddy and Foddy (1994), open-ended questionnaires allow the respondent to state an opinion without being guided by the investigator. In other words, ‘respondent is asked to give a reply to a question in his/her own words and no answers are suggested’ (Patra, 2019). Participants may qualify their explanations or highlight the strength of their viewpoints. Open-ended questions are clearly preferable for collecting details that would be overlooked in a forced-choice model (Geer, 1991).

The advantages and drawbacks of various methods of questionnaire design are well defined in the literature (Siemiatycki, 1979; Woodward and Chambers, 1983; Jain et al., 2016). For example, the more in-depth answers provided in response to open-ended questionnaires mean that much effort is required in the data analysis phase. In comparison with responses to closed-ended questionnaires, analysis tends to be a more time-consuming task. McClelland (1994) identifies a clear disadvantage of utilising the open-ended type as its extreme subjectivity to the participant's understanding of the question and the considerable amount of time needed for them to read and understand the question, and record their responses in some kind of organised context. Open-ended questionnaires should be presented in a simple, straightforward and effective way (Fowler, 1992). All questions related to a specific problem or those with a similar explanation structure should be clustered together. This provides clarification and reduces the workload involved in collating, ranking and interpreting data (McClelland, 1994). Adapted from Polgar and Thomas (1995), Table 4.9 lists some advantages and disadvantages of both questionnaire types.

Table 4.9: A comparison of open-ended and closed-ended questionnaires (adapted from Polgar and Thomas, 1995)

Type of questionnaire	Advantage	Disadvantage
Open-ended	• More in-depth answers elicited	• Less structured • Responses difficult to encode and analyse • More time required to respond • A more difficult task in terms of writing for respondents
Closed-ended	• Tightly structured • Responses easily encoded and analysed • Less time in data collection process	• Less detailed answers • May frustrate respondents

4.9.3.4 Closed-ended Questionnaire Structure Adopted for this Study

A closed-ended questionnaire was developed for this study to elicit quantitative data regarding the first two objectives and facilitate a better understanding of the importance of the affecting factors. The questionnaire referred to is available in Appendix 2. The format of the questionnaire was designed in a way that all participants regardless of discipline, age and position could easily understand the questions and the process of data collection. In other words, it was straightforward and comprehensible. By targeting independent individuals with different qualifications and experience, the questionnaire aimed to infuse the diverse viewpoints of stakeholders and experienced construction experts into the study to obtain the best possible outcome. Participants had different levels of perception regarding the first two objectives, regarding VE and delay causations, although they were all reasonably experienced in marine projects. They were experts from either the public or private sector with a range of roles including project planner, construction manager, project engineer and technical office engineer; they typically represented contractors, consultants and clients. In the opening part of the questionnaire, participants were provided with an outline of the process via the mention of delay, VE, cost and marine projects as pivotal topics. They were then gradually directed to the target questions and asked to describe their own point of view at some stages. Closing questions asked for their name and current position/qualifications. Having 73 delay factors and 19 VE agents made completion of the questionnaire a time-consuming task; however, participants replied to the questions patiently and a total of 126 reports was received. Outcomes of the questionnaire provided the basis for development of a qualitative tool (open-ended questionnaire) to determine the relationships among the most prominent delay factors and key VE variables in marine projects.

4.9.3.5 Open-ended Questionnaire Structure Adopted for this Study

In this study, an open-ended questionnaire enabled external validation of the findings based on expert knowledge. A team of purposefully selected professionals (experts from different disciplines who were familiar with marine construction and the VE approach, with either site-based or academic experience) formed the group tasked with investigating the relationship between themes and obtained variables, and how they impact the schedule. The aim was to build the most appropriate conceptual model as a result. Since the marine environment is considered a highly specialised and multidisciplinary area, researcher decided to benefit from the viewpoints of professionals in different disciplines, making sure the developed model is the most accurate and all-embracing one. These targeted respondents were assumed to represent an appropriate population as they were selected from different disciplines to enable integration of broad knowledge and experience into the model and build the most appropriate framework for this industry. The results from the previous objectives were presented for review. All generated ideas and viewpoints were noted and documented to form the final concept, which was based on agreement regarding the effect of VE factors on schedule overrun. The questionnaire is included in Appendix 1. The questionnaire was formatted in such a way that all participants in different disciplines, age groups and roles could easily understand and express their opinions on the study topic.

Participants' profiles are presented later in this chapter. Feedback obtained from use of the open-ended questionnaire is discussed in Chapter 8.

4.9.3.6 Translation of the Questionnaires

Since most data were retrieved from projects carried out in Iran, the questionnaire had to be translated from English into Persian for accuracy and consistency purposes. The key challenge was the accuracy of translation. Poor translation of content can create delays, uncertainty, discrepancies and potentially unreliable data (Tsang et al., 2017). Since I am an accredited translator from English to Persian, I was able to conduct the translation myself. Careful attention was paid to the process and all technical terminologies were double-checked. The translation was also checked with another translator to obtain a second opinion.

4.10 Data Collection

Eliciting data using appropriate tools is considered the first step towards achieving research objectives. To meet the objectives described in Section 1.5, data collection was required. Considering the quantitative nature of the first two objectives, most of the important delay causations and VE variables in marine projects were identified through case studies and the literature review. This was developed by shaping a questionnaire survey and sending it to experts involved in marine construction projects. Along with the questionnaire, a consent form, information statement and survey invitation letter were sent to potential participants to ensure they had access to all information regarding the process and were aware of their rights. All participants had to sign the form and send it back to the email address provided. All data gathered by means of the questionnaire were analysed via a descriptive technique, the appropriate tool for quantitative data analysis. Fisher and Marshall (2009) consider descriptive statistics as a numerical process or graphics-illustrated technique by which the particularities of a sample can be described. The aim is to determine the frequency distribution, midpoint or central tendency, and dispersion (spread of the scores around the midpoint) of data. Proceeding with the first stage, the survey questionnaire was emailed to 151 participants who were key stakeholders involved in delivering marine construction projects, VE experts, academics and professionals with site-based experience. The target group were mainly professionals from either the private or public sector who had knowledge of VE mechanisms and experience in marine construction.

4.11 Reliability of Data

The collection of reliable data is fundamental to any research project. The most popular tool used by researchers to determine reliability is called the internal consistency coefficient, or Cronbach's alpha (Onwuegbuzie and Daniel, 2002). Agreed upon by the majority of the researchers, 'it is one of the most frequently generated estimates for instruments composed of a number of items or variables that will be formed into a linear composite' (Ferketich, 1990). The mathematical formula for Cronbach's alpha is shown in Figure 4.2 (Cronbach, 1951):

$$\alpha = \frac{N \cdot \bar{c}}{\bar{v} + (N-1) \cdot \bar{c}}$$

Figure 4.2: Cronbach's alpha formula

where *N* is the number of items; *c*-bar is the average inter-item covariance among the items; *v*-bar and is the average variance.

4.12 Participant Sample Profile for the Qualitative Part of the Research

A team of selected experts in the field with completion experience in marine construction projects and considerable professional or management responsibilities were involved in the qualitative part of the study—the open-ended questionnaire in particular. This team of purposefully selected professionals from different disciplines was familiar with marine construction and the VE approach with both site-based and office-based experience, and represented contractors, consultants and clients. They were invited to share their opinions as an invaluable contribution to the study to provide a deeper understanding of schedule overrun issues in the marine construction industry and allow exploration of potential mitigation strategies.

In this study, the open-ended questionnaire was sent to 10 participants with at least 15 years of experience in marine construction projects in a range of positions, including senior project manager, site engineer/manager, senior consultant, quality control manager, senior engineering office manager, senior quality assurance/quality control engineer, senior marine works technician and director. Table 4.10 lists the participants' profiles and their respective roles within their organisations. The participant consent form and open-ended questionnaire are available in Appendix 3 and 1, respectively.

Table 4.10: Summary of qualitative study participants' profiles

No.	Role	Years of experience	Work discipline
1	Senior project manager	20+	Contractor
2	Site engineer	18+	Contractor
3	Site manager	20+	Contractor
4	Senior engineering office manager	20+	Contractor
5	Senior consultant engineer	25+	Consultant
6	Director	30+	Contractor
7	Quality control manager	15+	Consultant
8	Senior QA/QC engineer	18+	Client
9	Senior marine works technician	30+	Client
10	Senior consultant engineer	20+	Consultant

4.13 Participant Sample Profile for the Quantitative Part of the Research

To carry out the quantitative part of the study, a total of 151 questionnaires was sent to experts, selected carefully via the snowball sampling method. Key criteria for inclusion were experience of completion in marine construction projects and substantial technical or management responsibilities. A total of 126 (83%) responses were retrieved and considered valid. Around 64% of the respondents had more than 10 years of experience in marine projects. Respondents were also grouped into the three main categories of client, contractor and consultant. Table 4.11 shows the frequency and percentage of each group participating in the survey. With a response rate of 83% for this study in a minimally accessible and highly specialised environment throughout a year, informative conclusions could be drawn.

Table 4.11: Description of quantitative study participants' sample profile

Category	Frequency	Percentage	Cumulative
Contractor	70	55.6	55.6
Consultant	35	27.8	83.3
Client	21	16.7	100.0
Total	126	100	

4.14 Data Analysis

Data analysis is carried out using items, termed statistics, that are organised as variables (Bannon, 2013). Using statistics, researchers can encapsulate vast analytical sets of data, predict future patterns and assess whether different 'experimental treatments' have resulted in substantially different findings (Leedy and Ormrod, 2015). Acquired data should be examined and elucidated using suitable methods to address a pre-designed research question and add value to the research context. There is a vast literature on qualitative and quantitative research relating to different stages of data analysis (Bailey et al., 1996; Creswell, 2009; Bannon, 2013; Graue, 2015). The approach adopted for this study follows the straightforward six-step procedure defined by Creswell (2009):

1. create a table listing data and demographic information on respondents
2. develop a mechanism by which bias in responses can be determined
3. develop a process of conducting a descriptive data analysis for all variables
4. define the appropriate statistical methodology (e.g. factor analysis) and refer to reliability checks to validate the consistency of the data (e.g. Cronbach's alpha)
5. use statistical software to assess the main 'inferential research questions or hypotheses'
6. represent the findings in tables, charts or graphs and interpret statistical test results.

Step 6 includes reporting the statistical significance, interaction between the results and research question/hypothesis, explanation of the potential rationale behind such findings and a discussion on the implications of findings and future research directions.

4.14.1 Approach Adopted for the Quantitative Data Analysis

Remenyi et al. (1998) identify the research method as a procedural mechanism by which research is carried out. According to Amaratunga et al. (2002), the goal should be filling a knowledge gap by adding something valuable to the body of knowledge. Hence, adopting the best approach is essential for obtaining the best outcome. A quantitative approach in this study is implemented to investigate the data acquired from the questionnaires and to identify the relationship between two sets of data. Fellows and Liu (2015) outline the different stages of quantitative research as follows:

- obtaining quantitative data
- utilising appropriate tools to analyse and test the data
- obtaining the results/relationship
- clarifying the result/explaining/discussing
- inferences/insights
- consequence/contribution to body of knowledge/industry.

In this study, a close ended questionnaire was distributed to experts carefully selected using snowball sampling. The inclusion criteria were experience in completing marine construction projects, substantial executive or management skills and knowledge of VE workshops. Data were obtained from clients/owners, consultants, experienced contractors, project planners, construction managers, project engineers and technical office engineers involved in marine projects. They were classified into three categories: client, contractor and consultant.

Participants were asked to rate variables based on a conventional Likert scale. Key factors were obtained by grouping the variables using factor analysis. Leedy and Ormrod (2015) define factor analysis as a tool for investigating correlations between a set of variables and defining patterns of interrelations within data that represent underlying themes. This technique is used to classify a set of variables and reduce their number to a set of grouped variables using a dimension reduction tool (DeCoster, 1998). Both CFA and EFA (Field, 2013) were used in the present study. The model obtained from EFA was validated using SEM to analyse the extent of data fit and the covariance between observed variables. The internal consistency of the dataset was calculated using Cronbach's alpha (Statistical Consulting Group, 2016). SPSS 25, Bartlett's test of sphericity, the Kaiser–Meyer–Olkin (KMO) index and anti-image correlation were used to check correlations and sampling adequacy before commencing data extraction (Field, 2013).

4.14.1.1 Structural Equation Modelling

According to Sturgis (2020), 'SEM is a general modelling framework that integrates a number of different multivariate techniques into one model fitting framework'. It integrates the following processes:

- measurement theory
- factor (latent variable) analysis
- path analysis
- regression
- simultaneous equations.

All these techniques form the dynamic modelling environment of SEM. In the literature, SEM is known by different names including covariance structure analysis, analysis of moment structures, analysis of linear structural relationships (LISREL) and causal modelling. Some of the software packages that can fit SEMs are Mplus, EQS, AMOS, Calis, Mx, SEPATH, Tetrad, R and Stata. AMOS software was employed in this study. Since SEM is a path analysis utilising latent variables, it is necessary to introduce these two terms before proceeding further in this chapter.

4.14.1.2 Latent Variables

The majority of social scientific concepts are not directly observable; for example, intelligence and trust (Sturgis, 2020). This renders them hypothetical or latent constructs. Based on Blunch (2008), since it is not possible to measure latent variables directly, they are measured using observable indicators—generally questions in the form of a questionnaire or other types of assessment as observable indicators for a latent construct. It should be noted that the variance of a questionnaire item can be affected by the latent variable aiming to be measured as well as other factors such as errors. Adopted from Sturgis (2020), the following equation represents the measured variable in an SEM model and its related components:

$A = t + e$

where A is the measured variable; t is the true value of the construct; and e is the error, which is comprised of systematic and random error.

The path diagram shown in Figure 4.3 simplifies the concept presented in the above equation.

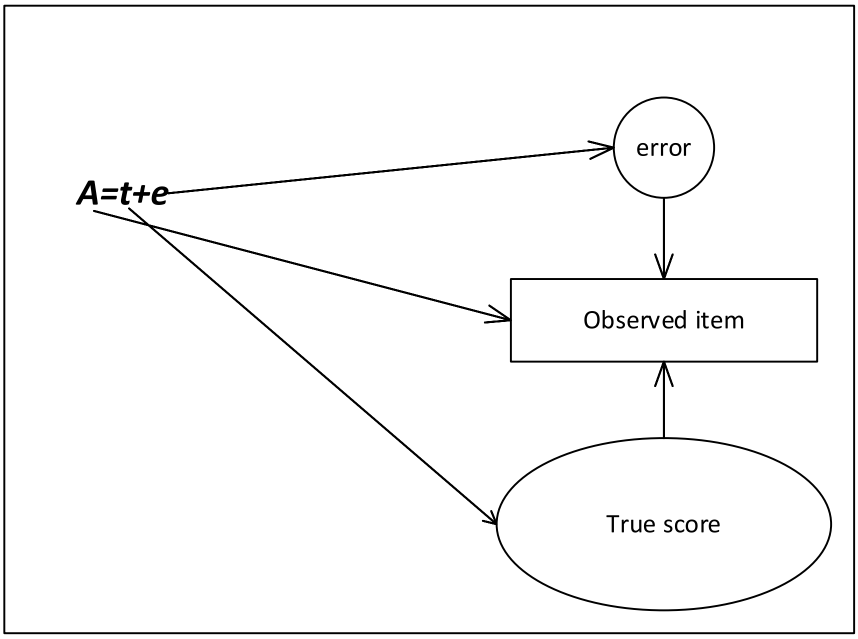


Figure 4.3: Measured variable concept

From Sturgis's point of view, identifying t and e requires multiple indicators for latent variables. This can be achieved by applying various models such as factor analysis or principal component analysis (PCA), which provide a reduced set of components relative to the primary indicators. Figure 4.4 shows a general model and the different elements comprising the model. Figure 4.4, b1, b2, b3 and b4 indicate the correlation between a factor and related indicators. The correlations are high (close to 1) only if the indicators are good representatives of the latent variables.

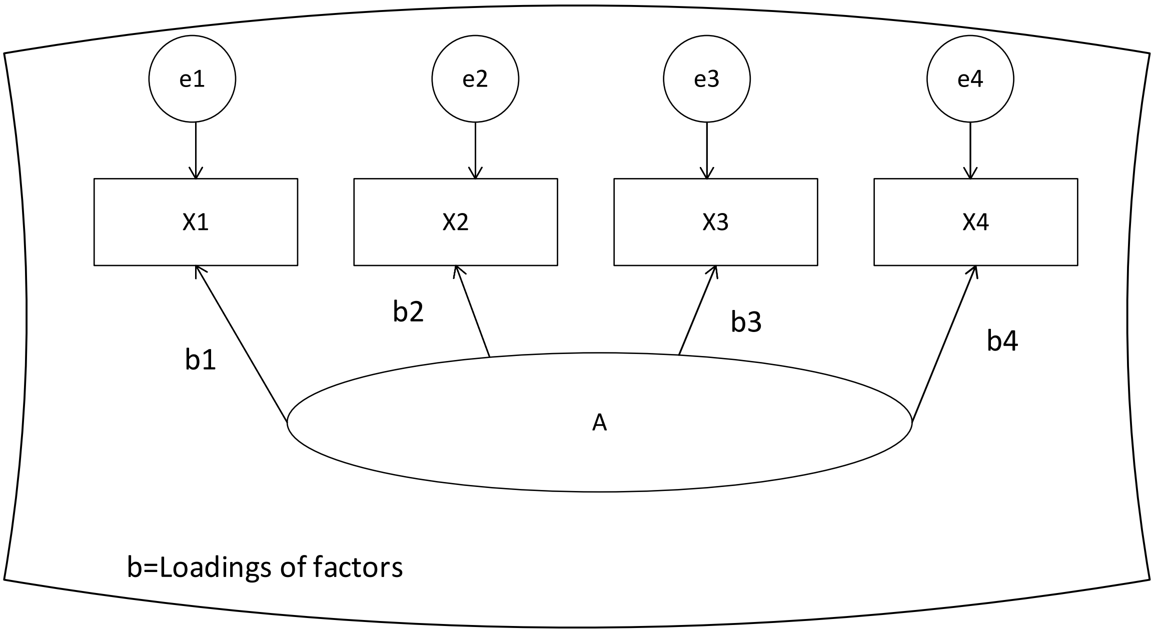


Figure 4.4: General factor model (adopted from Sturgis, 2020)

4.14.1.3 Advantages of Employing Latent Variables

There are some benefits in using latent variables that assist in obtaining accurate data:

- It is not easy to cover all aspects of a variable with just one single question. Having multiple indicators helps to achieve a good coverage of the concept. In other words, single measures are not capable of appropriately embracing the whole context.
- They assist in removing or diminishing random errors in the construct aimed to be measured. This leads to a more precise outcome.

4.14.1.4 Path Analysis

Geneticist Sewall Wright developed the path analysis technique to support quantitative analysis of genetics in his profession. According to Wright (1960b), this method determines the consistency of a set of presented interpretations. Path analysis is applicable to a broad variety of systems comprising structural equations. It helps in better understanding a model with a more comprehensible facade (Land, 1969). Some key features of path analysis, based on Sturgis (2020), are as follows:

- It represents the model that will be fitted to the data diagrammatically, rather than an equational shape. The visual dimension of the diagram is very helpful for researchers and facilitates data interpretation.

- It articulates the equations of regression between variables already observed or measured.
- The emphasis is not only on the direct effects of variables, but also on the indirect and cumulative effects.

4.14.1.5 Path Diagram Standardised Symbols

Adopted from Wright (1960a), Figure 4.5 shows notations reflecting various parts of a model, which are commonly interpreted when explaining the model. When a path diagram contains latent variables rather than just observable/measurable variables, this implies it represents SEM.

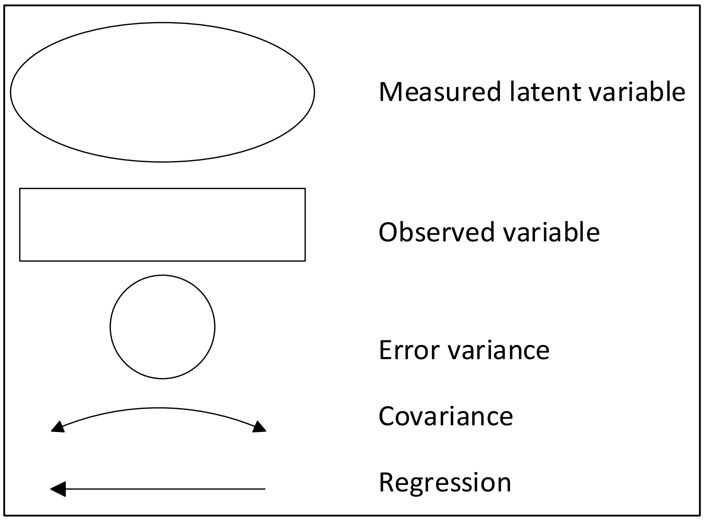


Figure 4.5: Path diagram symbols

4.14.2.5 Validating a Model Obtained Using Exploratory Factor Analysis

SEM is a robust technique for combining complex path models with latent factors (Hox and Bechger, 1998). These authors outline that as a general statistical modelling technique, this approach provides a graphical path diagram that illustrates a structure for the covariances among obtained variables. To validate the model obtained from EFA, SEM was used in this study as a particular statistical method to determine to what degree the model matched the data. In other words, through CFA, the structure of the observed variables was verified. As an outstanding and adaptable statistical method, CFA has been used progressively in the education research area in recent years. According to Grimm (2015), the main focus of CFA is modelling the relationships between underlying latent factors and observed indicators. Thurstone (1947) describes the aim of both CFA and SEM as identifying underlying variables by utilising indicators.

As standard procedure, Grimm (2015) advises researchers and scientists to evaluate a primary set of items utilising a specific EFA model, followed by a CFA framework. The framework that eventuates delivers a more meticulous evaluation of how observed data are represented by a conceptual model. Grimm’s approach was adopted in this study to obtain a conceptual model that helps in interpretation of the data.

4.14.2.6 Minimum Acceptable Sample Size for Structural Equation Modelling

Researchers and academics have always faced challenges regarding the appropriate sample size for SEM. Recent progress in statistical modelling and developments in new technologies have made latent variable analyses quite popular among these groups. However, there remains uncertainty about the minimum sample size required to evaluate such models. SEM’s practicality in analysing complex relationships using different types of data and assessing alternative models is considered a benefit of this methodology. Simultaneously, these attributes hinder the formation of an accepted universal structure with regard to sample size requirements (MacCallum et al., 1999; Wolf et al., 2013).

There are different views of the appropriateness of these models. Models established with larger sample sizes (Boomsma, 1982; Velicer and Fava, 1998; Gagne and Hancock, 2006), those that include more indicators for each variable (Gagne and Hancock, 2006; Marsh et al., 1998) and those with larger figures in loadings (Gagne and Hancock, 2006) are believed to be more precise.

Conversely, the suitable sample size for SEM mainly depends on how complex the model is and factors such as data normality and missing patterns. The rule of thumb for estimating the sample size is controversial. Some scholars recommend using sample sizes of at least 200; or 10 factors per variable (Kline, 2011). However, two of the most recent simulation studies recommend rather small sample sizes as sufficient. Wolf et al. (2013) believe in a range from 30 for simple CFA with the pick of 450. In a recent study on models of functional brain connectivity with four latent variables, Sideridis et al. (2014) discovered that a sample size of 50–70 would be sufficient.

Overall, if the aim is to obtain an extremely precise estimate, and even small errors are considered a problem (e.g. when measuring unemployment rates by governments), then larger samples should be sought. Conversely, if the goal is to analyse significance levels, more important than sample size is the use of a probability sampling method to select the participants. In other words, a procedure should be utilised to ensure that different units in the population have an equal chance to cooperate in the study. Various disciplines familiar with marine construction and VE were involved in data collection for this study, and participants had either site-based or academic experience. This ensured accuracy of the sampling. After receiving 126 responses and examining standard deviations (Convergence), the researcher decided to stop collecting more data and concentrate on analysing the responses. Adopted from Chai et al. (2015), Table 4.12 displays different recommendations in the literature regarding the appropriate sample size for SEM. A sample size of 126 may be considered appropriate for this study according to the table, and adequate for commencing SEM. Chai and colleagues even reviewed several construction management reports that used SEM. According to their review, the smallest research sample (n = 52) was used by Mainul Islam and Faniran (2005) and the largest (n = 166) by Eybpoosh et al. (2011).

Table 4.12: SEM sample size recommendations in the literature (adopted from Chai et al., 2015)

Reference	Sample size
Gorsuch (1983)	At least five responses per construct; no fewer than 100 individuals per analysis
Anderson & Gerbing (1984)	100–150
Hatcher & Stepanski (1994)	At least five times the number of latent variables, or a minimum of 100
Hutcheson & Sofroniou (1999)	150–300
Bagozzi & Yi (2012)	Above 100, preferably above 200
Zainudin (2012)	Minimum of 100 for fewer than five latent variables; minimum of 300 for fewer than seven latent variables

The data obtained from the quantitative part of the study were statistically examined using SEM, as a recent statistical modelling technique. It is one of the most commonly used methods for scholars to check if a model fits the data (Hooper et al., 2008). This method enables researchers to identify interactions between non-observable and latent constructs. It also helps define latent variables, and represents the model to be fitted to the data diagrammatically rather than in the form of an equation (Sinkovics et al., 2016). The visual aspect of the diagram is fascinating for researchers and facilitates a more straightforward interpretation of data. A graphical path diagram as provided by SEM demonstrates the covariance structure among the variables obtained (Hox and Bechger, 1998). These authors identify SEM as a robust statistical modelling technique with the potential to combine complex path models with latent factors.

Two principal protocols to be adopted by SEM are ‘composite-based partial least squares (PLS-SEM) and factor-based covariance-based (CB-SEM)’ (Sinkovics et al., 2016). The former can be conducted using PLS-Graph, VisualPLS, SmartPLS and WarpPLS and the latter uses software packages such as AMOS, EQS, LISREL and MPlus. The two protocols vary greatly in their methodologies and have unique aims and requirements (Hair et al., 2011).

CB-SEM is the most commonly used technique in SEM and many scholars refer to CB-SEM simply as SEM (Astrachan et al., 2014). This is supported by results of an analysis carried out by Sinkovics et al. (2016) of 324 studies, where only 45 employed the PLS-SEM method. Moreover, in a review of six major journals over 24 years, Sinkovics and colleagues noticed that 89% of the studies adopted CB-SEM. ‘Stronger distribution’ and ‘longer history of CB-SEM’s application’ are the two main reasons stated by Sinkovics and colleagues for the high application rate. It remains the preferred technique for statistical analysis by researchers aiming to validate or refute theories by hypothesis testing (Wong, 2013). Wong emphasises the practicality of this method ‘when the sample size is large, the data are normally distributed, and most importantly, the model is correctly specified’. Hair Jr et al. (2017) add that CB-SEM is mainly applied to validate established theories. According to Hair et al. (2012), ‘the statistical objective of CB-SEM is to estimate model parameters that minimise the differences between the observed sample covariance matrix (calculated before the analysis) and the covariance matrix estimated after the revised theoretical model is confirmed’.

PLS-SEM is an SEM modelling technique that makes no data distribution assumptions (Esposito Vinzi et al., 2008; Wong, 2013). PLS-SEM can be viewed as a replacement for CB-SEM in some circumstances, such as (Wong, 2013):

- small sample size
- poor existence of theory in applications
- vitally important predictive precision
- no guarantee in accurate model specification.

Wong does not recommend this method for statistical analysis of all types. Despite its restrictions, PLS is beneficial for SEM in academic research studies, especially when the sample size is small. PLS-SEM's statistical target is to ‘maximise the variance explained in the dependent variables’ (Hair Jr et al., 2017). Moreover, ‘PLS-SEM based approaches can work with virtually any level of complexity in constructs, observables and multi-level structural models’ (Astrachan et al., 2014). These authors highly recommend using this method because of its accessibility, the helpful guidelines on the websites and the large number of supportive scholars who are skilled in this approach. Likewise, Sinkovics et al. (2016) urges researchers not to be hesitant to use PLS-SEM in the theorising process where possible. In the light of the above definitions, the choice of CB-SEM as the best method to apply in this study is reasonable.

4.14.2 Approach Adopted for the Qualitative Data Analysis

An archival report as a case study constitutes the first qualitative part of this research. Sometimes scholars rely on a single, specific case study for their research, perhaps because its exceptional or outstanding attributes may encourage understanding or knowledge development for similar circumstances (Leedy and Ormrod, 2015). These authors argue that case study appears to be the most effective for supporting one or more theories about an examined phenomenon. Adopted from Leedy and Ormrod (2015), Table 4.13 shows different characteristics of a case study design including the data analysis method. The strategy stated in the table has been employed for the purpose of data analysis in this study.

An open-ended questionnaire survey as the second qualitative part of the study was conducted to evaluate the findings from the experts' perspectives. The design of the questionnaire was based on the summary of findings from quantitative part of the research, listed as themes and their associated variables classified as delay or VE. Oberjé et al. (2015) state that an open-ended questionnaire organised with precise and correct instructions can be an effective technique for qualitative data analysis. Reja et al. (2003) adhere to Oberjé et al. (2015) in this context. Reja and his team emphasise the need to pay particular attention to the accuracy of the terminology in open-ended questionnaires, to prevent them contributing to inaccurate responses. They also report that open-ended questions appear to suffer greater levels of incomplete items, which results in a greater variety of responses compared with closed-ended questions. Denscombe (2008) highlights the potential for receiving superficial responses when using open-ended questionnaires.

However, open-ended questionnaires have the benefit of giving respondents the freedom to articulate their opinions associated with the subject under study (Naoum, 2012). Naoum highlights the importance of coding in this type of questionnaire, which facilitates the analysis process. Open-ended type responses may also provide researchers with a particularly rich source of information (Vannette and Krosnick, 2017).

It is paramount that adequate response time is given to participants if a quality response is sought. Griffith et al. (1999) confirms the time-consuming nature of this form of query, stating that open-ended questions require substantial time to collect information and make a decision, as no predefined options are available. Emde and Fuchs (2012) introduce a further two items that need to be considered to obtain rich and precise results in an open-ended questionnaire: 'motivating instructions' and 'visual design'. The open-ended questionnaire designed for this study is presented in Appendix 1. It was structured in such a way that all respondents could provide their answers conveniently and in a timely manner in the specified fields.

Table 4.13: Characteristics of case study design (source: Leedy and Ormrod, 2015)

Purpose	Focus	Methods of data collection	Methods of data analysis
To understand one person or situation (or perhaps a very small number) in great depth	One case or a few cases within the natural setting	• Observations • Interviews • Appropriate written document and/or audio-visual material	• Categorisation and interpretation of data in terms of common themes • Synthesis into an overall portrait of the case(s)

NVivo 12 as a powerful qualitative data analysis software was employed to assess the responses. It was used to codify, identify and report similar patterns occurring in the participants' responses (Edhlund and McDougall, 2019).

4.15 Validation

Validity is characterised as the degree to which a variable within a research study is measured accurately (Heale and Twycross, 2015). It defines whether the study actually measures what it was designed to measure, and to what extent the outcomes of the research reflect reality (Golafshani, 2003). In other words, it encompasses the whole study and determines if the conclusions drawn satisfy all research method criteria. According to Heale and Twycross (2015), there are three main types of validity in quantitative research: content, construct and criterion validity. Adopted from these authors, Table 4.14 shows each validity type with a corresponding description. Roberts and Priest (2006) define the three validity forms listed as internal validity assessment methods, and highlight content validity as the lowest standard of validity.

Table 4.14: Quantitative validity types (source: Heale and Twycross, 2015)

Type	Description
Content	The extent to which a research instrument accurately measures all aspects of a construct
Construct	The extent to which a research instrument (or tool) measures the intended construct
Criterion	The extent to which a research instrument is related to other instruments that measure the same variables

Wainer and Braun (1988) define validity as construct validity in quantitative research. This refers to the basic notion, query or hypothesis that decides what data to collect and how to collect them. It reveals if the measuring instruments are reliable and whether they measure what they are meant to measure. In the view of Roberts and Priest (2006), establishing construct validity includes demonstrating the ‘relationships between the concepts under study and the relevant construct or theory’.

Construct validity was the method adopted in this research and factor analysis was used as one way of demonstrating construct validity (Roberts and Priest, 2006). DeCoster (1998) articulates that factor analysis is used to classify the sequence of variables and ameliorate variable groupings using a dimension reduction tool. According to Field (2013), there are two methods for factor analysis: CFA and EFA. Both were employed in this study. CFA was conducted to validate the model obtained from EFA, to determine to what extent the obtained model fit the data. In other words, through CFA, the structure of the observed variables was verified.

In a qualitative study, ‘Validity is assessed in terms of how well the research tools measure the phenomena under investigation’ (Roberts and Priest, 2006). These authors identify two potential biases in the validity process in qualitative research, as ‘selective collection and recording of data’ and ‘interpretation based on personal perspectives’. Trochim (2000) identifies four key criteria to be met for qualitative validity:

- Confirmability: refers to having the entire findings reviewed by an independent/external investigator

- Transferability: refers to the generalisability of the findings to other perspectives
- Dependability: refers to correspondence between the research process and product
- Credibility: refers to identifying qualitative research findings as legitimate or unreliable based on the research participants' perceptions.

Creswell (2018) enumerates eight validating strategies: triangulation of data; 'member checking'; 'using rich thick descriptions'; bias clarification; 'present negative or discrepant information'; 'Spend prolonged time in the field'; 'Use peer debriefing'; and 'Use an external auditor'. These can be categorised using the abovementioned criteria of Trochim (2000). Table 4.15 shows the criteria and strategies adopted for the purpose of qualitative validation in this research.

Table 4.15: Qualitative validation criteria and adopted strategies

Validation criteria	Strategy	Adopted for this study
Credibility	Member checking	Ask for participants' feedback on the final report
Transformability	Bias clarification Rich, thick description	Details and supporting documentation for the report has been created
Dependability	Peer debriefing	Review of the entire study process by an independent investigator
Confirmability	Triangulation of data Using external audition	• Use of different data sources • Case studies • Study slightly modified based on review by a professional in the field

4.16 Triangulation Exercise to Enhance Confirmability

Assessing the findings in a quantitative or qualitative research study using validity and reliability techniques is of utmost importance (Taylor, 2005). As discussed previously regarding the questionnaire design, a pilot survey was conducted at the primary investigation stage and participants' feedback was considered to examine reliability and validity. Such a process mitigates possible errors and enhances reliability and validity of a questionnaire (Taylor, 2005). Further, the two benchmarks of reliability and validity were examined at the primary stage of investigation by employing

statistical approaches including Cronbach's alpha. This was done to ensure that the questions were appropriate indicators of the responses to be measured.
A triangulation exercise was also conducted in this study to check the validity and reliability of the findings. Under the mixed method research approach taken in this study, both qualitative and quantitative methodologies were employed in the data analysis and data collection stages. According to Heale and Forbes (2013), reliability and validity can be constructed through triangulation of the findings in a research study. These authors agree with Golafshani (2003) about the superiority of this exercise among diverse approaches to establish validity of findings.

Two triangulation exercises were undertaken in this study to validate the findings: CFA through SEM; and an open-ended questionnaire for qualitative validation of the findings. Descriptions of the validation processes in both SEM and the open-ended questionnaire are provided in Chapters 7 and 8 respectively.

4.17 Study Framework

Figure 4.6 depicts the study framework adopted for this research.

4.18 Ethics and Confidentiality

Prior to commencing a study, it is always essential to consider ethical issues and confidentiality in any type of research, whether qualitative or quantitative. Participants should be notified regarding their rights and how to address any issues relevant to the process. They should not be forced to proceed with the procedure, and must be assured about their privacy. It is always worthwhile to work with a liaison during the data collection process, which guarantees validity to a high level and develops future relationships. In this study, participants were provided with an information statement sheet and asked to read it carefully and be confident that they understood its contents before deciding whether to participate. The topic of the study, aim, activities in which they had to be involved and estimated time to complete the survey were outlined in the information statement. They were assured that apart from giving up their time, there was no risk or cost associated with taking part in the study. They were also advised regarding the possibility of publishing the study findings in scientific journals or conference presentations, ensuring their confidentiality. All of the participants were provided with contact details to request a summary of the final results or to withdraw at any stage. Withdrawal could be either verbal or via email. A copy of the consent form, information statement and survey invitation letter is available in the Appendix.

Approval from Curtin University HREC was obtained before commencing any type of data collection. The approval number is HRE2017-0641).

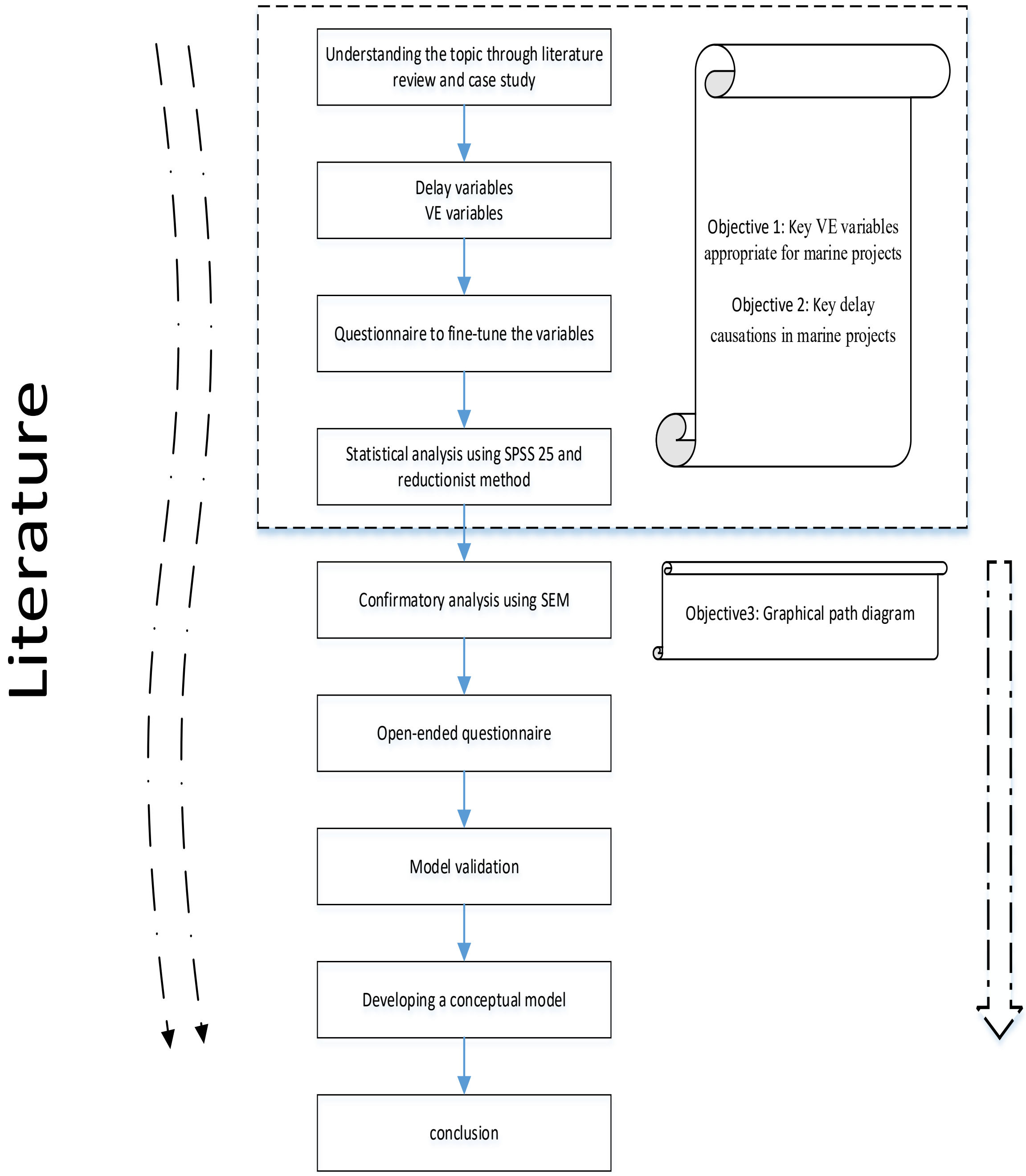


Figure 4.6: Study framework adopted

CHAPTER 5: PRELIMINARY DATA ANALYSIS

5.1 Introduction

One of the objectives of this study is to identify potential VE variables appropriate for the purpose of delay mitigation in marine construction projects. As discussed in Chapter 2, 19 variables were identified from the literature review that can effectively be integrated with or into other technical or management improvement approaches—schedule management in particular. To identify variables that did not emerge from the literature review, establish the validity of the review and further investigate the topic from particular perspectives, a cross-check with archival data was conducted. A case study report that was relevant to the study's topic assisted in reinforcing the variable selection before proceeding to primary data collection. As discussed in Section 4.3, archival analysis was considered a suitable strategy in this research study (Yin, 2003). By means of this archival analysis, the researcher was able to identify variables that were not generated in the literature review. The analysis provided details and discussed various approaches used in a real-world project, as well as optimal solutions based on the best practical method; these were considered VE variables in the current investigation.

5.2 Analysing the Case Study Report

Kish is an island situated among the Persian Gulf coral reefs. The southern coast of Iran and the United Arab Emirates are the nearest and most distant mainland regions to this island; 18 km and 200 km, respectively. The Kish Free Zone Corporation, the main development authority, developed a plan for a jetty with a 35,000-ton-vessel capacity. The jetty would be 39 m wide and 389.6 m long, to be designed and constructed to the east of the original jetty (with a 12,000-ton-vessel capacity) to cater for the increasing number of cargo vessels. Satellite photos of the development are shown in Figures 5.1 and 5.2.

Figure 5.1: Satellite photo of Kish Harbour (KSP, 2016)

Figure 5.2: Satellite photo showing the existing and proposed jetty at Kish Harbour (KSP, 2016)

Consultant engineering group KSP (2016) was assigned as the VE team in February 2016 to reassess the design and recommend suitable alternatives for the piles, deck and method of construction. Representatives of stakeholders and contractors were included at the design stage to outline their expectations and ensure their requirements for the development would be met. This particular type of collaborative effort can enhance the satisfaction of stakeholders by improving project performance (Gayani and Kosala, 2017). Figure 5.3 shows how a collaboration web helps to achieve the best outcome.

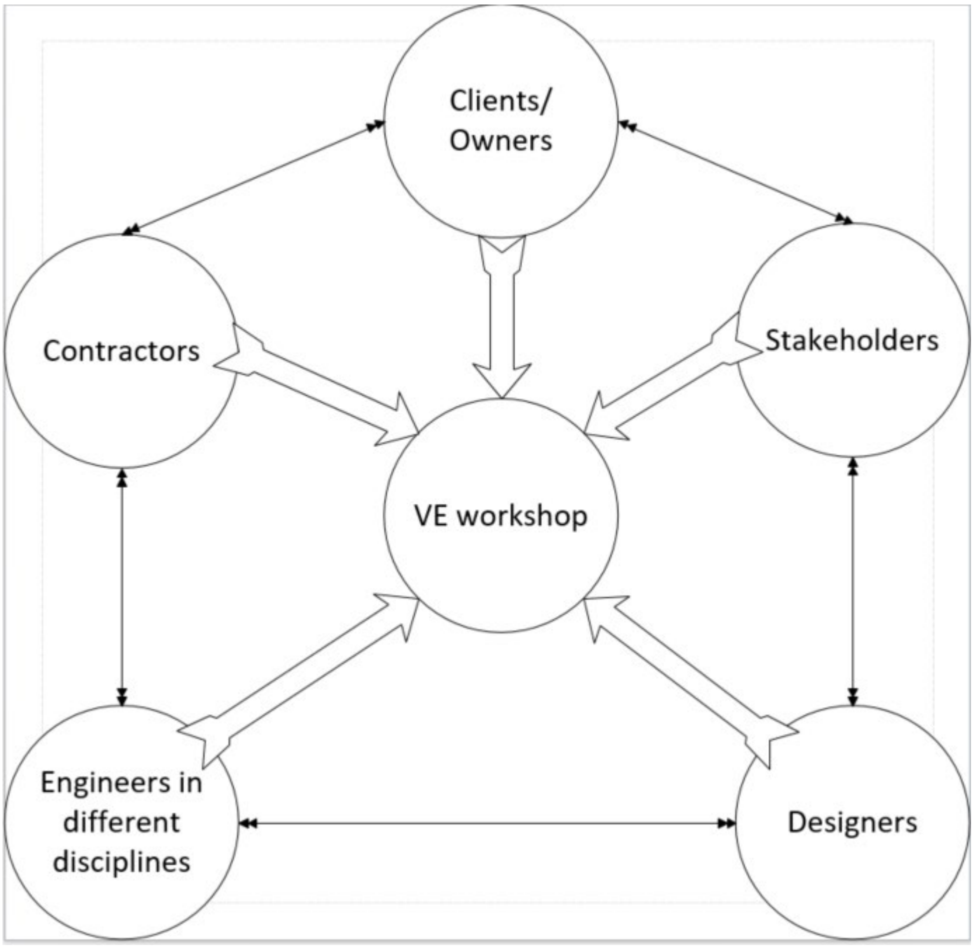


Figure 5.3: VE collaboration web

5.2.1 Case Study Function Analysis System Technique Diagram

Understanding and analysing functions are the two most critical success factors stemming from VE procedures. A typical methodology for function analysis includes function identification, classification, practical models for cost evaluation of functions, cost of functions, estimation of value index and choice of optimised solution for further development. To analyse the functions of various components and show the sequences of the actions, a FAST diagram was initially utilised. Figure 5.4 shows the interrelated steps that assist in developing ideas and innovative plans.

5.2.2 Evaluation Stage and Developing the Appropriate Option

Eight potential alternatives discussed during the VE's workshop creativity process were:

- having the pile thickness reduced, but compensated for by an adequate coating and cathodic protection
- consideration of alternate types of concrete piles, especially pre-stressed
- substituting the steel piles of the crane foundation with cast-in-place concrete piles
- use of suspended-deck systems, which are ideal for open-type jetties
- utilising cast-in-place concrete walls instead of steel piles in the form of load-bearing structures
- design and construction of a concrete gravity wall structure
- substituting the steel piles in the front row of the pile arrangements with cast-in-place concrete piles
- considering piles with smaller diameters braced with batter piles as the supporting system.

From among these eight suggestions, the evaluation process outlined the following four as the most suitable. All alternatives were evaluated against cost and time constraints initially determined:

- Option 1: Reduction in pile thickness and use of dedicated coatings and cathodic protection. This method was considered reasonable because of the diversity of, and ease of access to, high-quality protective coating systems suitable for inclement weather conditions in marine environments.

  Requirements:

  a. appropriate coating implementation based on the environmental circumstances
  b. ongoing cathodic protection during the operation phase
- Option 2: Substitution of cast-in-place concrete piles for the steel piles in the

front row. This was seen as another acceptable option, based on geotechnical assumptions about the seabed and similar efforts in the region.

Requirements:

To enable easy access of piling and concreting machinery to the job site, the gap between the initially driven tubular casings and the shoreline should be filled with suitable materials. Since all these activities can take place simultaneously, there is no expected time overrun.

- Option 3: Using cast-in-place piles for the crane foundation and load-bearing system.

  Requirements:

  A cast-in-place piling technique using tubular casings should be implemented. There is no expected time overrun because the activities can take place simultaneously.

- Option 4: Substituting cast-in-place piles for concrete piles in the crane foundation, and a cast-in-place concrete wall for the steel load-bearing system piles.

  Requirements:

  A cast-in-place piling technique using tubular casings should be implemented. The concrete wall will be constructed according to standard procedures. There is no expected time overrun as all activities can take place simultaneously.

Throughout the development phase of the VE process—which aimed to determine the most effective individual or combined approach to enhance project performance—alternatives 1 and 3 were considered the most appropriate in terms of the proposed construction methods, associated costs, potential savings and possible functional improvements. In line with the literature reviewed, this case study identifies a variety of VE variables that might be important for this research study, including construction methods, substitute resources, contractor participation, geotechnical assumptions and significance of pilot studies, utilising up-to-date technologies, knowledge gained from successful similar projects and the interaction of industry professionals. The case study further reveals VE’s potential to enhance the performance and scheduling of a project while lowering expenses and time overruns; at the same time adding value.

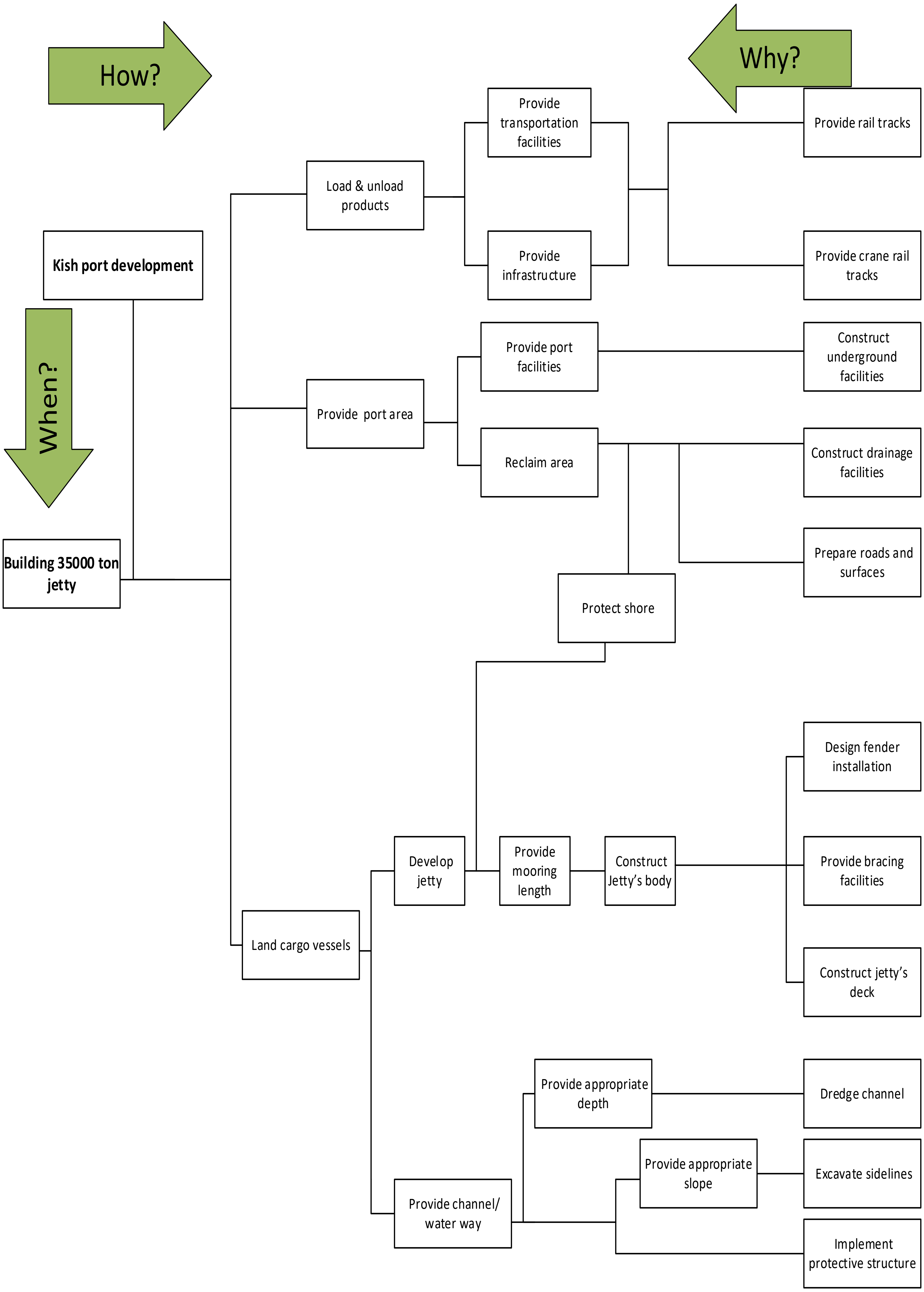


Figure 5.4 Kish Port development FAST diagram

CHAPTER 6: ANALYSIS OF RESULTS

6.1 Introduction

This chapter provides an overview of the quantitative data collected through a questionnaire survey administered to predominantly Iran-based marine construction professionals. A limited number of professionals are involved in this field of construction, compared with other types of projects, which makes the process of data collection time consuming and challenging. Participants from countries such as Australia, Iran, Hong Kong, Malaysia, Ecuador, Kazakhstan and Turkey with academic qualifications and site-based experiences also responded to the survey. While most of the data were obtained from Iran construction projects, the goal was to consider other countries as a complementary source, to obtain a model applicable to all marine projects irrespective of their geographical location. The developed model can assist stakeholders and the research community to better understand the significance of marine infrastructures and how to deal with related issues such as time and cost overruns.

This chapter mainly provides a summary of the results obtained from the questionnaires. The focus is on analysing the findings and meeting the first two fine-tuned objectives of the study by means of a reductionist method. This feeds into the next stage to create a model. Data gathered were mainly collected from experts in the marine construction industry who were familiar with the VE mechanism and originated from both the private and public sectors.

Inferential and descriptive analyses were carried out utilising diverse statistics including Cronbach's alpha, standard deviations, means, relative importance and SEM.

6.2 Normality of Data

Ghasemi and Zahediasl (2012) state that most statistical approaches, namely the study of correlation, regression and variance analysis, assume that data are normally distributed. This means that populations from which samples are developed are believed to be normally distributed (Field et al., 2012). Ghasemi and Zahediasl (2012) outline several tests for examining normality: the Kolmogorov–Smirnov (KS) test, Lilliefors corrected KS test, Shapiro–Wilk test, Anderson–Darling test, Cramer–von Mises test, D'Agostino skewness test, Anscombe–Glynn kurtosis test, D'Agostino–Pearson omnibus test and Jarque–Bera test. Given the Shapiro–Wilk test's popularity among scholars (Thode, 2002), and its higher performance (Miot, 2017), this method was employed to verify data normality in the current study, using SPSS 25.

To examine the distribution using the Shapiro–Wilk test, the following null and alternative hypotheses were considered:

- H0: Data are normally distributed
- H1: Data are not normally distributed

Results from the Shapiro–Wilk test for both delay and VE variables are provided in the Appendix. An associated *p*-value less than 0.05 for all variables demonstrated the non-normal distribution of data. This means the null hypothesis could be rejected and the test was statistically significant. The lower the significance level applied, the stronger the evidence that the null hypothesis should be rejected.

It should be noted that when a data distribution is close to normal, all statistical analysis methods can be applied to the data. Further, if the sample size is sufficiently large, methods that require data normality may still be applicable even if the distribution is not even close to normal, due to the central limit theorem. Based on the previous discussion and Shapiro–Wilk test results, the data appear non-normal. However, this test is the most conservative of all. Moreover, since normal distribution of data is one of the major concerns in conducting SEM, which also verifies the adequacy of the outcomes, the researcher decided to also perform skewness and kurtosis tests for normality. Overall, 'real-world data do not have even univariate, let alone multivariate, normal distributions' (Gao et al., 2008). To bring sample data closer to acceptance criteria, researchers may remove outliers (Bagley and Mokhtarian, 2002).

A frequency test implemented in SPSS 25 and checks of skewness and kurtosis for both the VE and delay variables indicated some deviation from the range of ±1. For VE variables in particular, ‘implementing methods for major tasks’ and ‘considering previous studies on similar projects in the region’ had skewness values greater than 1 while ‘using practical methods from similar projects’ and ‘using up-to-date technology in design options if possible’ had both skewness and kurtosis values greater than 1. Distributions were re-examined and outliers were removed to bring the sample closer to the acceptable range. Just one variable remained slightly above 1, which was considered approximately normal. Among the delay variables, two had values slightly above 1, namely ‘poor communication and management skills’ and ‘delay in importing materials from other countries due to political issues’, which was considered approximately normal.

Based on the above normality test results, the data were determined to be normally distributed.

6.3 Suitability of Data

Statistical analyses were employed in this research study to examine quantitative data collected through the designed questionnaire. Data suitability was investigated prior to statistical tests being carried out, to ensure accuracy of the results. In the context of data suitability, the primary examination measured the reliability and missing data embedded in the responses provided by the participants.

6.3.1 Reliability of Data

Data are deemed reliable if a value of 0.70 or greater is achieved for alpha (Cronbach, 1951; Sijtsma, 2009). According to Gliem and Gliem (2003), Likert scale-type questions are commonly used to deal with data collected to obtain different opinions. Following this approach, for two questions, the Likert scale model was adopted in the questionnaire designed for this study. Internal validity and consistency within the datasets were measured using Cronbach’s alpha reliability estimating procedure in SPSS 25. A near absolute Cronbach’s alpha value of 0.979 was returned on the 73 delay variables. Likewise, a Cronbach’s alpha value of 0.949 was returned for the 19

VE factors, confirming the reliability of the questionnaire design. Tables 6.1–6.3 show the reliability range and Cronbach's alpha index for the VE and delay variables.

Table 6.1: Reliability range of Cronbach's alpha (Cronbach, 1951)

Cronbach's alpha	Internal consistency
$\alpha \geq 0.9$	Excellent
$0.9 > \alpha \geq 0.8$	Good
$0.8 > \alpha \geq 0.7$	Acceptable
$0.7 > \alpha \geq 0.6$	Questionable
$0.6 > \alpha \geq 0.5$	Poor
$0.5 > \alpha$	Unacceptable

Table 6.2: Reliability statistics for the VE variables

		N	%	Cronbach's alpha	No. of items
	Valid	126	100		
Case	Excluded	0	0	0.949	19
	Total	126	100		

Table 6.3: Reliability statistics for the delay variables

		N	%	Cronbach's alpha	No. of items
	Valid	126	100		
Case	Excluded	0	0	0.979	73
	Total	126	100		

6.3.2 Missing Data analysis

Missing data analysis was conducted utilising SPSS 25 as a further stage in ascertaining data suitability. Results from the descriptive frequency analysis show that all 73 delay and all 19 VE variables had zero missing values. This validates the efficiency and simplicity of the data collection tools, which provided sufficient information to enable the participants to answer every question with a suitable answer.

6.4 Demographic Information for Respondents

Participants in this research study were categorised using criteria relating to work experience, discipline, roles and responsibilities. The results are described in the following subsections.

6.4.1 Work experience and work discipline

A total of 151 questionnaires were sent to experts who were carefully selected using snowball sampling. Key inclusion criteria were completion experience in marine construction projects and considerable professional or management responsibilities. A total of 126 (83%) responses were retrieved. Baruch and Holtom (2008) define the response rate as a significant factor in evaluating the outcomes of a research study. The high response rate in this study represents substantial willingness of the respondents to complete the survey.

The descriptive statistics for the respondents (Table 6.4) show that 11.9% (15) of the participants had 0–5 years' experience in marine construction industry. Among those surveyed, 24.6% (31) identified themselves as having 6–10 years of professional experience, and 21.4% (27) had 11–15 years of work experience in marine construction industry. A high percentage (27%) of the sample (34) reported spending 16–20 years in marine construction. Further, 9.5% (12) of the professionals indicated 21–25 years' involvement in related projects. Finally, 5.6% (7) had more than 25 years' work experience in marine construction projects.

Table 6.4 categorises the respondents' experience in marine projects. Around 64% of had more than 10 years' experience in marine projects. The respondents were also grouped into three main categories (client, contractor and consultant) and Table 6.5 shows the frequency and percentage of each group among the survey participants. More than 83% of the respondents were from contracting and consulting organisations.

Table 6.4: Number of responses based on years of work experience in marine construction

Years of experience	Frequency	%
0–5	15	11.9
6–10	31	24.6
11–15	27	21.4
16–20	34	27.0
21–25	12	9.5
>25	7	5.6
Total	126	100

Table 6.5: Number of responses based on work discipline

Category	Frequency	%
Contractor	70	55.6
Consultant	35	27.8
Client	21	16.7
Total	126	100

6.4.2 Roles and responsibilities

The survey questionnaire had two main focuses:

- gathering data on the work history of the participants; that is, years' experience involved in marine construction projects, familiarity with VE and roles and responsibilities
- eliciting the participants' professional perspectives regarding the variables and level of importance of each.

The second objective is addressed later in this chapter. To meet the first objective, various perspectives were captured from diverse disciplines involved in marine construction projects. Based on the responses received, 41 (32%) of the participants were civil engineers employed in construction projects in either the public or private sector. The second largest sample (30%) was project engineers, while 24% identified their role as a project manager involved in delivering projects and, 7 (5%) were senior marine construction surveyors. The remaining respondents (9%) were project planners, scholars, directors and marine construction technicians. It should be noted that the respondents represented contractors, consultants and clients. Figures 6.1 and 6.2 summarise the participants' actual responsibility/role and their frequency based on geographical location.

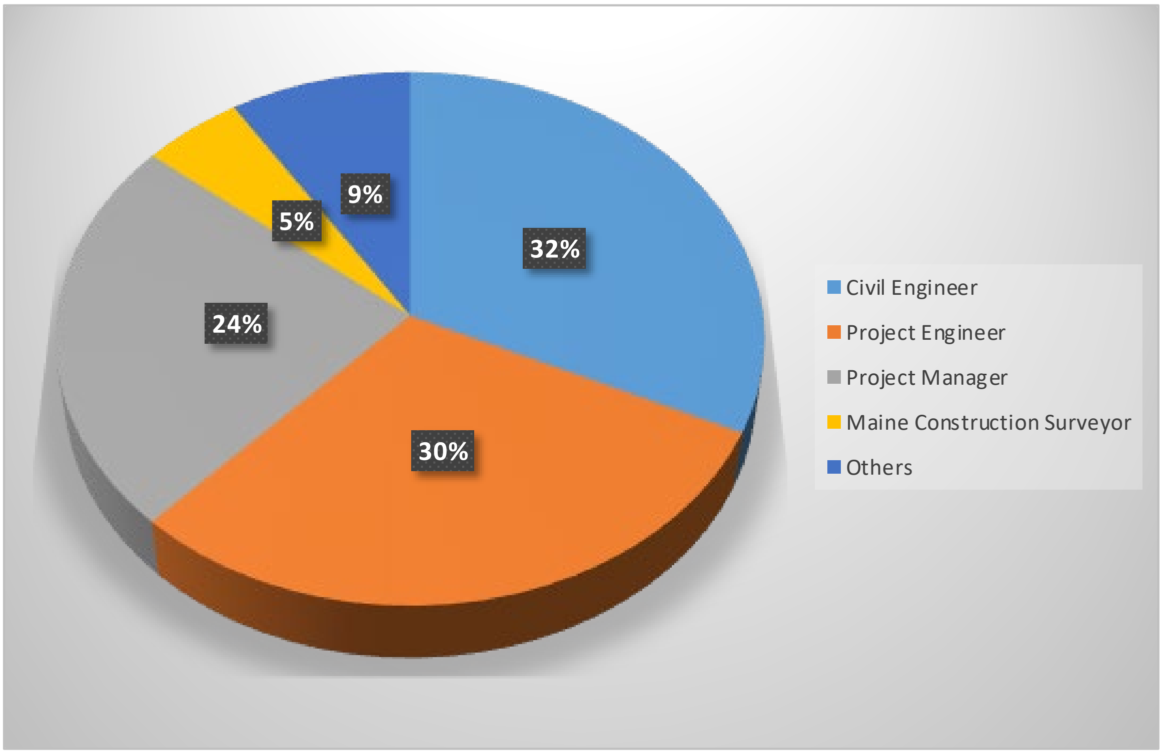


Figure 6.1: Participants' positions

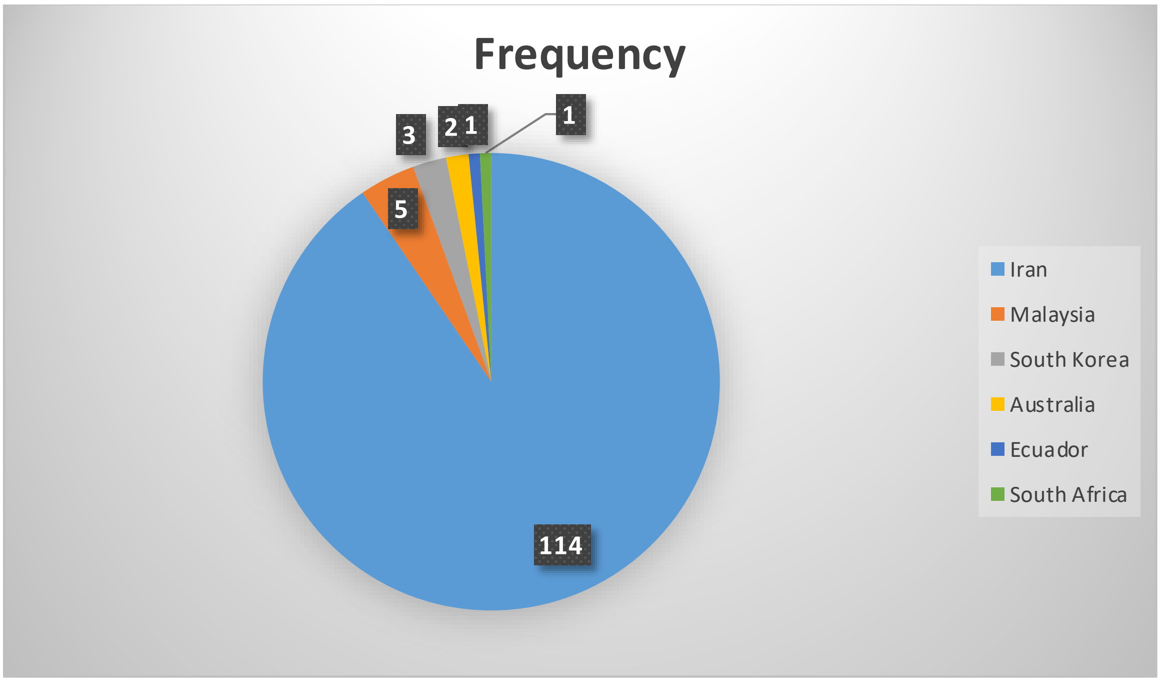


Figure 6.2: Participants' geographical locations

6.5 Data Analysis

This section of the thesis presents the quantitative analysis of data gathered from the closed-ended questionnaire administered to professionals in the marine construction industry. The aim was to identify scope-related overrun causations and potential VE variables applicable in creating delay mitigation strategies in marine construction projects.

6.5.1 The Applied Likert Scale

In this study, the data analysis focus was on exploring and establishing the relationship between two variables. A total of 73 delay causal factors and 19 VE variables were defined through case studies and a literature review. The questions aimed to identify the most important variables, and used a Likert scale. Participants were asked to appraise the level of importance of the delay factors and prioritise the VE factors according to their practicality. Scales were based on five and seven points for the delay and VE factors respectively, as shown in Tables 6.6 and 6.7.

Table 6.6: Likert scale design for delay variables

Delay causation scales
1- Extremely important
2-Very important
3-Moderately important
4- Slightly important
5-Not important at all

Table 6.7: Likert scale design for VE variables

VE variable scales
1-Strongly agree
2-Agree
3-Somewhat agree
4-Neither agree nor disagree
5-Somewhat disagree
6-Disagree
7-Strongly disagree

6.5.2 Quantitative Analysis of Obtained Data

Respondents in this study were asked to represent the frequency of delay occurring in their organisation with reference to a Likert scale question: 'How often are projects facing delay in your organisation?'. The results are presented in Table 6.8 and Figure 6.3: almost 70% of the participants indicated that delay was a highly significant issue in their organisation, and affected most projects. It is interesting to note that no on-time project completion was mentioned and the frequency of 'Never' responses in the Likert scale was equal to 0 (Table 6.8). This indicates that time overrun was a common dissatisfaction factor for project stakeholders, which often affected their expectations.

Table 6.8: Delay frequency in participants' organisations

Scale	Frequency	Valid %	Cumulative
Always	27	21.4	21.4
Most of the time	67	53.2	74.6
About half the time	20	15.9	90.5
Sometimes	12	9.5	100
Never	0	0.00	100
Total	126	100	

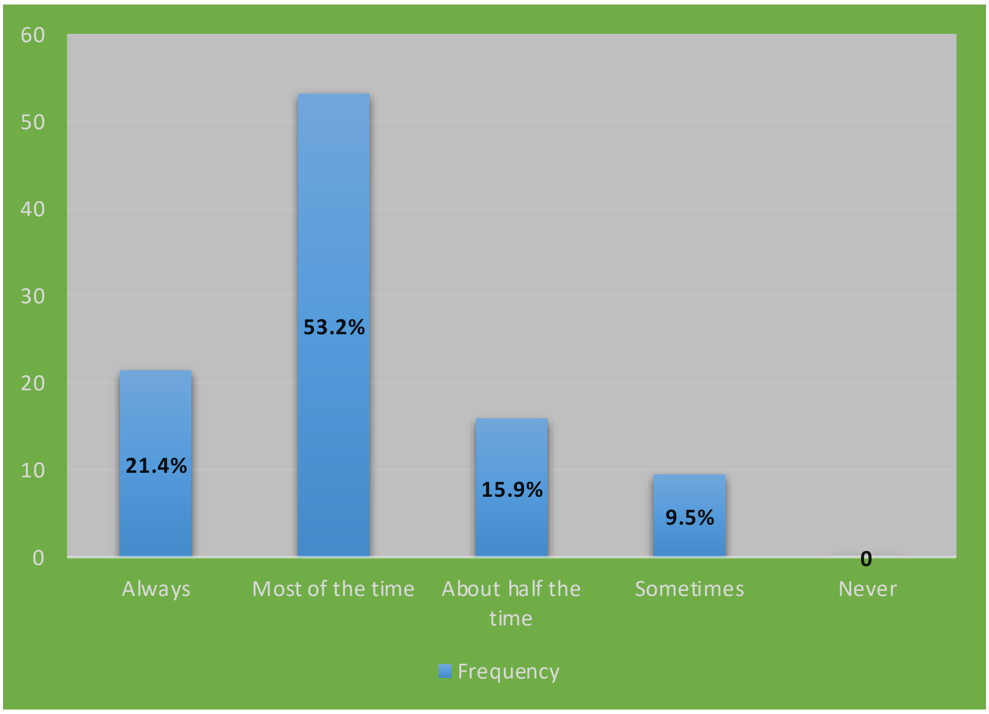


Figure 6.3: Delay frequency in organisations under investigation

6.5.3 Delay Intensity and Marine Projects

To collect data regarding project delays in the marine environment, experts from diverse positions including site engineers, project managers and technicians, under the three main categories of clients, consultants and contractors who were familiar with different stages of construction in marine projects, were asked to complete the questionnaires. Scholars with an academic background were also asked to participate with the aim of integrating their knowledge of the construction industry. Participants were from different age groups and had different records in construction to achieve the most practical outcome that is reliable and valid. The contributors were asked to comment specifically on the extent of delays in marine projects. Table 6.9 summarises their points of view, indicating strong similarity among responses: almost 89% reported a high likelihood of time overrun, which requires further consideration.

Table 6.9: Participants' views on marine-specific likelihood of delay

Scale	Frequency	Valid percent	Cumulative
Far too much	20	15.9	15.9
Moderately too much	63	50	65.9
Slightly too much	29	23	88.9
Neither too much nor too little	10	7.9	96.8
Slightly too little	4	3.2	100
Total	126	100	

6.6 Factor Analysis

A quantitative analysis was undertaken to define the relative importance of two sets of variables in their respective groups via a factor analysis. DeCoster (1998) identifies factor analysis as a dimension reduction tool to reduce a group of variables to a smaller set. Field (2013) specifies two methods for factor analysis: CFA and EFA. The latter was used in this study to conduct an initial analysis. Following Field (2013), EFA was then applied to define a set of components that each include underlying themes. Field highlights the following requirements that must be met before implementation of factor analysis:

- The analysis should be applied to a large sample size of variables that result in precise measurement of factors. The KMO index can be applied to measure sample appropriateness.
- Independence of all participants should be ensured.
- Bartlett's test should be implemented to check for correlation among variables.
- An R-matrix should be examined to identify correlations between pairs of variables and check the acceptance range for each variable.

6.6.1 Kaiser–Meyer–Olkin Index, Bartlett's Test of Sphericity and Correlation Matrix

The KMO index was applied to the sample variables to test the sampling appropriateness. This test is scaled from 0 (unacceptable) to 1 (reliable) for the factor analysis. Field (2013) provides KMO ranges and acceptability rates as shown in Table 6.10. There are two options when the KMO value is less than 0.5: either collecting more data or reviewing the variables before carrying on (Field, 2013).

Table 6.10: KMO level of acceptance

KMO	Level of acceptance
0.5	Barely acceptable
0.5–0.7	Mediocre
0.7–0.8	Good
0.8–0.9	Great
> 0.9	Superb
< 0	Not acceptable

Bartlett's test should be applied to identify the presence of any correlation between variables. This helps ensure an adequate outcome from a factor analysis. Field (2013) emphasises the necessity of an importance level of less than 0.05 for this test. Additionally, to examine the validity of variables and the presence of unreliable items that should be eliminated, an anti-image correlation matrix for both set of variables should be assessed. According to Field (2013), all diagonal components of such a matrix should be above the bare minimum of 0.5.

Following factor analysis, the adequacy of both set of variables (delay and VE) was assessed by using SPSS 25 to calculate the KMO index. Results are provided in Tables 6.11 and 6.12. For the delay variables, sampling adequacy indicated 0.876 while Bartlett's test of sphericity indicated an absolute *p*-value of < 0.001. Controlling the anti-image matrix diagonally also confirms the adequacy of the variables, as all values are greater than 0.5 (see Appendix 9). This verifies that all the delay variables should be retained for further analysis.

Similarly, for the VE variables, the sampling adequacy tests verify the appropriateness of the sampling process. Controlling the anti-image matrix diagonally (see Table 6.13) further indicated the adequacy of the variables, as all values are greater than 0.5; thus, all the VE variables should be retained.

Table 6.11: KMO and Bartlett's test of sphericity for delay variables

KMO	Bartlett's test	Degrees of freedom	*p*-value
0.876	7750.15	2628	< 0.001

Table 6.12: KMO and Bartlett's test of sphericity for VE variables

KMO	Bartlett's test	Degrees of freedom	*p*-value
0.908	1626.12	171	< 0.001

Table 6.13: Anti-image correlation matrix for VE variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	.950[a]																		
2	-0.222	.944[a]																	
3	-0.084	-0.129	.887[a]																
4	-0.077	0.069	-0.647	.881[a]															
5	0.043	-0.185	-0.049	-0.065	.963[a]														
6	-0.040	-0.045	0.235	-0.272	-0.274	.899[a]													
7	0.052	-0.009	-0.167	0.039	-0.010	-0.143	.944[a]												
8	0.095	0.012	0.105	-0.072	0.039	-0.132	-0.440	.900[a]											
9	-0.100	-0.036	0.042	-0.071	-0.091	-0.185	0.030	-0.355	.874[a]										
10	-0.015	0.123	0.038	-0.019	-0.053	0.208	-0.135	-0.021	-0.434	.858[a]									
11	-0.097	-0.016	-0.295	0.080	0.111	-0.161	0.093	-0.167	0.098	-0.256	.929[a]								
12	-0.006	-0.100	-0.049	-0.026	-0.080	-0.091	-0.078	0.099	0.286	-0.336	-0.153	.904[a]							
13	-0.220	0.016	-0.019	0.046	-0.087	0.127	-0.074	-0.170	-0.031	0.049	-0.102	-0.246	.936[a]						
14	0.086	0.093	-0.040	-0.048	-0.058	0.099	-0.068	0.169	-0.308	0.321	-0.141	-0.135	-0.278	.889[a]					
15	-0.015	-0.263	-0.076	0.125	0.095	0.139	-0.056	-0.043	-0.098	-0.134	0.064	-0.008	0.077	-0.176	.919[a]				
16	-0.112	-0.024	-0.011	0.085	-0.063	-0.186	-0.013	-0.041	-0.061	0.120	0.060	-0.382	0.105	-0.065	-0.300	.928[a]			
17	0.037	-0.116	-0.070	0.082	-0.103	-0.300	0.072	-0.031	0.249	-0.409	0.141	0.215	-0.221	-0.415	-0.036	-0.031	.881[a]		
18	-0.101	-0.144	-0.069	-0.012	0.026	-0.012	-0.063	-0.006	0.048	-0.066	0.003	0.074	0.050	-0.003	0.110	-0.202	-0.091	.913[a]	
19	0.114	0.098	0.034	-0.009	-0.068	0.055	0.001	0.057	-0.187	0.123	-0.226	-0.185	0.059	0.063	-0.149	0.098	-0.070	-0.533	.869[a]

6.7 Value Engineering Variables and Descriptive Statistics

The questionnaire respondents used a seven-point Likert scale (see Section 6.5.1) to rate their agreement regarding effectiveness of each of the 19 VE variables for establishing delay mitigation strategies in marine projects. Table 6.14 presents descriptive statistics for the 19 VE variables, along with allocated numbers used to refer to them in subsequent tables. *N* indicates the number of participant responses considered in the analysis. Values for the sample statistics shown in Table 6.14 are utilised as the primary figures to test hypotheses using inferential statistics, as described in the next subsection.

Figure 6.4 provides a graphic representation of the responses, highlighting that the majority (more than 60%) of participants used either ‘strongly agree’ or ‘agree’ to rate the usefulness of each of the VE variables for establishing delay mitigation strategies. ‘Using expert knowledge to analyse the duration of initial tasks on major activities to ensure they are accurate’ and ‘using up-to-date technology in design options if possible’ were rated almost equally as the highest. Respondents rated the former as ‘strongly agree’ (43%) or ‘agree’ (39%), and the latter as ‘strongly agree’ (42%) or ‘agree’ (34%). This was followed by four other variables, rated as 'strongly agreed' or 'agreed' by 72–75% of participants: ‘having a detailed work breakdown for critical activities’, ‘using practical methods from similar projects’, ‘considering previous studies on similar projects in the region’ and ‘involving industry experts in the creativity phase of VE workshop’. Two variables, namely ‘Considering a pilot study in relation to the ground conditions’ and ‘monitoring weather conditions daily to plan ahead for severe weather conditions’, were considered differently from the other VE variables in that 0.03% of the respondents indicated they did not consider them effective.

Overall, Figure 6.4 shows that all respondents agreed on the effectiveness of the variables for developing delay mitigation strategies.

Table 6.14: Descriptive statistics (*N* = 126)

Variable no.	Description	Mean	Median	Mode	Std. deviation
1	Implementing methods for major tasks	1.96	2	2	0.958
2	Contractor's involvement to integrate expert knowledge into design options	2.08	2	2	1.025
3	Analysing alternative resources	2.03	2	2	1.019
4	Analysing alternative methods	2.02	2	1	0.971
5	Addressing activities that can be affected by weather conditions	2.20	2	2	1.117
6	Establishing a flexible schedule for activities that can be affected by weather conditions	2.13	2	2	0.938
7	Having a detailed work breakdown for critical activities	2.05	2	1	1.116
8	Specifying a budget for a pilot study to prevent unpredictable delays	2.25	2	1	1.205
9	Considering a pilot study in relation to the ground conditions	2.37	2	2	1.263
10	Monitoring/optimising resource allocation	2.17	2	2	1.064
11	Having appropriate procedures for repetitive tasks and mass production (e.g. pre-cast and pile preparation)	2.33	2	2	1.064
12	Using practical methods from similar projects	2.06	2	1	1.164
13	Outsourcing mass productions (e.g. pre-cast) to save time	2.46	2	2	1.312
14	Monitoring weather conditions daily to plan ahead for severe weather conditions	2.36	2	2	1.311
15	Using up-to-date technology in design options if possible	1.97	2	1	1.124
16	Considering previous studies on similar projects in the region	2.02	2	1	1.117
17	Using plan-ahead packages to deal with inclement weather conditions	2.23	2	2	1.140
18	Involving industry experts in the creativity phase of VE workshop	1.99	2	1	1.054
19	Using expert knowledge to analyse the duration of initial tasks on major activities to ensure they are accurate	1.79	2	1	0.870

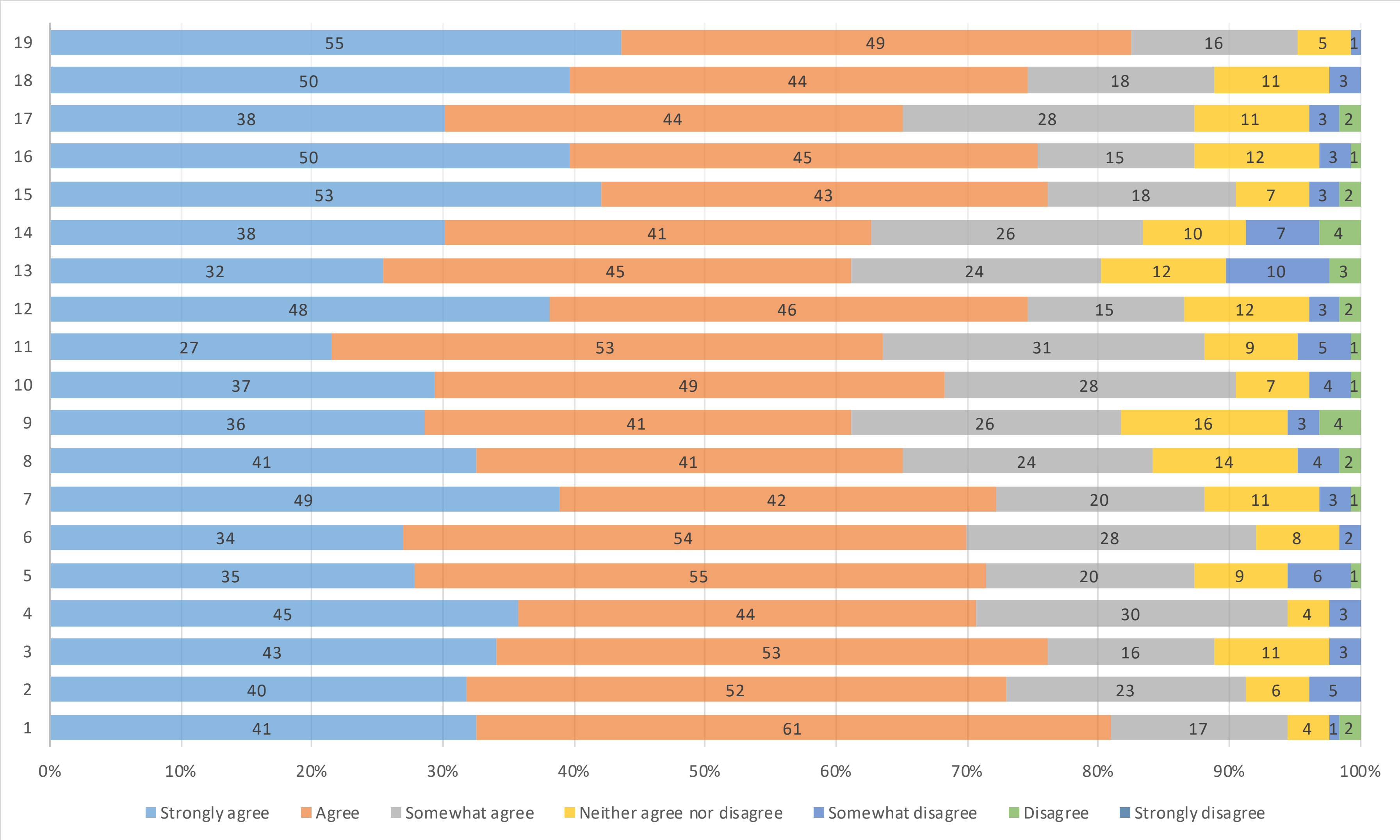


Figure 6.4: Participant response ratings for VE variables

6.7.1 Inferential Statistics for Value Engineering Variables

For the data obtained regarding VE variables, it was necessary to determine the mean tendencies for the population using an appropriate inferential statistical test. The sample mean can only be used to hypothesise about population means. The importance of the VE variables can be explained on the basis of population tendencies. To calculate the population central tendency, a one-sample *t*-test for normally distributed data was used. Inferential statistics can imply the practicality of VE variables in establishing delay mitigation strategies, from which the population of this study could benefit.

To examine the population parameters, mean values were utilised as the related central tendency. With respect to sample means from the descriptive statistics, the population tendency (mean) values were hypothesised. Results of the *t*-test are shown in Table 6.15. As the *p*-values in the last column are all > 0.05, it can be concluded that the sample population mean and the actual population mean are not statistically significantly different. In other words, there is no difference between the hypothesised values and the actual mean values for the population.

Based on the population tendencies, ‘outsourcing mass productions’ was ranked the most suitable by the respondents for developing delay mitigation strategies. This was followed by ‘considering a pilot study in relation to the ground conditions’ and ‘monitoring weather conditions daily to plan ahead for severe weather conditions’, which were mean-ranked 2.37 and 2.36, respectively. ‘Having appropriate procedures for repetitive tasks and mass production’ was mean-ranked fourth (Table 6.15).

Table 6.15: Central tendencies related to the VE variables

No.	Description	Mean	Hypothesised mean	*t*-value	*p*-value (2–tailed)
1	Implementing methods for major tasks	1.96	2	-0.465	0.643
2	Contractor's involvement to integrate expert knowledge into design options	2.08	2.04	0.431	0.667
3	Analysing alternative resources	2.03	2.01	0.239	0.811
4	Analysing alternative methods	2.02	2	0.183	0.855
5	Addressing activities that can be affected by weather conditions	2.20	2.10	0.989	0.325
6	Establishing a flexible schedule for activities that can be affected by weather conditions	2.13	2.2	-0.874	0.384
7	Having a detailed work breakdown for critical activities	2.05	1.95	0.982	0.328
8	Specifying a budget for a pilot study to prevent unpredictable delays	2.25	2.10	1.361	0.176
9	Considering a pilot study in relation to the ground conditions	2.37	2.45	-0.684	0.495
10	Monitoring/optimising resource allocation	2.17	2.00	1.758	0.081
11	Having appropriate procedures for repetitive tasks and mass production (e.g. pre-cast and pile preparation)	2.33	2.20	1.322	0.189
12	Using practical methods from similar projects	2.06	2	0.612	0.542
13	Outsourcing mass productions (e.g. pre-cast) to save time	2.46	2.6	-1.195	0.234
14	Monitoring weather conditions daily to plan ahead for severe weather conditions	2.36	2.4	-0.367	0.714
15	Using up-to-date technology in design options if possible	1.97	2	-0.317	0.752
16	Considering previous studies on similar projects in the region	2.02	2.2	-1.850	0.067
17	Using plan-ahead packages to deal with inclement weather conditions	2.23	2.15	0.790	0.431
18	Involving industry experts in the creativity phase of VE workshop	1.99	2.02	-0.297	0.767
19	Using expert knowledge to analyse the duration of initial tasks on major activities to ensure they are accurate	1.79	1.9	-1.372	0.173

6.7.2 Value Engineering Variables and Factor Extraction

Two main extraction methods are used in factor analysis: PCA and principal access factoring (PAF). Both utilise a sample from the whole population (Field, 2013), so extrapolation of obtained results is not applicable. The choice of PCA or PAF depends on the purpose of the analysis: PCA is employed when a reduction in the number of variables is desirable, while PAF reveals the structure of variables that are considered undiscovered. By default, SPSS 25 uses PCA, which was thus employed in this study. The communalities presented in Table 6.16 indicate the common variance of the variables after factor extraction using SPSS 25. For example, variable 4 has 80.7% of its variance explained by factors.

Table 6.16: Communalities for VE variables

Variable no.	Initial	Extraction
1	1.000	0.527
2	1.000	0.576
3	1.000	0.813
4	1.000	0.807
5	1.000	0.578
6	1.000	0.610
7	1.000	0.703
8	1.000	0.803
9	1.000	0.735
10	1.000	0.602
11	1.000	0.622
12	1.000	0.682
13	1.000	0.567
14	1.000	0.562
15	1.000	0.667
16	1.000	0.670
17	1.000	0.587
18	1.000	0.567
19	1.000	0.475
Extraction method: PCA		

There are two options for identifying the number of variables that require interpretation: the total variance explained and a scree plot. The total variance explained in a factor analysis (Field, 2013) can be illustrated in a table presenting the number of grouped variables that need to be interpreted. A scree plot considers eigenvalues greater than 1 to form a grouping of variables. Table 6.17 and Figure 6.5 show the three grouping variables extracted from the 19 VE variables, demonstrating that the variables should be optimised based on the underlying themes of each group. The total variance for the first three variables is 63.96% (see Table 6.17).

Table 6.17: Total variance explained—VE variables

		Component		
		1	**2**	**3**
	Total	9.957	1.171	1.025
Initial eigenvalues	% of variance	52.403	6.164	5.393
	Cumulative %	52.403	58.567	63.960
	Total	9.957	1.171	1.025
Squared loadings	% of variance	52.403	6.164	5.393
	Cumulative %	52.403	58.567	63.960
	Total	4.480	4.134	3.538
Loadings	% of variance	23.578	21.759	18.622
	Cumulative %	23.578	45.338	63.960

Note. Extraction method: PCA

The scree plot in Figure 6.5 confirms the three groupings of variables to the left of the inflection point.

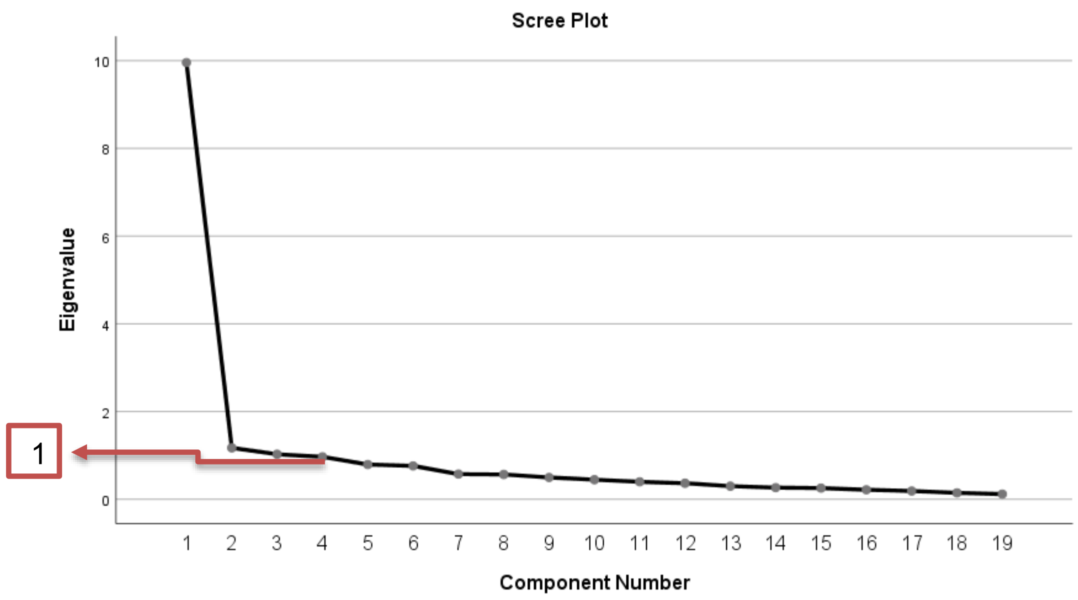


Figure 6.5: Scree plot—VE variables

The assumptions in defining the various elements in the SPSS factor analysis dialogue box were based on arranging the variables by size and not considering any coefficient less than 0.4. Following the extraction stage and to better accommodate the data, factors were rotated using the varimax method in SPSS 25. The matrix resulting from the rotation clearly shows the loadings between the factors. Given that SPSS is not capable of identifying the underlying themes and logic behind each combined grouping, any correlations between generated factors must be reviewed and validated. Table 6.18 presents the proposed rotated component matrix for the VE variables and how they were reduced to three main groups.

Table 6.18: Rotated component matrix[a] (variable groupings in bold)

Variable no. and description		Component		
		1	2	3
15	Using up-to-date technology in design options if possible	**0.756**		
16	Considering previous studies on similar projects in the region	**0.713**		
18	Involving industry experts in the creativity phase of VE workshops	**0.638**		
12	Using practical methods from similar projects	**0.625**		0.471
2	Contractor's involvement to integrate expert knowledge into design options	**0.623**		
19	Using expert knowledge to analyse duration of initial tasks on major activities to ensure accuracy	**0.620**		
14	Monitoring weather conditions daily to plan ahead against severe weather conditions	**0.557**		
17	Using plan-ahead packages to deal with inclement weather conditions	**0. 542**	0.466	
8	Specifying budgets for pilot studies to prevent unpredictable delays		**0.865**	
9	Considering a pilot study in relation to the ground conditions		**0.783**	
7	Having a detailed work breakdown for critical activities		**0.719**	
10	Monitoring/optimising resource allocation		**0.626**	
6	Establishing a flexible schedule for activities that can be affected by weather conditions		**0.620**	
5	Addressing activities that can be affected by weather conditions	0.409	**0.481**	0.423
13	Outsourcing mass productions such as pre-cast to save time	0.422	**0.443**	0.439
4	Analysing alternative methods			**0.828**
3	Analysing alternative resources			**0.811**
1	Implementing methods for major tasks	0.406		**0.583**
11	Having appropriate procedure for repetitive tasks and mass production (e.g. pre-cast and pile preparation)	0.406		**0.576**

Note: Rotation converged in six iterations. Extraction method: PCA.

Based on the results in Table 6.18, the outcomes of the factor analysis are three combined variables (instead of 19) that should have a common theme in each component. In accordance with the rotated component matrix, some variables loaded onto more than one factor, which were checked numerically and logically. Eligible factors are specified in Table 6.18. Implicit themes were developed by evaluating the variables in components 1 and 3. Thoroughly reviewing the variables in component 2 revealed two logical themes. It should be noted that it is the researcher's duty to review the outcome of an SPSS analysis and check the identified variables thoroughly to ensure a logical pattern among them. Although they might be numerically related, re-evaluation of logical dependency is also necessary. Table 6.19 presents the themes relating to the grouped VE factors.

Table 6.19: Elicited themes

Component	Description of elicited underlying theme
1	Integrating statistics, knowledge and empirical practices into design options
2a	Geotechnical assumptions
2b	All-embracing schedule (work breakdown, resource allocation and inclement weather conditions)
3	Process and method optimisation

6.7.3 Reliability of the Components—Cronbach's Alpha

When using Likert scale-type questionnaires, it is necessary to evaluate and report reliability via Cronbach's alpha, which identifies the consistency of responses (Gliem and Gliem, 2003). To ensure response patterns are consistent, questions relating to all variables should be all positively or all negatively worded. Alteration may be required to ensure all variables have the same wording and are eligible for reliability analysis. This can be done by reverse coding in SPSS. In this study, there was no need for reverse coding and all variables were worded the same way. A Cronbach's alpha reliability test was performed for all three combined components.

6.7.3.1 Component 1

In component 1 there were eight variables, two (12 and 17) of which loaded on two separate components. Both variables 12 and 17 were associated with component 1, numerically and logically. Following the reliability procedure using SPSS, two types of tables were developed: reliability statistics and item-total satisfaction (Field, 2013).

The reliability statistics table (Table 6.20) shows the number of items used in the first component, which was eight in this test. The Cronbach's alpha value of 0.894 is ideal and indicates good consistency between the items (ranging between 0.8 and 0.9).

Table 6.20: Component 1—Reliability statistics

Cronbach's alpha	No. of items
0.894	8

Table 6.21 identifies variables that are inconsistent within the component and might be considered an issue. The last column reports Cronbach's alpha following deletion of a variable. According to Table 6.21, it is not desirable to exclude any of the items given that removal of any item reduces the overall Cronbach's alpha value. Following elimination of an item that results in a large increase in Cronbach's alpha, the test needs to be re-run to recheck the reliability of factors. It is also crucial that all values in the corrected item-total correlation column are greater than 0.3. Values below 0.3 indicate an imperfect relationship between variables, which thus need to be removed from the analysis. Evaluating all results for component 1 highlights ideal internal consistency between the variables and that they can all be integrated into one variable as concluded above.

Table 6.21: Component 1—item-total statistics

Variable no.	Scale mean if item deleted	Scale variance if item deleted	Corrected item-total correlation	Cronbach's alpha if item deleted
16	14.48	33.996	0.747	0.873
15	14.53	35.099	0.647	0.883
12	14.44	33.784	0.726	0.875
18	14.51	35.580	0.658	0.882
19	14.71	37.921	0.587	0.888
2	14.42	35.830	0.660	0.882
14	14.14	32.955	0.684	0.880
17	14.27	34.471	0.688	0.879

6.7.3.2 Component 2

A reliability test was also applied to component 2 variables (seven items) and results reviewed to confirm the consistency of the variables. Table 6.22 reports the Cronbach's alpha for seven variables, indicating good internal consistency.

Table 6.22: Component 2—reliability statistics

Cronbach's alpha	No. of items
0.898	7

Of the seven variables, two were loaded on all three components. Evaluation of those factors shows that they can be classified under component two. Similar to component 1, the item-total satisfaction matrix in Table 6.23 identifies reasonable consistency between variables. In other words, no variable needs to be excluded from the component. The results confirm ideal internal consistency.

Table 6.23: Component 2—item-total statistics

Variable no.	Scale mean if item deleted	Scale variance if item deleted	Corrected item-total correlation	Cronbach's alpha if item deleted
8	13.37	29.132	0.751	0.878
9	13.25	28.603	0.751	0.878
7	13.57	29.831	0.761	0.877
10	13.45	31.066	0.687	0.885
6	13.49	32.092	0.694	0.886
13	13.16	29.527	0.638	0.893
5	13.42	30.774	0.672	0.887

The seven variables in component 2 are numerically related, but they should be logically correlated as well. Investigation of the variables in component 2 suggests the possibility of classifying them into two different logical themes. Hence, component two was separated into two themes as shown in Table 6.24.

Table 6.24: Component 2—extracted variables

Geotechnical assumptions	**Specifying budgets for pilot studies to prevent unpredictable delays**
	Considering a pilot study in relation to the ground conditions
All-embracing schedule (work breakdown, resource allocation and inclement weather conditions)	Having a detailed work breakdown for critical activities
	Monitoring/optimising resource allocation
	Establishing a flexible schedule for activities that can be affected by weather conditions
	Addressing activities that can be affected by weather conditions
	Outsourcing mass productions such as pre-cast to save time

6.7.3.3 Component 3

The reliability test conducted for component 3 provided a Cronbach's alpha coefficient of 0.848 as shown in Table 6.25.

Table 6.25: Component 3-Reliability statistics

Cronbach's alpha	No. of items
0.848	4

The Cronbach's alpha value for component 3 indicates good consistency among variables. Out of four variables, two were loaded on both components 1 and 3. Assessment of these two shows that they belong to component 3 both logically and numerically. The item-total statistics in Table 6.26 indicate acceptable consistency among variables, and it is evident that removing variable 1 (Implementation methods for major tasks) increased alpha to 0.852. Since this does not represent an extensive increase from 0.848, it can be ignored and does not warrant re-running the whole test.

Table 6.26: Component 3—Item-total statistics

Variable no.	Scale mean if item deleted	Scale variance if item deleted	Corrected item-total correlation	Cronbach's alpha if item deleted
3	6.30	6.004	0.810	0.752
4	6.32	6.602	0.709	0.798
1	6.37	7.212	0.575	0.852
11	6.01	6.392	0.662	0.819

6.7.4 Summary of Value Engineering Extracted Factors

Utilising factor analysis to analyse the data and reduce the number of VE variables resulted in four themes achieved by exploring the underlying context among different groups and classifying them as separate themes. The four following elicited themes contribute to development of the platform to obtain the model for this study:

- VE1–Integrating statistics, knowledge and empirical practices into design options
- VE2–Geotechnical assumptions
- VE3–All-embracing schedule (work breakdown, resource allocation and inclement weather conditions)
- VE4–Process and method optimisation

6.8 Delay Variables and Descriptive Statistics

The process used to analyse the VE variables was followed to analyse data obtained regarding delay factors. The descriptive statistics in Table 6.27 present delay variables with allocated numbers used to refer to them in subsequent tables. In addition, the table provides the mean index, median, mode and standard deviation related to each variable, calculated using SPSS 25. *N* indicates the number of participants considered in the analysis. Parameters for the sample statistics shown in Table 6.27 are utilised as the primary figures to test hypotheses under inferential statistics. This is described further in the next section.

The questionnaire respondents rated their agreement about the importance of 73 delay variables in delaying marine construction projects (Table 6.27). This was conducted using a five-point Likert scale (see Section 6.5.1). A graphical representation of the responses is provided in Appendix 16.

Almost half of the respondents (50%) listed ‘owners’ financial security’ as an extremely important factor that might impact the project schedule. This was followed by ‘unresponsive marine equipment’ (44%), ‘financial difficulties of the contractor’ (44%) and ‘inappropriate contractor’ (46%), also rated as extremely important. Following this and among the top 10 factors ranked as extremely important by the participants were 'weather considerations' (41%), 'delay in importing materials due to political conditions' (38%) and 'not utilising lessons learned from similar projects' (38%). 'Inexperienced personnel', 'impractical design' and 'procurement and resource allocation' were all ranked by 37% of the participants as extremely important. 'Shop drawing preparation and approval' and 'not involving the contractor in early design phase' were rated the least important by almost 0.08% of the participants. 'Inadequate form of contract', 'social and cultural factor', 'neighbours' interference' and 'inappropriate work breakdown system by the contractor' were rated similarly as being not important at all, by around 0.07% of the respondents.

The graphical representation of the participant ratings in Appendix 16 shows that all respondents agreed on the importance of the delay variables in marine construction projects.

Table 6.27: Descriptive statistics—delay variables (*N* = 126)

Variable no.	Description	Mean	Median	Mode	Std. deviation
1	Weather considerations	1.88	2	1	0.909
2	High and low tides	2.64	3	2	1.031
3	Unresponsive marine equipment	1.76	2	1	0.814
4	Owner's financial security	1.67	1.5	1	0.778
5	Financial difficulties of the contractor	1.70	2	1	0.719
6	Inexperienced personnel	1.87	2	2	0.829
7	Lack of efficient design	1.98	2	2	0.867
8	Improper site instructions imposed on contractors	2.40	2	2	0.922
9	Delay in land delivery	2.39	2	2	1.035
10	Inappropriate communications	2.00	2	2	0.963
11	Poor site control by contractors	2.10	2	2	0.884
12	Poor consultant's auditing system	2.38	2	3	0.954
13	Lack of consultant's practical experience	2.15	2	2	0.939
14	Contradiction between tender documents and actual situation	2.14	2	2	0.918
15	Lack of execution methods for major tasks	2.06	2	2	0.949
16	Change orders imposed by the client	2.39	2	2	1.020
17	Delayed resources	1.98	2	2	0.912

Variable no.	Description	Mean	Median	Mode	Std. deviation
18	Inappropriate contractor	1.75	2	1	0.809
19	Estimation errors in early design phase	2.34	2	3	0.956
20	Delay in documents/drawings approval	2.36	2	2	0.984
21	Lack of pilot study prior to construction	2.25	2	2	0.892
22	Over-optimism scheduling	1.98	2	2	0.829
23	Lack of VE department in organisation	2.22	2	2	1.035
24	Inadequate form of contract	2.71	3	2	1.089
25	Inefficient coordination among critical disciplines	2.36	2	2	1.008
26	Outdated technology	2.22	2	2	0.857
27	Low speed in job site transfer	2.56	3	3	0.916
28	Impractical contract duration imposed by client	2.31	2	3	0.907
29	Inappropriate decision processes	2.39	2	2	0.955
30	Delays in subcontractors' job delivery	2.35	2	2	0.906
31	Unstable management structure and style of contractor	2.00	2	2	0.921
32	Construction method	2.06	2	2	0.856
33	Skill shortage	2.14	2	2	0.936
34	Lack of liabilities in different parties	2.37	2	2	1.001
35	Late work approval	2.50	2	2	0.986
36	Lack of appropriate quality assurance system on site	2.46	2	2	0.969
37	Inefficient information stream	2.41	2	2	0.974
38	Delay in test results approval	2.71	3	2	1.050
39	Inadequate design team experience	2.10	2	2	0.875
40	Impractical design	1.95	2	1	0.893
41	Lack of proper cooperation between consultant and contractor	2.14	2	2	0.883
42	Lack of cooperation between client and consultant	2.28	2	2	1.025
43	Procurement and resource allocation	2.01	2	1	0.934
44	Delay in importing materials due to political conditions	1.95	2	1	0.970
45	Escalation in resource prices	2.19	2	2	0.883
46	Skill shortage for high-end marine equipment	2.20	2	2	0.930
47	Labour's productivity	2.28	2	2	0.845
48	Social and cultural factor	2.89	3	3	1.052
49	Uncooperative owner	2.31	2	2	1.016
50	Insufficient communication of owner and design team in design phase	2.25	2	2	0.995

Variable no.	Description	Mean	Median	Mode	Std. deviation
51	Unavailability of professional construction management	2.26	2	2	1.067
52	Lack of financial incentive for contractor to finish ahead of schedule	2.35	2	3	0.941
53	Neighbours' interference	2.89	3	3	1.067
54	Unforeseen ground conditions	2.43	2	2	1.069
55	Price fluctuations	2.21	2	2	0.932
56	conditions of water table on construction site	2.56	2	2	1.024
57	Unreliable geological assumptions	2.34	2	2	1.067
58	Shop drawings' preparation and approval	2.73	3	2	1.120
59	Lack of database in estimating activity duration and resources	2.38	2	2	1.102
60	Safety issues	2.30	2	2	1.045
61	Damaging marine equipment during execution due to lack of safety	2.16	2	2	1.069
62	Lack of safety training and meetings prior to commencing construction	2.44	2	2	1.016
63	Poor judgment and experience in estimation processes	2.29	2	2	0.939
64	Inspection procedures employed in construction site	2.61	2	2	0.971
65	Accident during construction	2.48	2	3	1.144
66	Extreme bureaucracy in client's organisation	2.44	2	2	0.976
67	Lack of considering alternative resources	2.44	2	2	0.959
68	Inappropriate work breakdown system by the contractor	2.54	2	2	1.093
69	Not adopting flexible timetable for certain tasks	2.37	2	2	0.960
70	Not involving the contractor in early design phase	2.71	3	2	1.125
71	Lack of optimising/monitoring resource allocation	2.35	2	2	1.014
72	Lack of planning for mass production	2.37	2	2	1.032
73	Not utilising lessons learned from similar projects	1.98	2	1	0.971

6.8.1 Inferential Statistics for Delay Variables

For the data obtained regarding delay variables, the mean tendencies in the population were determined using the appropriate inferential statistical test. The sample mean can be used only to hypothesis about the population mean. The importance of delay variables can be examined on the basis of population tendencies. To calculate the population central tendency, as with the VE variables, a one-sample *t*-test for normally distributed data was employed. Inferential statistics can identify the importance of delay variables in marine construction projects, from which the population of this study could benefit.

To examine the population parameters, mean values were utilised as the relevant central tendency. With respect to sample means from the descriptive statistics, population tendency (mean) values were hypothesised. Results of the *t*-test are shown in Table 6.28.

Table 6.28: Central tendencies related to the delay variables

Variable no.	Description	Mean	Hypothesised mean	*t*-value	*p*-value (2-tailed)
1	Weather considerations	1.88	2.00	-1.471	0.144
2	High and low tides	2.64	2.5	1.555	0.122
3	Unresponsive marine equipment	1.76	1.9	-1.904	0.059
4	Owner’s financial security	1.67	1.8	-1.809	0.073
5	Financial difficulties of the contractor	1.70	1.8	-1.587	0.115
6	Inexperienced personnel	1.87	1.8	0.988	0.325
7	Lack of efficient design	1.98	1.9	1.089	0.278
8	Improper site instructions imposed on contractors	2.40	2.5	-1.159	0.249
9	Delay in land delivery	2.39	2.3	0.964	0.337
10	Inappropriate communications	2.00	2.1	-1.165	0.246
11	Poor site control by contractors	2.10	2.00	1.310	0.193
12	Poor consultant's auditing system	2.38	2.40	-0.224	0.823
13	Lack of consultant's practical experience	2.15	2.2	-0.558	0.557
14	Contradiction between tender documents and actual situation	2.14	2.10	0.524	0.601
15	Lack of execution methods for major tasks	2.06	2.00	0.657	0.512
16	Change orders imposed by the client	2.39	2.30	0.979	0.330
17	Delayed resources	1.98	2.10	-1.426	0.156
18	Inappropriate contractor	1.75	1.85	-1.442	0.152
19	Estimation errors in early design phase	2.34	2.4	-0.689	0.492
20	Delay in documents/drawings approval	2.36	2.45	-1.060	0.291

Variable no.	Description	Mean	Hypothesised mean	*t*-value	*p*-value (2-tailed)
21	Lack of pilot study prior to construction	2.25	2.35	-1.309	0.193
22	Over-optimism scheduling	1.98	2.10	-1.568	0.119
23	Lack of VE department in organisation	2.22	2.30	-0.844	0.400
24	Inadequate form of contract	2.71	2.8	-0.966	0.336
25	Inefficient coordination among critical disciplines	2.36	2.45	-1.034	0.303
26	Outdated technology	2.22	2.30	-1.019	0.310
27	Low speed in job site transfer	2.56	2.65	-1.060	0.291
28	Impractical contract duration imposed by client	2.31	2.40	-1.119	0.265
29	Inappropriate decision processes	2.39	2.45	-0.718	0.474
30	Delays in subcontractors' job delivery	2.35	2.40	-0.629	0.530
31	Unstable management structure and style of contractor	2.00	2.10	-1.219	0.225
32	Construction method	2.06	2.10	-0.479	0.633
33	Skill shortage	2.14	2.20	-0.686	0.494
34	Lack of liabilities in different parties	2.37	2.45	-0.952	0.343
35	Late work approval	2.50	2.60	-1.139	0.257
36	Lack of appropriate quality assurance system on site	2.46	2.55	-1.039	0.301
37	Inefficient information stream	2.41	2.5	-1.006	0.316
38	Delay in test results approval	2.71	2.8	-0.917	0.361
39	Inadequate design team experience	2.10	2.20	-1.242	0.216
40	Impractical design	1.95	2.05	-1.227	0.222
41	Lack of proper cooperation between consultant and contractor	2.14	2.20	-0.727	0.469
42	Lack of cooperation between client and consultant	2.28	2.35	-0.791	0.430
43	Procurement and resource allocation	2.01	2.10	-1.107	0.271
44	Delay in importing materials due to political conditions	1.95	2.05	-1.129	0.261
45	Escalation in resource prices	2.19	2.25	-0.757	0.451
46	Skill shortage for high-end marine equipment	2.20	2.15	0.585	0.560
47	Labour's productivity	2.28	2.20	1.033	0.304
48	Social and cultural factor	2.89	2.8	0.948	0.345
49	Uncooperative owner	2.31	2.40	-1.00	0.319

Variable no.	Description	Mean	Hypothesised mean	*t*-value	*p*-value (2-tailed)
50	Insufficient communication of owner and design team in design phase	2.25	2.20	0.609	0.544
51	Unavailability of professional construction management	2.26	2.20	0.651	0.516
52	Lack of financial incentive for contractor to finish ahead of schedule	2.35	2.40	-0.606	0.546
53	Neighbours' interference	2.89	2.80	0.935	0.352
54	Unforeseen ground conditions	2.43	2.50	-0.750	0.455
55	Price fluctuations	2.21	2.30	-1.128	0.262
56	conditions of water table on construction site	2.56	2.50	0.696	0.488
57	Unreliable geological assumptions	2.34	2.40	-0.618	0.538
58	Shop drawings' preparation and approval	2.73	2.65	0.803	0.423
59	Lack of database in estimating activity duration and resources	2.38	2.30	0.825	0.411
60	Safety issues	2.30	2.35	-0.520	0.604
61	Damaging marine equipment during execution due to lack of safety	2.16	2.25	-0.958	0.340
62	Lack of safety training and meetings prior to commencing construction	2.44	2.50	-0.702	0.484
63	Poor judgment and experience in estimation processes	2.29	2.35	-0.674	0.502
64	Inspection procedures employed in construction site	2.61	2.55	0.706	0.481
65	Accident during construction	2.48	2.55	-0.647	0.519
66	Extreme bureaucracy in client's organisation	2.44	2.50	-0.730	0.466
67	Lack of considering alternative resources	2.44	2.50	-0.743	0.459
68	Inappropriate work breakdown system by the contractor	2.54	2.45	0.921	0.359
69	Not adopting flexible timetable for certain tasks	2.37	2.45	-0.993	0.323
70	Not involving the contractor in early design phase	2.71	2.65	0.562	0.575
71	Lack of optimising/monitoring resource allocation	2.35	2.40	-0.562	0.575
72	Lack of planning for mass production	2.37	2.45	-0.923	0.358
73	Not utilising lessons learned from similar projects	1.98	2.10	-1.339	0.183

The *p*-values in Table 6.28, which are all greater than 0.05, indicate that for all variables there was no significant difference between the sample and population means. That is, there is no difference between the hypothesised values and the actual mean values for the population.

Another way to assess the population mean is by using SPSS to create confidence intervals around the sample mean; that is, the range of values within which the population mean is most likely to occur. Results for the first three variables considering α = 0.05 are provided in Table 6.29, confirming the previously discussed method and the results in Table 6.28. All other variables follow the same process.

Table 6.29: Actual population tendencies

Variable	Minimum	Maximum	Mean	Std. deviation	95% confidence interval for mean	
					Lower bound	Upper bound
Weather conditions	1	4	1.88	0.081	1.72	2.04
High and low tides	1	5	2.64	0.092	2.46	2.82
Lack of proper marine equipment	1	4	1.76	0.073	1.62	1.91

6.8.2 Delay Variables and Factor Extraction

Proceeding with factor analysis according to Field (2013), more SPSS output tables need to be examined. Table 6.30 presents the communalities for the delay factors; that is, the common variance of the variables after factor extraction. For example, variable 4 has 80.8% of its variance explained by factors.

Table 6.30: Communalities—delay variables

Variable	Extraction	Variable	Extraction	Variable	Extraction	Variable	Extraction
1	0.721	20	0.788	39	0.672	58	0.770
2	0.717	21	0.686	40	0.747	59	0.786
3	0.721	22	0.779	41	0.719	60	0.830
4	0.808	23	0.686	42	0.730	61	0.832
5	0.755	24	0.695	43	0.744	62	0.842
6	0.735	25	0.788	44	0.742	63	0.700

7	0.704	26	0.706	45	0.702	64	0.805
8	0.708	27	0.752	46	0.664	65	0.764
9	0.738	28	0.749	47	0.810	66	0.749
10	0.694	29	0.746	48	0.672	67	0.763
11	0.742	30	0.785	49	0.744	68	0.715
12	0.821	31	0.791	50	0.760	69	0.818
13	0.729	32	0.703	51	0.756	70	0.727
14	0.718	33	0.732	52	0.688	71	0.820
15	0.774	34	0.701	53	0.724	72	0.767
16	0.625	35	0.730	54	0.761	73	0.603
17	0.756	36	0.709	55	0.781		
18	0.792	37	0.769	56	0.832		
19	0.724	38	0.808	57	0.824		

Employing a reductionist method and similar to the procedure applied to the VE variables, delay variables requiring interpretation were identified using the total variance explained table and a scree plot. All variables elicited are shown in Table 6.31: 16 components were extracted from the 73 delay variables. Similarly, the scree plot (Figure 6.6) shows 16 factors to the left of the inflection point. This is based on the specification of eigenvalue greater than 1 and reveals that the variables require optimisation based on their underlying themes. The total variance explained by the first four components is 51.677%. The table also shows the total variance for the 16 factors (74.583%).

PCA was applied to identify the themes above as it is the default method in SPSS software. The scree plot confirms the number of themes concluded on the basis of the total variance explained matrix. The inflection point in Figure 6.6 identifies the number of remaining factors to the left of the point as the appropriate number of factors. As for the total variance explained matrix, it is clear that there are 16 themes to the left of the inflection point.

Table 6.31: Total variance explained—delay variables

	Initial eigenvalues			**Extraction sums of squared loadings**		
Component	Total	% of Variance	Cumulative (%)	Total	% of Variance	Cumulative (%)
1	29.541	40.468	40.468	29.541	40.468	40.468
2	3.159	4.328	44.795	3.159	4.328	44.795
3	2.767	3.790	48.585	2.767	3.790	48.585
4	2.257	3.092	51.677	2.257	3.092	51.677
5	2.069	2.834	54.511	2.069	2.834	54.511

6	1.778	2.436	56.946	1.778	2.436	56.946
7	1.616	2.213	59.160	1.616	2.213	59.160
8	1.496	2.050	61.210	1.496	2.050	61.210
9	1.457	1.996	63.206	1.457	1.996	63.206
10	1.395	1.912	65.117	1.395	1.912	65.117
11	1.304	1.787	66.904	1.304	1.787	66.904
12	1.217	1.667	68.570	1.217	1.667	68.570
13	1.168	1.600	70.171	1.168	1.600	70.171
14	1.121	1.536	71.706	1.121	1.536	71.706
15	1.087	1.489	73.195	1.087	1.489	73.195
16	1.013	1.388	74.583	1.013	1.388	74.583

Note. Extraction method: PCA

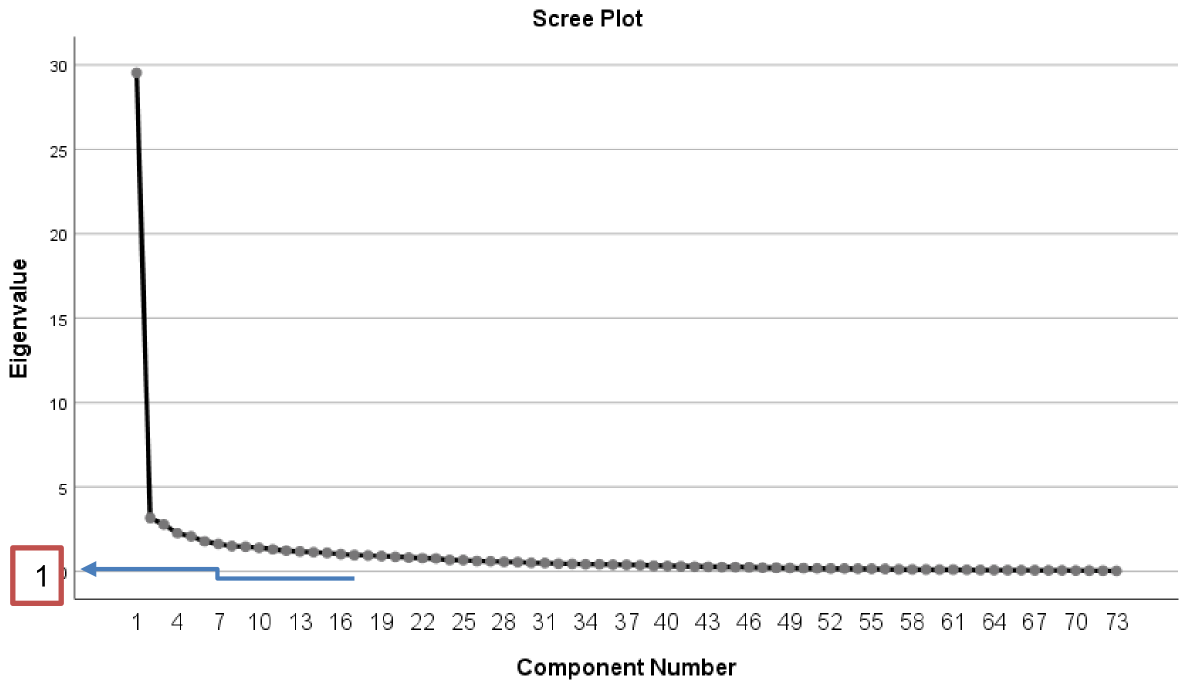


Figure 6.6: Scree plot—delay variables

Proceeding with the analysis and to better accommodate the data, factors were rotated using the varimax method. The purpose of rotation is to create a simple structure that can be easily interpreted. The resulting rotated component matrix clearly displays the loadings between factors. As SPSS is not capable of locating the underlying themes and logics behind each combined grouping, correlations among the extracted factors must be carefully reviewed and validated.

Utilising PCA as the extraction method, matrix rotation for the 73 delay variables returned 16 components. Some variables loaded on more than one component; these were checked both numerically and logically. As mentioned previously, it is the researcher's duty to review the SPSS output for common themes among components, and identify the variables identified for each. Although they may be numerically related, re-assessment is necessary to identify any logical theme to the related ones. Table 6.32 displays the rotated component matrix for the delay variables and how they can be reduced to 16 main groups. The settings used in SPSS for the rotation of delay variables were chosen by organising the variables by size and taking into consideration any coefficient below 0.1 (compared with 0.4 for the VE variable rotation). This technique was applied because of the significance of all variables and the need to evaluate the variables in detail both numerically and logically.

Table 6.32: Rotated component matrix[a] (variable groupings shaded in green)

		Component															
No.	Variable no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	V-29	0.727	0.163	0.127	0.116		0.157	0.183	0.178			0.178			-0.109		
2	V-30	0.675	0.115	0.291	0.163	0.266					0.206		0.126		0.212		-0.110
3	V-58	0.558	0.409	0.143	0.251	0.111		0.182	0.326					-0.102	0.152		
4	V-9	0.546	0.144	0.103	0.204	0.132	0.235	0.323			0.118		0.102	0.180	0.220	0.264	0.116
5	V-25	0.536	0.157	0.259	0.104		0.218	0.158	0.127	0.132	0.126	0.277	0.106		0.292		
6	V-28	0.514	0.200			0.268	0.375	0.220			0.186	0.237		0.185			0.188
7	V-35	0.500	0.307	0.290	0.112	0.126	0.388			0.112		0.167	0.100		0.233		
8	V-37	0.449	0.314	0.227	0.243	0.185	0.204	0.332				0.358		0.106		-0.126	
9	V-66	0.435	0.272	0.326	0.366	0.143	0.138					0.118	0.361	0.193			
10	V-16	0.397	0.190		0.112	0.149	0.137		0.218		0.270	0.242	0.128		0.229	0.349	
11	V-46	0.354	0.305	0.186	0.120	0.102	0.317	0.264	0.250		0.144		0.203		0.124	-0.169	0.211
12	V-71	0.165	0.673	0.193	0.164	0.184	0.102	0.130	0.105	0.208	0.183	0.299	0.190				
13	V-70	0.198	0.637	0.194		0.106	0.236	0.205		0.213			0.188			0.151	
14	V-67	0.282	0.620	0.279	0.276	0.213	0.137	0.168		0.136				0.104			
15	V-68	0.360	0.515	0.299	0.225	0.192		0.113			0.162	0.166				0.179	0.135
16	V-69	0.141	0.488	0.379	0.127	0.475			0.115		0.199	0.173			0.168	-0.121	0.187
17	V-63	0.241	0.478	0.375	-0.133		0.188	0.141	0.257		0.169	0.205	0.116	0.109	0.118		
18	V-36	0.417	0.469	0.236	0.163		0.228	0.235	0.195		0.118				0.195		-0.104
19	V-72	0.265	0.433	0.153		0.349	0.339	0.209				0.194	0.329	0.122			0.153
20	V-62	0.166	0.254	0.770		0.120	0.197	0.142	0.134	0.202							
21	V-60	0.208	0.128	0.725	0.115	0.211	0.121		0.164	0.157	0.160				0.121	-0.234	
22	V-61	0.231	0.237	0.713	0.110	0.107	0.140	0.216	0.252				0.121	0.116	0.117		
23	V-64	0.144	0.355	0.550	0.232		0.240	0.165		0.342	0.159		0.144			0.161	
24	V-65	0.266	0.210	0.491	0.124					0.402			0.370	0.162		0.191	
25	V-15			0.488	0.342			0.226	0.288		0.115	0.286	0.158		0.125	0.289	0.223

		Component															
No.	**Variable no.**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
26	**V-24**	0.289	0.180	0.471	0.321	0.346		0.163								0.269	
27	**V-8**	0.135		0.116	0.705				0.193	0.117				0.255	0.107		
28	**V-14**	0.330	0.175	0.149	0.630				0.120		0.132	0.145		0.106		0.258	0.108
29	**V-12**	0.108	0.115	0.275	0.580		0.344	0.312		0.112			0.253				-0.264
30	**V-48**		0.395		0.548	0.256				-0.125		0.147	0.159		0.230		
31	**V-7**	0.115	0.199		0.443	0.311	0.158	0.266	0.141		0.403			0.158	0.139	-0.146	
32	**V-59**	0.353	0.427	0.116	0.428	0.206		0.246	0.275				0.209	0.123			0.112
33	**V-50**		0.300	0.208	0.422	0.332	0.187	0.158				0.325	0.240	0.123	0.126	0.263	
34	**V-41**	0.243	0.180	0.218	0.207	0.589	0.206	0.109	0.174		0.236	0.123		0.135			
35	**V-42**	0.256	0.273	0.270		0.550		0.141	0.346		0.127			0.107	0.118		0.111
36	**V-49**	0.247	0.241		0.332	0.484	0.120					0.112	0.279	0.246	0.207	0.226	
37	**V-51**	0.259	0.302	0.181	0.138	0.466	0.208	0.314			0.127	0.224	0.310				
38	**V-32**	0.174		0.187		0.432	0.222	0.339	0.217	0.192	0.174		-0.134	0.223	0.122		-0.282
39	**V-6**	0.183	0.146	0.205	0.131		0.647	0.161			0.320	0.125		0.100	0.164		
40	**V-13**	0.197	0.185	0.212	0.437	0.148	0.516				0.213	0.135	0.126				-0.179
41	**V-39**	0.130	0.184	0.126	0.211	0.175	0.501	0.248	0.186		0.353				-0.108		0.184
42	**V-53**	0.207	0.140	0.126	0.179	0.158	0.448		0.364	0.240	-0.171		0.288	0.188			-0.173
43	**V-21**		0.214	0.250	0.378		0.433	0.130	0.247		0.126	0.294		-0.132	0.151		
44	**V-40**	0.308				0.359	0.427	0.199	0.283		0.299	0.121		0.221	-0.116	0.212	
45	**V-54**	0.190	0.261	0.177	0.223	0.126	0.354	0.102	0.302	0.247		0.291	0.237	0.154		0.316	
46	**V-26**	0.201		0.101		0.261		0.644	0.113	0.187	0.191		0.117	-0.144		-0.142	0.122
47	**V-23**	0.169	0.355	0.182	0.231		0.231	0.587							0.118		0.128
48	**V-10**	0.143	0.282	0.182	0.223		0.132	0.587	0.160		0.143	0.200		0.117		0.194	
49	**V-34**	0.394	0.171	0.260	0.147	0.160		0.504		0.103		0.282	0.259	0.215			
50	**V-11**		0.212	0.175	0.287	-0.161	0.165	0.413	0.117	0.205	0.304	0.401			0.164	0.111	
51	**V-45**	0.134				0.175		0.135	0.709	0.153	0.214		0.109	0.162			

		Component															
No.	**Variable no.**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
52	**V-55**	0.176	0.150	0.216	0.130				0.667	0.357			0.120	0.212			
53	**V-52**		0.143	0.238	0.341	0.182	0.281		0.409	0.110		0.107	0.374				0.186
54	**V-20**	0.146	0.249	0.275	0.176		0.308	0.136	0.381			0.373		0.210	0.368		
55	**V-1**									0.810	0.112			0.105			
56	**V-2**		0.149	0.160				0.109	0.146	0.755					0.118		0.137
57	**V-56**		0.236	0.166		0.246	0.210		0.333	0.532			0.250		0.418		
58	**V-57**	0.158	0.322		0.141	0.380	0.105		0.288	0.487			0.132		0.298	0.241	-0.124
59	**V-18**		-0.101	0.140		0.172	0.165		0.151		0.775		0.231				0.102
60	**V-33**	0.108	0.290		0.269		0.155	0.241		0.305	0.586	0.126	-0.113				
61	**V-17**	0.128	0.140	0.112	0.104	0.349				-0.113	0.531	0.137		0.315	0.130	0.352	
62	**V-43**	0.305	0.207	0.113	0.122	0.274	0.107		0.284		0.412	0.186	0.381	0.173		-0.123	-0.109
63	**V-22**	0.238	0.114			0.137		0.123	0.139		0.122	0.742		0.220			0.174
64	**V-19**	0.169	0.240		0.359		0.160					0.625	0.125		0.130	0.110	
65	**V-31**	0.357		0.219	0.173	0.375		0.180	0.207		0.184	0.470	0.184				-0.245
66	**V-44**	0.104	0.151	0.137				0.208	0.220		0.186		0.693	0.172	0.142		
67	**V-47**	0.125	0.414	0.278	0.116		0.146	0.363	0.182		0.350		0.416		0.171		
68	**V-73**	0.175	0.250	0.192	0.161	0.223	0.229	0.271	0.166	0.150		0.167	0.290		-0.153	0.142	0.245
69	**V-4**				0.179	0.114			0.218	-0.108				0.819		0.119	
70	**V-5**									0.242	0.107	0.187	0.166	0.739	0.163	-0.103	0.109
71	**V-27**	0.257		0.218	0.320	0.136		0.109						0.134	0.669		
72	**V-38**	0.325	0.261	0.228		0.126	0.441	0.255		0.221				0.130	0.448	0.107	
73	**V-3**			0.131		0.121		0.233	0.129	0.376	0.138	0.116	0.144	0.197			0.604

6.8.3 Themes and Reductionist Methodology Procedure

Table 6.32 shows that 16 combined components were identified in the factor analysis that should each share a common theme. It is important to understand that variable identification in the analysis is based entirely on mathematical calculations. The software is not capable of understanding the underlying nature of variables to recognise any logical themes for related variables (Field, 2013). It is the researcher's responsibility to examine the factors and variables defined within each to identify any common themes. Some variables loaded on more than one factor; these were checked both numerically and logically. For example, although lack of execution methods for major activities loaded numerically on component 3, it loaded logically on component 15. Likewise, the form of contract loaded numerically on component 3, but logically on component 5. Numerically, skill shortage for high-end marine equipment loaded on component 1 while logically it was loaded on component 16. Eligible factors are shaded green in Table 6.32. Themes relating to grouped delay factors for each component identified in the literature review and explored using a reductionist methodology were elicited and are shown in Table 6.33. The table contains factor loadings, mean, standard deviation, item-total correlation and Cronbach's alpha coefficient, to provide a clearer understanding and promote interpretation of the findings.

Table 6.33: Outcome of reductionist approach applied to delay factors

Delay factor	Factor matrix	Mean	Std. deviation	Item-total correlation	Cronbach's alpha
D1-Client-contractor interruptions					
Delay in land delivery	0.257	2.39	1.035	0.499	0.9787
Inappropriate decision processes	0.727	2.39	0.955	0.625	0.9785
Delays in subcontractors' job delivery	0.675	2.35	0.906	0.623	0.9785
Low speed in job site transfer	0.546	2.56	0.916	0.701	0.9784
Inefficient information stream	0.449	2.41	0.974	0.756	0.9783
Change orders imposed by the client	0.397	2.39	1.020	0.607	0.9785
D2-Inadequate planning					
Lack of optimising/monitoring resource allocation	0.673	2.35	1.014	0.730	0.9783
Not involving the contractor in early design phase	0.637	2.71	1.125	0.626	0.9785

Delay factor	Factor matrix	Mean	Std. deviation	Item-total correlation	Cronbach's alpha
Lack of considering alternative resources	0.620	2.44	0.959	0.747	0.9783
Lack of appropriate quality assurance system on site	0.469	2.46	0.969	0.735	0.9783
Lack of planning for mass production	0.433	2.37	1.032	0.739	0.9783
D3-Safety practices					
Lack of safety training and meetings prior to commencing construction	0.770	2.44	1.016	0.676	0.9784
Safety issues	0.725	2.30	1.045	0.613	0.9785
Damaging marine equipment during execution due to lack of safety	0.725	2.16	1.069	0.725	0.9783
Inspection procedures employed in construction site	0.550	2.61	0.971	0.733	0.9783
Accident during construction	0.491	2.48	1.144	0.643	0.9785
D4-Instructions/communications					
Improper site instructions imposed on contractors	0.705	2.40	0.922	0.501	0.9787
Contradiction between tender documents and actual situation	0.630	2.14	0.918	0.602	0.9785
Poor consultant's auditing system	0.580	2.38	0.954	0.630	0.9785
Social and cultural factor	0.548	2.89	1.052	0.546	0.9786
Lack of efficient design	0.443	1.98	0.867	0.567	0.9786
Lack of database in estimating activity duration and resources	0.428	2.38	1.102	0.777	0.9782
D5-Management approaches					
Lack of proper cooperation between consultant and contractor	0.589	2.14	0.883	0.702	0.9784
Lack of cooperation between client and consultant	0.550	2.28	1.025	0.673	0.9784
Inadequate form of contract	0.346	2.71	1.089	0.605	0.9785
Construction method	0.432	2.06	0.856	0.549	0.9786
Unstable management structure and style of contractor	0.375	2.00	0.921	0.655	0.9785
Unavailability of professional construction management	0.466	2.26	1.067	0.737	0.9783
D6-Design and construction issues					
Inexperienced personnel	0.647	1.87	0.829	0.490	0.9787
Lack of consultant's practical experience	0.516	2.15	0.939	0.578	0.9786
Inadequate design team experience	0.501	2.10	0.875	0.601	0.9785
Lack of pilot study prior to construction	0.433	2.25	0.892	0.631	0.9785
Impractical design	0.427	1.95	0.893	0.605	0.9785
Unforeseen ground conditions	0.354	2.43	1.069	0.739	0.9783

Delay factor	Factor matrix	Mean	Std. deviation	Item-total correlation	Cronbach's alpha
D7-Organisational structure					
Outdated technology	0.644	2.22	0.857	0.467	0.9787
Lack of VE department in organisation	0.587	2.22	1.035	0.610	0.9785
Inappropriate communications	0.587	2.00	0.963	0.648	0.9785
Inefficient coordination among critical disciplines	0.504	2.36	1.008	0.679	0.9784
Poor site control by contractors	0.413	2.10	0.884	0.601	0.9785
Lack of liabilities in different parties	0.158	2.37	1.001	0.675	0.9784
Not utilising lessons learned from similar projects	0.271	1.98	0.971	0.638	0.9785
D8-Political/cultural factors					
Neighbours' interference	0.364	2.89	1.067	0.597	0.9785
Delay in importing materials due to political conditions	0.220	1.95	0.970	0.519	0.9787
D9-Environmental uncertainties					
Weather considerations	0.810	1.87	0.909	0.261	0.9790
High and low tides	0.755	2.64	1.031	0.309	0.9790
conditions of water table on construction site	0.532	2.56	1.024	0.574	0.9786
Unreliable geological assumptions	0.487	2.34	1.067	0.663	0.9784
D10-Extreme and complex resources					
Skill shortage	0.586	2.14	0.936	0.621	0.9785
Inappropriate contractor	0.775	1.75	0.809	0.394	0.9788
delayed resources	0.531	1.98	0.912	0.504	0.9787
Procurement and resource allocation	0.412	2.01	0.934	0.659	0.9784
Labour's productivity	0.350	2.28	0.845	0.731	0.9784
D11-Activity estimation errors					
Over-optimism scheduling	0.742	1.98	0.829	0.497	0.9787
Estimation errors in early design phase	0.625	2.34	0.956	0.524	0.9786
Impractical contract duration imposed by client	0.237	2.31	0.907	0.674	0.9784
Poor judgment and experience in estimation processes	0.205	2.29	0.939	0.646	0.9785
Not adopting flexible timetable for certain tasks	0.173	2.37	0.960	0.662	0.9784
D12-Owner's stagnant structure					
Lack of financial incentive for contractor to finish ahead of schedule	0.374	2.35	0.941	0.622	0.9785
Uncooperative owner	0.279	2.31	1.016	0.659	0.9784
Insufficient communication of owner and design team in design phase	0.240	2.25	0.995	0.711	0.9784
Extreme bureaucracy in client's organisation	0.361	2.44	0.976	0.679	0.9784

Delay factor	Factor matrix	Mean	Std. deviation	Item-total correlation	Cronbach's alpha
D13-Financial issues					
Owner's financial security	0.819	1.67	0.778	0.330	0.9789
Financial difficulties of the contractor	0.739	1.70	0.719	0.351	0.9788
Escalation in resource prices	0.162	2.19	0.883	0.489	0.9787
Price fluctuations	0.212	2.21	0.932	0.586	0.9786
D14-Delay in approval processes					
Late work approval	0.233	2.50	0.986	0.734	0.9783
Delay in test results approval	0.448	2.71	1.050	0.685	0.9784
Delay in documents/drawings approval	0.368	2.36	0.984	0.708	0.9784
Shop drawings' preparation and approval	0.152	2.73	1.120	0.652	0.9785
D15-Construction strategies					
Lack of execution methods for major tasks	0.289	2.06	0.949	0.632	0.9785
Inappropriate work breakdown system by the contractor	0.179	2.54	1.093	0.715	0.9783
D16-Marine equipment					
Unresponsive marine equipment	0.604	1.76	0.814	0.463	0.9787
Skill shortage for high-end marine equipment	0.211	2.20	0.930	0.672	0.9784

As outlined by Olatunji (2019), 'Factor analysis helps to determine the relative statistical significance of the decision factors such that it is possible to identify items that are most significant beyond descriptive ranking'. According to Olatunji, the results from a factor analysis enhance the descriptive mean ranking. The process can highlight high mean-ranked items that are not statistically significant based on their descriptive rankings. Findings from the factor analysis in Table 6.33 identify both owners' financial security and weather considerations among the top 10 factors, with high statistical significance. However, owners' financial security was mean-ranked the lowest, close to financial difficulties of the contractor. These top two were followed by another two items: inappropriate contractor and lack of safety training and meetings prior to commencing construction. Although inappropriate contractor was reported as statistically significant, it was mean-ranked near the bottom of the table. The fifth most important delay factor was high and low tides, mean-ranked 7th. The sixth and seventh factors were overoptimistic scheduling and financial difficulties of the contractor: mean-ranked 65th and 72nd, respectively. Inappropriate decision processes was the eighth most significant delay factor in the factor score matrix, mean-ranked 21st.

Safety issues and damaged marine equipment during construction were next, mean-ranked 38th and 50th, respectively. Results also show some that items with low mean rankings were statistically significant. For example, inexperienced personnel was ranked as the 14th most important delay factor, but mean-ranked 69th out of the 73 delay variables.

6.9 Structural Modelling Analysis and Discussion of Value Engineering Variables

The SEM technique has the ability to model relationships between multiple independent and dependent constructs at the same time (Chai et al., 2015). Unlike techniques such as ANOVA (analysis of variance) and MANOVA (multivariate analysis of variance), Chai and colleagues consider this approach is capable of analysing more than ‘one layer of linkage between independent and dependent variables at a time’.

As discussed in Section 6.6.1, both the KMO measure of sampling adequacy and Bartlett's test of sphericity confirmed the adequacy of factor analysis using SEM for the VE variables. Nineteen VE variables identified from the literature were classified into three components using a reductionist method. Underlying themes related to each component were discussed in section 6.7.2.

Figure 6.7 shows a graphical path diagram constructed using AMOS software to illustrate the structure of covariances among the obtained variables. The figure also describes the relationships among the three components. The SEM model suggests high covariance between the components, indicating a strong relationship. The actual SEM output for the VE variables is available in Appendix 14.

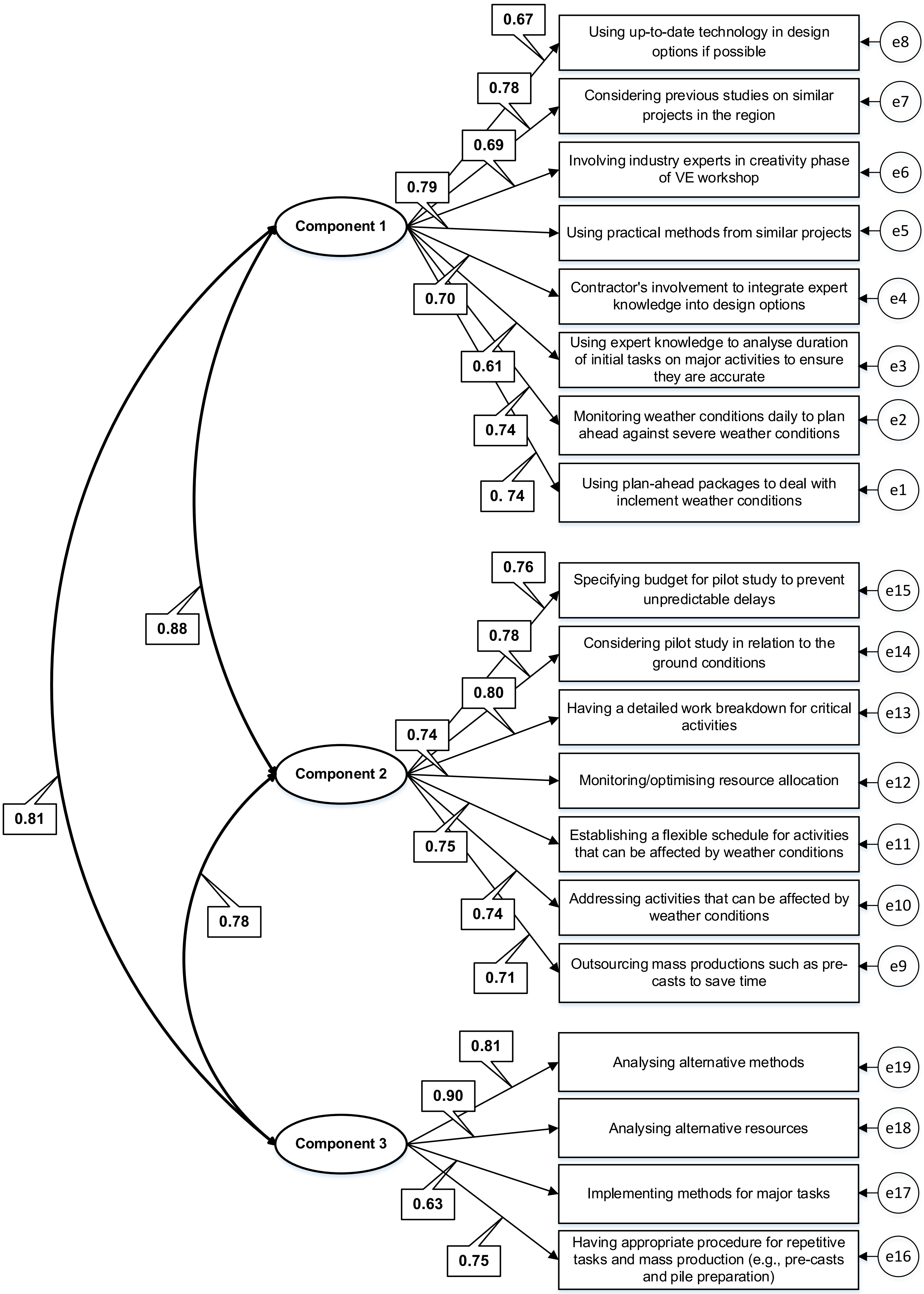


Figure 6.7: VE graphical path diagram

Figure 6.7 diagrammatically illustrates the relationships between underlying latent factors and the observed indicators. It also represents the correlation between the latent factors (components). The diagram enables meticulous evaluation of how the observed data are illustrated by a conceptual model. To facilitate the analysis, Figure 6.7 is simplified and adapted in Table 6.34.

The results in Figure 6.7 and Table 6.34 are consistent with the findings from the factor analysis and dimension reduction process. Factor loadings in Figure 6.7 reveal correlations between the three components and each of their relevant variables. If these variables are good indicators of the components (latent variables), these loadings should be high. In other words, we would expect the correlation between a reasonably good indicator (variable) for a component and the component itself to approach 1. The highest and lowest loadings are associated with 'analysing alternative resources' and 'analysing alternative methods', respectively—the two main objectives of the VE workshops. This is followed by 'having a detailed work breakdown for critical activities' and 'using practical methods from similar projects'. 'Considering pilot study in relation to the ground condition' and 'considering previous studies on similar projects in the region' have equal loadings and are reasonably good indicators of their related component. The lowest loading relates to 'implementation methods for major tasks', although the value is still in an acceptable range and reveals a strong correlation with its latent variable.

Overall, the model quantitatively validates the outcome from the factor analysis and the indicators (variables) well represent the concepts (latent variables). Model fit indices are reported in Section 6.12.

Table 6.34: Summary of VE path diagram—regression weights

Variable no.	Description	Component		
		1	2	3
15	Using up-to-date technology in design options if possible	**0.67**		
16	Considering previous studies on similar projects in the region	**0.78**		
18	Involving industry experts in the creativity phase of VE workshops	**0.69**		
12	Using practical methods from similar projects	**0.79**		
2	Contractor's involvement to integrate expert knowledge into design options	**0.70**		
19	Using expert knowledge to analyse duration of initial tasks on major activities to ensure accuracy	**0.61**		
14	Monitoring weather conditions daily to plan ahead against severe weather conditions	**0.74**		
17	Using plan-ahead packages to deal with inclement weather conditions	**0. 74**		
8	Specifying budgets for pilot studies to prevent unpredictable delays		**0.76**	
9	Considering a pilot study in relation to the ground conditions		**0.78**	
7	Having a detailed work breakdown for critical activities		**0.80**	
10	Monitoring/optimising resource allocation		**0.74**	
6	Establishing a flexible schedule for activities that can be affected by weather conditions		**0.75**	
5	Addressing activities that can be affected by weather conditions		**0.74**	
13	Outsourcing mass productions such as pre-casts to save time		**0.71**	
4	Analysing alternative methods			**0.81**
3	Analysing alternative resources			**0.90**
1	Implementing methods for major tasks			**0.63**
11	Having appropriate procedure for repetitive tasks and mass production (e.g. pre-casts and pile preparation)			**0.75**

6.10 Reviewing Different Fit Indices

Hooper et al. (2008) explain model fit indices as measures identifying the model that best represents the data and reflects the underlying theory. They classify model fit indices commonly applied by researchers into three categories: absolute, incremental and parsimony fit indices.

6.10.1 Absolute Fit Indices

According to Hooper et al. (2008) four major indices in this category are as follows:

- Model chi-square (χ^2):
  Hooper et al. (2008) consider this value 'the traditional measure for evaluating overall model fit'. They suggest as appropriate a value ranging from 2 (based on Tabachnick et al., 2007) to 5 (based on Wheaton et al., 1977).
- Root mean square error of approximation (RMSEA):
  This value 'tells us how well the model, with unknown but optimally chosen parameter estimates would fit the population's covariance matrix' (Hooper et al., 2008). Based on these authors' review of the literature, RMSEA for a well-fitting model is generally considered to range from near 0 to less than 0.08.
- Goodness of Fit Index (GFI) and Adjusted Goodness of Fit Index (AGFI):
  GFI 'shows how closely the model comes to replicating the observed covariance matrix' (Diamantopoulos et al., 2000) and AGFI 'adjusts the GFI based upon degrees of freedom, with more saturated models reducing fit' (Tabachnick et al., 2007). Both GFI and AGFI range from 0 to 1, and values greater than 0.9 indicate good fit (Hooper et al., 2008).
- Root mean square residual (RMR) and standardised root mean square residual (SRMR):
  The RMR is 'the square root of the difference between the residuals of the sample covariance matrix and the hypothesised covariance model' (Hooper et al., 2008). According to Kline (1998), interpretation of RMR in Likert scale-type questionnaires is complicated because the RMR range is determined on the basis of each indicator's scale. Thus, the RMR is difficult to interpret if a questionnaire includes items of varying levels (e.g. both 1–5 and 1–7 are used in this study). The SRMR addresses this issue. SRMR values range from 0 to 1, with 0.05 considered a good fit and 0.08 as the highest acceptable level (Hooper et al., 2008).

6.10.2 Incremental Fit Indices

These indices are 'a group of indices that do not use the chi-square in its raw form but compare the chi-square value to a baseline model' (Hooper et al., 2008). These authors identify two such indices:

- Normed Fit Index (NFI):
  According to Hooper et al. (2008) this index 'assesses the model by comparing the χ^2 value of the model to the χ^2 of the null model. The null/independence model is the worst case scenario as it specifies that all measured variables are uncorrelated'. A significant downside to this index is its sample size sensitivity, which leads to underestimation of fit for sample sizes below 200 (Bentler, 1990). Researchers tend to use a Non-normed Fit Index, usually defined as the Tucker–Lewis Index (TLI). This index considers simpler models to resolve the issue. TLI ranges from 0 to 1, with 0.8 suggested by scholars as the lower limit for acceptable fit (Hooper et al., 2008).
- CFI (Comparative Fit Index):
  Unlike NFI, 'CFI performs well when the sample size is small' (Tabachnick et al., 2007). This index varies from 0 to 1, with a lower limit of 0.9 being acceptable, and a value close to 1 indicating good fit (Hu and Bentler, 1999).

6.10.3 Parsimony Fit Indices

Two parsimony fit indices developed by Mulaik et al. (1989) are the Parsimony Goodness-of-Fit Index and Parsimony Normed Fit Index (PNFI). The unavailability of defined standard thresholds makes it difficult to interpret these figures (Hooper et al., 2008). The authors recommend smaller values as indicating a good fit, based on the literature. Reliable results are expected for sample sizes larger than 200.

6.11 Reporting Model Fit Indices

Hooper et al. (2008) underline two important factors to be considered when selecting the best indices to report:

- not intentionally adopting fit indices that suggest the best fit
- not considering indices used most commonly as the best approach.

Based on the wealth of literature and reviewing guidelines from different reports, Hooper and colleagues recommend that a report should include 'Chi-Square statistic, its degrees of freedom and p-value, the RMSEA, the SRMR, the CFI and one parsimony fit index such as the PNFI.

6.12 Value Engineering Model Validation and Corresponding Indices

The validity of the model was checked by employing model fit indices. Chai et al. (2015) present a table of fit indices that can be used to assess the level of acceptance. Researchers have determined that meeting the requirements of at least one index in each category is satisfactory for model validation (Singh, 2009; Bagozzi and Yi, 2012; Zainudin, 2012). Adopted from Chai et al. (2015), Table 6.35 displays the index category and level of acceptance.

Table 6.35: Index category and level of acceptance (source: Chai et al., 2015)

Category	Index	Zainudin (2012)	Bagozzi and Yi (2012)	Singh (2009)
Absolute fit	χ^2	> 0.05		
	RMSEA	< 0.08	≤ 0.05 to ≤ 0.08	≤ 0.10
Incremental fit	CFI	> 0.90	≥ 0.93	0–1
	TLI	> 0.90	≥ 0.92	≥ 0.95
Parsimonious fit	χ^2/df	< 5.0	0–2	1–2

Note: *df* = degrees of freedom

A review of the model fit in the initial SEM trial returned the following fit indices: χ^2 = 365.454, df = 149, p = 0.000, χ^2/df = 2.453, CFI = 0.861, RMSEA = 0.087, SRMR = 0.0668 and PNFI = 0.687. According to Table 6.35, guidelines from the literature as outlined above and criteria introduced by Hooper et al. (2008) for reporting indices, the model satisfactorily fit the data and met the requirements. Some indices were borderline but still acceptable. In SEM, p = 0.000 can indicate absence of fit. Because SEM tends to be a large sample approach and the chi-square test is influenced by the size of the sample, it is not unusual for a chi-square test to be statistically significant. Evidence from the overall model fit indicates that the model was a relatively good fit for the data.

6.13 Structural Modelling Analysis and Discussion of Delay Variables

As explained in Section 6.6.1, the KMO measure of sampling adequacy and Bartlett's test of sphericity confirm the adequacy of factor analysis using SEM for the delay variables. KMO was 0.876, and for Bartlett's test of sphericity the absolute *p*-value was less than 0.001. The 73 delay variables identified from the literature were classified into 16 components using a reductionist method. Underlying themes related to each component were discussed in section 6.8.3. Figure 6.8 shows a graphical path diagram constructed using the AMOS software, which illustrates the structure of covariances among the obtained themes and variables (note that values have been rounded up to two digits). The figure illustrates the relationships between the 16 underlying latent factors and their relevant observed indicators. It also highlights correlations between the latent factors (components). The diagram enables a close evaluation of how the observed data are illustrated by a conceptual model.

Because of the large number of variables in the model, and to facilitate interpretation of results, statistics from the model are summarised in Tables 6.35 and 6.36. Table 6.36 presents standardised regression weights between themes (components) and corresponding variables, while Table 6.37 shows covariances among themes. The SEM model suggests high covariance between the components, indicating a strong relationship (see Table 6.36). The actual SEM output for delay variables is available in Appendix 17.

The results in Figure 6.8 and Tables 6.35 and 6.36 are consistent with outcomes from the factor analysis and reductionist approach. Factor loadings indicate correlations between the components and each variable. Most of the loadings are greater than 0.5, indicating a reasonably good correlation between the observed indicators and latent variables. Although some variables have loadings less than 0.5, none are lower than 0.4, which is an indication of an approximately good fit.

Overall, the model quantitatively validates the outcomes from the factor analysis, and shows that the indicators (variables) are good representatives of the concepts (latent variables). Model fit indices are reported in Section 6.14.

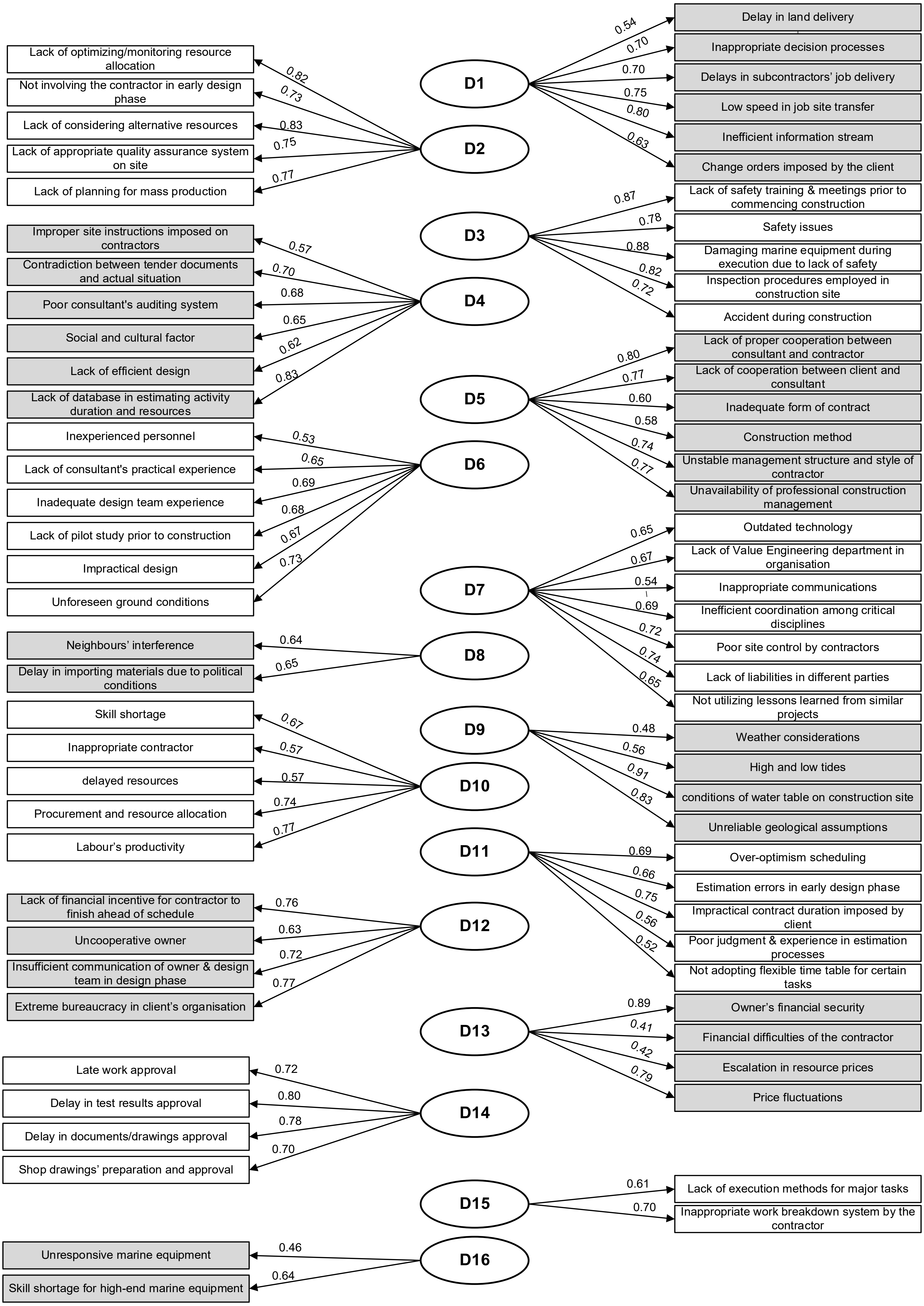


Figure 6.8: SEM model for delay factors

Table 6.36: Standardised regression weights—delay variables

Description of variable		Theme	Estimate
Change orders imposed by the client	<---	D1	0.632
Inefficient information stream	<---	D1	0.805
Low speed in job site transfer	<---	D1	0.754
Delays in subcontractors' job delivery	<---	D1	0.697
Inappropriate decision processes	<---	D1	0.696
Delay in land delivery	<---	D1	0.542
Lack of planning for mass production	<---	D2	0.770
Lack of appropriate quality assurance system on site	<---	D2	0.750
Lack of considering alternative resources	<---	D2	0.833
Not involving the contractor in early design phase	<---	D2	0.729
Lack of optimising/monitoring resource allocation	<---	D2	0.824
Accident during construction	<---	D3	0.718
Inspection procedures employed in construction site	<---	D3	0.816
Damaging marine equipment during execution due to lack of safety	<---	D3	0.881
Safety issues	<---	D3	0.783
Lack of safety training and meetings prior to commencing construction	<---	D3	0.873
Lack of database in estimating activity duration and resources	<---	D4	0.835
Lack of efficient design	<---	D4	0.621
Social and cultural factor	<---	D4	0.654
Poor consultant's auditing system	<---	D4	0.680
Contradiction between tender documents and actual situation	<---	D4	0.694
Improper site instructions imposed on contractors	<---	D4	0.569
Unavailability of professional construction management	<---	D5	0.775

Description of variable		Theme	Estimate
Unstable management structure and style of contractor	<---	D5	0.738
Construction method	<---	D5	0.583
Inadequate form of contract	<---	D5	0.608
Lack of cooperation between client and consultant	<---	D5	0.770
Lack of proper cooperation between consultant and contractor	<---	D5	0.799
Unforeseen ground conditions	<---	D6	0.734
Impractical design	<---	D6	0.669
Lack of pilot study prior to construction	<---	D6	0.680
Inadequate design team experience	<---	D6	0.693
Lack of consultant's practical experience	<---	D6	0.649
Inexperienced personnel	<---	D6	0.535
Poor site control by contractors	<---	D7	0.650
Inefficient coordination among critical disciplines	<---	D7	0.738
Inappropriate communications	<---	D7	0.716
Lack of VE department in organisation	<---	D7	0.690
Outdated technology	<---	D7	0.542
Lack of liabilities in different parties	<---	D7	0.686
Not utilising lessons learned from similar projects	<---	D7	0.648
Delay in importing materials due to political conditions	<---	D8	0.648
Neighbours' interference	<---	D8	0.635
Unreliable geological assumptions	<---	D9	0.827
conditions of water table on construction site	<---	D9	0.914
High and low tides	<---	D9	0.555
Weather considerations	<---	D9	0.478

Description of variable		Theme	Estimate
Labour’s productivity	<---	D10	0.769
Procurement and resource allocation	<---	D10	0.744
delayed resources	<---	D10	0.574
Inappropriate contractor	<---	D10	0.565
Skill shortage	<---	D10	0.665
Estimation errors in early design phase	<---	D11	0.523
Over-optimism scheduling	<---	D11	0.559
Impractical contract duration imposed by client	<---	D11	0.746
Poor judgment and experience in estimation processes	<---	D11	0.662
Not adopting flexible timetable for certain tasks	<---	D11	0.695
Insufficient communication of owner and design team in design phase	<---	D12	0.767
Uncooperative owner	<---	D12	0.723
Lack of financial incentive for contractor to finish ahead of schedule	<---	D12	0.628
Extreme bureaucracy in client’s organisation	<---	D12	0.757
Escalation in resource prices	<---	D13	0.790
Financial difficulties of the contractor	<---	D13	0.425
Owner’s financial security	<---	D13	0.411
Price fluctuations	<---	D13	0.889
Delay in documents/drawings approval	<---	D14	0.706
Delay in test results approval	<---	D14	0.781
Late work approval	<---	D14	0.804
Shop drawings’ preparation and approval	<---	D14	0.721
Inappropriate work breakdown system by the contractor	<---	D15	0.706
Lack of execution methods for major tasks	<---	D15	0.614

Description of variable		Theme	Estimate
Skill shortage for high-end marine equipment	<---	D16	0.639
Unresponsive marine equipment	<---	D16	0.462

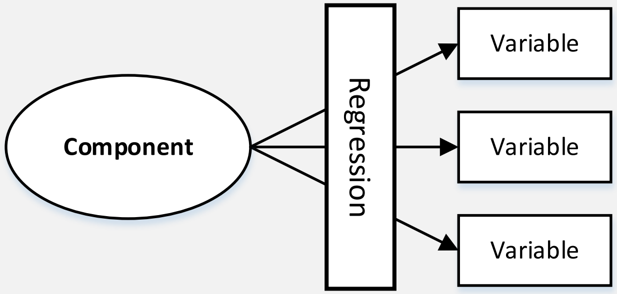
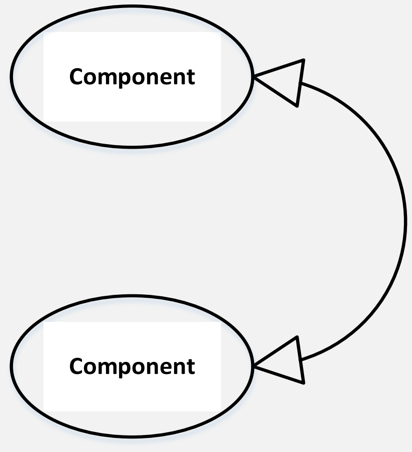


Table 6.37: Correlation among themes—delay variables

Theme	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16
D1																
D2	0.852															
D3	0.727	0.779														
D4	0.860	0.849	0.645													
D5	0.886	0.834	0.742	0.817												
D6	0.831	0.845	0.719	0.881	0.861											
D7	0.918	0.881	0.768	0.868	0.849	0.855										
D8	0.739	0.761	0.721	0.783	0.724	0.822	0.786									
D9	0.520	0.619	0.624	0.497	0.590	0.561	0.557	0.748								
D10	0.819	0.793	0.710	0.800	0.854	0.922	0.817	0.884	0.595							
D11	0.936	0.935	0.730	0.806	0.913	0.892	0.896	0.724	0.566	0.883						
D12	0.876	0.855	0.758	0.969	0.884	0.881	0.808	0.916	0.552	0.802	0.857					
D13	0.522	0.538	0.563	0.603	0.567	0.614	0.590	0.759	0.613	0.623	0.586	0.564				
D14	0.944	0.886	0.782	0.809	0.820	0.844	0.864	0.828	0.692	0.768	0.895	0.822	0.557			
D15	0.963	0.950	0.935	0.976	0.944	0.945	0.990	0.806	0.605	0.887	1.002	1.047	0.541	0.934		
D16	0.956	0.947	0.913	0.915	0.878	0.989	1.012	0.980	0.784	0.995	1.030	0.920	0.788	0.976	1.087	



Chai et al. (2015) identify the standardised regression coefficient as a tool to measure the 'relative contribution between a predictor variable and an outcome variable'. As an effect size index (Nieminen et al., 2013), coefficients greater than 0.10 suggest a small effect, those greater than 0.30 represent a moderate effect and those greater than 0.50, a significant effect (Kline, 1998). The regression coefficients in Table 6.36 indicate a significant contribution of all delay factors to overrun issues.

6.14 Delay Model Validation and Corresponding Indices

As with the VE model, the validity of the delay model was checked by applying model fit indices. Chai et al. (2015) determine that for a model to be considered valid, it should satisfy one of the requirements in each group of absolute fit, incremental fit and parsimonious fit. The fit indices used in this study are in line with the work of Bagozzi and Yi (2012), Zainudin (2012) and Singh (2009), who all agree that a minimum of one requirement met in each category is satisfactory for model validation (see Table 6.35).

Evaluation of model fit in the initial SEM trial returned the following indices of fit: χ^2 = 4730.551, *df* = 2435, *p* = 0.000, χ^2/df = 1.94, CFI = 0.676, RMSEA = 0.087, SRMR = 0.0728 and PNFI = 0.475. According to Table 6.35, guidelines from the literature and criteria in Hooper et al. (2008) for reporting indices, the model satisfactorily fit the data and met the requirements. Some indices were borderline but still acceptable. In SEM, *p* = 0.000 can indicate absence of fit. Because SEM tends to be a large sample approach and the chi-square test is influenced by sample size, it is not unusual for a chi-square test to be statistically significant. Evidence from the overall model fit indicates that the model provided a relatively good fit for the data.

6.15 Summary

The overarching purpose of this chapter and an interpretation of the diverse methods carried out for analysing the findings were briefly explained in an introduction section. Data normality and suitability were then investigated prior to statistical tests being carried out, to ensure accuracy of the results. Demographic information for the respondents was also reviewed before commencing the data analysis section.

Quantitative analysis of data gathered from the close-ended questionnaire was presented in data analysis section. Scope-related overrun causations and potential VE variables applicable in creating delay mitigation strategies in marine construction projects were explored through factor analysis in this section. Employing this approach defined a set of components in delay causal factors and VE variables that each include underlying themes. This was followed by evaluating the descriptive statistics relevant to both delay and VE variables. Values for sample statistics were then utilised as the primary figure to test hypotheses using inferential statistics. Applying inferential statistics implied the practicality of the obtained variables, indicating that they can be generated to a population greater than the sample size.
Utilising factor analysis to analyse the data and reduce the number of delay and VE variables resulted in four themes (instead of 19) for VE and sixteen themes (instead of 73) for delay. This was achieved by exploring the underlying context among different groups and classifying them as separate themes. It should be noted that the identified variables were checked thoroughly to ensure a logical and numerical dependency among them. The elicited themes for VE and delay variables are represented in Tables 6.19 and 6.33 respectively. They contribute to development of a platform to obtain the most appropriate mitigation strategy in the scope of marine construction projects.

Findings from the factor analysis and dimension reduction process were further confirmed through a graphical diagram as the output of SEM, for both VE and delay variables. Factor loadings in the diagrams revealed a high correlation between the components and each of their relevant variables. In other words, the SEM model for both VE and delay variables quantitatively validated the outcome from the factor analysis and the indicators (variables) well represented the concepts (latent variables). Findings extracted through the analysis in this chapter were utilised to design an open-ended survey questionnaire to further evaluate the obtained model. The next chapter explains the viewpoints of the experts in response to the open-ended questionnaire.

CHAPTER 7: MODEL VALIDATION

7.1 Introduction

As explained in Chapter 4, an open-ended questionnaire was utilised to externally validate the findings using expert knowledge. A team of purposefully selected professionals formed a group investigating the relationships between the themes and obtained variables and how they impact project schedules, to obtain the most appropriate model. Responses in the form of agreements, explanations, suggestions, disagreements, practical examples and other useful feedback were recorded and are discussed in this chapter. In addition, an analysis of themes, relationships and dependencies is conducted using NVivo 12 software, which assists with the grouping of responses based on topics and terminology. As one of the most popular computer-assisted qualitative data analysis software used by scholars, NVivo helps to code, organise and logically group information into themes and patterns, and to develop an intuitive understanding (Feng and Behar-Horenstein, 2019). Employing NVivo mitigates the potential for bias in the coding process and offers efficiencies in the processing and revision of coding (Woods et al., 2016). Coding is a revealing tool that provides both the information and the means to convey the explanations of the information. The definition of coding depends strongly on the opinion of the researcher (Saldaña, 2015). The coding approach facilitates the process of gaining insight from raw data (Richards and Morse, 2002).

Final results are presented in the form of a diagram generated by analysing the descriptive responses to the questionnaire.

7.2 Analysing the Responses

As stated in Chapter 4, 10 industry experts, each with a minimum of 15 years' of experience contributed to the qualitative part of this study. They were selected from three main disciplines: contractor, consultant and client. A summary of the participants' profiles is provide in Table 4.7. Key inclusion criteria are experience in delivery of marine construction projects and significant technical or management responsibilities.

The viewpoints of the experts in response to the open-ended questionnaire were evaluated, analysed and documented under two categories: delay and VE. The open-ended questionnaire is provided in Appendix 1. Themes and corresponding variables are discussed in Chapter 6.

7.3 Extracted Value Engineering Themes and Corresponding Variables

As discussed in Chapter 6, all VE variables identified during this research were grouped into four themes, listed in Section 6.7.4 as VE1–VE4. Participants in the open-ended questionnaire survey were asked to assess the correlation between themes and corresponding variables. They were also asked to comment on the core message of the grouped variables presented to them and add constructive suggestions, preferably in the form of examples, to the provided findings. There follows a discussion of the VE themes.

7.3.1 VE1. Integrating Statistics, Knowledge and Empirical Practices into Design Options

Theme VE1 incorporates eight variables. The central message of these eight variables is to benefit from all potentials during the initial design phase to minimise future errors and issues at later stages of the project.

Valuable feedback and viewpoints were received in regard to this theme. For example, most respondents recommended using up-to-date technology in marine construction projects. However, one suggested that:

> *Applicability and practicability need to be considered too.*

In other words, the availability of resources for using the latest technology can influence project progress and costs:

> *Latest technologies bring improvement and prevent some of the delays, but every up-to-date technology brings its own issues, which is not practised yet; therefore there could be another area for delay that will be defined after usage of the new technology. Hence, credibility should be assured.*

Using petrolatum tape for splash-zone of steel driven piles is an example of using latest technology.

Another factor influencing the use of the latest technology as highlighted by the respondents was, for example:

Budget at the time of the project implementation.

While examining the broader picture can be helpful to a project, the availability of financial resources was considered essential. For example, in marine construction projects,

Using a coating system for driven piles that lasts longer than normal coatings can help the completed project in different ways such as reducing maintenance time/cost and continuous operation of the enterprise with no interruption for maintenance. This can happen only if sufficient budget exists.

'*Potential errors in the latest technology such as computer software'* as another aspect mentioned by the experts. '*Simulation software'* was a particular example provided. Conversely, as emphasised in one of the responses, employing '*reliable computer software'* is of paramount importance, as it '*eliminates the errors at the initial stages of design*'. Examples of relevant responses are:

Temperature of the outlet water from a cooling tower when meeting the sea water can be estimated using computer software to conform with environmental legislation.

Earthquake simulation and considering the standards when the access bridge of the jetty meets the shore and assessing if either concrete structure or rubble-mound should be implemented.

In the view of another respondent:

Sincenew technology covers various facets of the project in depth, it can improve implementation and reduce mistakes and costs.

As another significant variable under the first theme, inclement weather conditions should be '*precisely monitored*' by using '*reliable sources*' in marine construction projects:

> *These types of projects are very sensitive to weather conditions, not just in terms of operation, but also in terms of safety/environmental risks.*
>
> *Preventive action plans are required, particularly for directly affected activities such as pile driving, coating and welding.*
>
> *Productivity of personnel and also quality of work are likely to be influenced by inclement weather conditions.*
>
> *An efficient plan, which can be referred to as risk management, is required to conduct safe works during inclement weather conditions.*
>
> *The cyclonic environment is a good example. Another important point to note is that Mother Nature sometimes plays differently and still needs to consider the unexpected events.*
>
> *Ultimately, using up-to-date weather forecasts helps to formulate more rational and practical scheduling.*

Considering previous studies on similar projects in the region was highly recommended in the responses under the first theme:

> *TQs, or technical queries, of previous or similar projects can improve accuracy and reliability of project design outcomes. However, in terms of a geotechnical study in a marine construction project, it should be noted that the assumptions apply only to exact similar situations.*

Previous studies on similar projects—'*subject to accessibility*' and '*especially at design stage*'—were suggested to definitely help if all previous projects were properly documented and organised, and thus could be used as '*valid references*':

> *For example, using previous experience in diagonal pile driving fixture design or cathodic protection design.*

Guidelines from similar projects were considered by participants to also '*prevent potential rework*', help in '*formulating more realistic and practical scheduling*' and provide a pathway for '*creative solutions*'. Reference to recorded experiences and previous studies was also referred to as '*knowledge management*':

> *It would be very valuable if challenges in previous similar projects could be documented and made available to contractors by clients.*

All respondents suggested that using experts in each major field such as scheduling, structural design, welding, coating, concrete and earth work can help create an efficient execution plan.

Participants suggested that contractor involvement can help but it is not easy to get all contractors involved in the early stages. It was proposed that '*main contractor involvement*' is more practical for the design stage, although this depends on the '*type of contract*':

> *In an [EPC] contract where you can have the construction contractor on your side, then their involvement helps to prevent practical issues but in the E+PC contract you can hire a contractor for that purpose but if the lead contractor in the future is different then they may raise different issues based on their experience.*

Overall, involving an experienced contractor '*before final approval*' of drawings was considered to '*help in foreseeing future potential issues in construction phase*'. Moreover:

> *It facilitates precise allocation of resource and accelerates the project's implementation with fewer possible errors.*

Additional recommended variables with the potential to be considered in the first VE-related theme were:

- regular site visits during the initial design stage to accommodate the design and site conditions
- considering national/local industrial, safety and environmental requirements of different stakeholders in projects such as government, national bodies and non-government organisations
- considering design risk management methods
- considering efficiency in material selection at the initial design stage.

In summary (Based on interpreting and summarising the responses), because of the multidisciplinary nature, complexity and vast spending on marine construction projects, it is important to evaluate them from various dimensions to avoid schedule overruns and consequent cost blowouts. All variables are correlated to prevent potential problems and mitigate the disruptive effect of uncertainty on marine construction projects. Efficient methods are required to identify and prevent/correct possible issues resulting from uncertainties. These preventive/corrective techniques can be applied through the use of various strategies. The inputs to feed them are variables such as findings from previous projects, expert expertise in various cases such as design and estimation, statistics and effective functional tested methods. What ameliorates the implementation of such strategies is utilising the latest applicable technologies to analyse and evaluate their functionality against current standards.

7.3.2 VE2. Geotechnical Assumptions

Theme VE2 contains two variables whose central message is the importance of assessing geotechnical conditions and the implementation of precise pilot studies to mitigate potential issues at later stages, in particular the construction phase. Participants' viewpoints are explained below.

The participants reported that both variables are highly correlated with their theme. It was noted by one that:

> *The allocating of funds for the purpose of initial studies at a construction site is importan, particularly if it is the prerequisite for an important task in the construction phase such as pile driving. For this reason, detailed studies of the geology of the project site are effective in terms of economics, efficiency and prevention of possible delays due to lack of knowledge of the project site.*

There led to the recommendation to:

> *Perform a field test at several points after completing geological studies and verify the accuracy of the assumptions. This is important because potential issues will be identified during the practice run, indicating that a more*

accurate study is needed.

Such an approach:

> *Can prevent unpredictable delays in the project and help the schedule and budget.*

Inadequate initial studies were considered to leads to delays in a project:

> *Delays could be the consequence of so many attempts and errors during the execution phase. As an example, some fabricated driven piles had to be truncated due to errors in penetration estimation.*

This is why test piles were highly recommended by participants:

> *Test piles before the actual construction are of great assistance in verifying the results of the geotechnical report. However, the verification can not be 100 percent, because the boreholes are not equal to the number of piles.*
>
> *Test piles driving records, static and dynamic load test results, and the resulting graphs will help in a precise design.*

One insightful recommendation was as follows:

> *Compile studies of previous designs in the region and prepare zoning drawings for basic design studies. It is very helpful, if possible, to use the experience of adjacent projects.*

Investigating the seabed for unexpected objects was also recommended by one respondent:

> *Unknown objects in the seabed may pose a risk to equipment and crew and may also interrupt the construction phase, resulting in time and cost overrun.*

The two aforementioned variables under geotechnical assumptions are correlated to mitigate uncertainties caused by environmental elements in marine construction projects. In line with the first theme, the second also refers to the effect of risks associated with uncertainties in marine construction and, in particular, deep foundations/piling and underwater operations. The allocation of appropriate funds is a requirement for the conduct of pilot studies and will help to ensure that the design is reliable. Although pilot studies support the precise design and efficient construction process, it should be noted that there will still be a degree of uncertainty based on unforeseeable circumstances. This was confirmed by several examples provided by respondents. The inconsistency between tender documents and actual circumstances is the most prominent risk factor in marine construction projects. This occurs when the client is hesitant to spend sufficient funds on pilot test beds at the initial design stage. Redesign, rework, waste of resources and schedule and budget overruns are potential implications of this unwillingness.

7.3.3 VE3. All-embracing Schedule (Work Breakdown, Resource Allocation and Inclement Weather Conditions)

This theme covers five variables. The perceptual message from these variables focuses on comprehensive planning at various levels with clearly specified and assessed resource management, activity breakdowns and how environmental conditions can impact these activities. Feedback received confirms the necessity of precise planning for the purpose of successful completion.

All participants mentioned the effectiveness of a detailed work breakdown system (WBS) in major marine construction projects:

> *The more detailed, the better. The presence of accurate work breakdowns is significant in planning, management of the workflow and above all, resource allocation, to meet the schedule.*

Failure to do so may impose:

> *Time overruns and also reduces the quality of work due to inappropriate resource allocation.*

It should be noted that:

> *There is a need for consistent monitoring of activities by the experts in this context to avoid any over/under resource allocation.*

This is because:

> *The allocation of human resources, financial resources, etc. would be different at each stage of the project.*

Moreover:

> *An accurate work breakdown prepared by an expert team is essential and can be of great help to the executive team in completing the activities on time with the predefined financial resources.*

It was underlined in all responses received that the specific characteristics and complexities of the marine environment demand:

> *A flexible timetable for interacting with unpredictable conditions imposed by weather-related issues and identifying potential activities that can and cannot be affected. This can also be considered in a risk matrix.*

Outsourcing mass production was considered popular in major construction projects:

> *Outsourcing centeralises the focuse of the project on the key tasks only if managed properly. Careful planning should, of course, be carried out in terms of time and location of this outsourcing so as not to disrupt the project process. Indeed, outsourcing comes with great promise of cost and time savings.*
>
> *The construction of prefabricated concrete parts in piers, bridges, etc. is proof of this claim, and as we know, in situ concreting requires spending the time required for proper curing.*
>
> *Selecting a capable contractor, on-time delivery and precise monitoring have been identified as determinant factors.*

One partially adverse view indicated that:

> *Outsourcing does not necessarily reduce costs, but saves time. The subject of quality control is also very critical.*

One additional recommendation was the preparation of a project risk matrix at the initial stages and the development of plan-ahead packages for potential issues.

In summary, participants emphasised the unique characteristics of marine projects and how these factors make them more susceptible to scheduling and resourcing problems. They observed that all five variables under the third VE-related theme are relevant to scheduling theories in marine construction projects. This highlights the importance of detailed planning and the use of in-depth scheduling strategies and resource allocation methodologies in marine projects, in particular taking into account environmental uncertainties in applied theories. In other words, it is important to ensure the applicability of planning strategies with regard to environmental uncertainties.

7.3.4 VE4. Process and Method Optimisation

The fourth theme in the area of VE protocols involves four variables whose message revolves around the need to evaluate all procedures and methods towards risk reduction and adding value to the project.

The majority of responses mentioned method optimisation as important for value enhancement, for example:

> *Investigating alternative methods has always been one of the common ways in value engineering to find a solution that ultimately reduces project time and cost.*

This should be done before proceeding to the implementation stage:

> *All different strategies must be discussed and the best ones must be nominated.*

This was noted as necessary for major marine construction projects:

> *The advantages have been reported at various levels of the organisations and different stages of the projects' lifecycle.*

Participants believed that:

Evaluating alternative resources may assist in maximising project value while maintaining cost effectiveness, quality and time.

Potential resources should ideally be accessible at all stages of work so that, in the case of any difficulties, access to other resources of the same desired quality is possible.

Another respondent noted that:

While certain resources may increase construction costs, they may reduce operational costs over the lifecycle of the project.

Every project has important activities that can impact the so-called critical paths in terms of time, cost and safety, and for which detailed planning must be conducted:

Predefined strategies are essential for the management of such tasks.

Specific activities require specific and predetermined solutions.

Highlighted in the responses were '*steel pile driving'* and '*massive box-girder' transportation* as specific tasks that require documented strategies:

Major tasks are considered high risk and need proper planning for completion.

It is evident from the responses that the cost and time effectiveness of predefined procedures for repetitive tasks and mass production was considered important by all participants, for example:

Success is guaranteed only if required resources (Including manpower, equipment and material), delivery frequency and approval procedures are considered and planned for.

Predefined procedures were considered to help to '*avoid time and cost overruns*'. Moreover:

They improve both efficiency and effectiveness and help to reduce some simple unnecessary schedule overruns.

As emphasised by one of the respondents:

Predefined procedures and specifications, auditing systems, etc. are integral components of every project. They should also be re-assessed from time to time on the basis of VE instructions to ensure practicality.

Participants did not recommend any additional variables for this theme.

The relationship between the four variables under the fourth VE-related theme can be summarised in a clear statement: to utilise various techniques/strategies to mitigate unnecessary costs, enhance the schedule and provide optimal value for the projects. This is called method or process optimisation.

Method optimisation should be considered at the early design stage or during strategic definition of a project. Key solutions need to be explored at this point to avoid unnecessary costs, time overruns and future maintenance-related expenses. This will significantly enhance the functionality and quality of the infrastructure over its entire lifecycle. Considering the complexity, high risk, environmental hazards, perilous working conditions and vast budget required by marine construction projects, method optimisation must be evaluated by experts with extensive experience in this particular field. Uncertainties also play an important role.

7.4 Delay-related Themes and Corresponding Variables

As explained in Chapter 6, all delay variables identified through this research were classified into 16 themes. They are presented in Table 6.33 as D1 to D16. Respondents to the open-ended questionnaire were asked to evaluate the association between themes and the corresponding variables. They were also asked to comment on the central message from the grouped variables represented to them and add constructive suggestions, preferably in the form of examples, to the provided findings. Below is a discussion of the delay themes.

7.4.1 D1. Client–Contractor Interruptions

Theme D.1 includes six variables. The core message of these variables focuses on various types of issues that can arise between client and contractor, such as each party's attitude, corruption, scope change and claim-related problems.

As stated in the responses, delays in land delivery are very common and originate from various factors such as environmental, economic and neighbourhood problems:

> *This leads the contractor to incur losses due to disruption in resource allocation and ongoing costs.*

Respondents indicated it is essential for the client to remove the obstacles to land delivery before the project begins:

> *Incomplete site delivery interrupts the contractor's schedule and should be compensated by the clients in a reasonable way.*

Deficient decision making at any level may have a significant effect on projects. In the most severe case, it leads to inefficiency in a defined construction project. Selecting '*experienced managers*' who are both '*familiar with the work scope*' and have a '*good managerial background*' is very helpful in resolving project problems and avoiding possible delays:

> *Commencing certain tasks without considering adequate resources is a good example of inappropriate decision making. It should be noted that this issue can occur with all categories of client, consultant and contractor.*

Most of the participants believe that delays in job delivery are more '*finance related* rather than being due to other factors such as '*technical capability*' of contractors. The problem of late completion typically emerges as a result of a '*client's payment sequences*'. Not least important and as highlighted by one of the respondents is the '*contractor selection model*' by which a client chooses the most appropriate contractor for a certain project. Another trigger for late job completion was said to originate from '*inadequate and unrealistic initial schedule*' and the impractical estimation of task duration.

The participants strongly agreed that inefficient information flow can cause potential problems and allegations. '*Documentation and the systematic flow of information*' is a significant factor in '*successful completion'*. One participant stated that:

> *Clients should allocate sufficient resources to conduct a precise study at the initial stages of the project to obtain the most reliable information and make it available to the contractors.*

This is necessary '*before commencing the implementation phase*'. One particular miscommunication was identified in relation to '*obstacles and concerns*' about projects that are not initially notified to the contractor by the client.

'*Enforcement for an early start*' and '*accelerating the design stage*' were agreed upon as the two most frequent reasons for scope changes imposed by clients. This leads to errors and redesign issues, affects the project schedule and usually causes time and cost overruns. A more '*efficient design team*' minimises the likelihood of scope change in the project. Every change has its own '*implications*', which is why '*change management*' is one of the core methods of project management.

Recommended by the participants were the four following additional variables:

- delay in on-time delivery of approved-for-construction drawings
- failure of the client to supply materials on time
- late approval of the WBS by the client, particularly in EPC projects
- unstable human resource management (frequent changes in key positions).

The underlying feature of all variables is the client's overriding role and how a client/owner can enhance project flow by introducing a cooperative organisational framework comprised of efficient cash flow management, information flow management and change management. Experts in key positions are required for the successful implementation of these management strategies. Lack of expertise in a client organisation was identified by the participants as a common concern. This is one problem the marine construction industry needs to address in the future.

7.4.2 D2. Inadequate Planning

The second delay-related theme includes five variables and underlines the importance of planning. In a construction project, planning refers to any required process that should be considered to identify and achieve the objectives of the project. Failure to plan properly leads to overruns in costs and time.

The respondents indicated that marine construction projects require careful consideration in resource allocation, especially in '*remote areas*' with '*logistical difficulties*'. '*Experts*' need to be involved in resource allocation to '*minimise interruptions in the project process*'. Lack of proper resource allocation was considered one of the key '*issues in project planning*'. For one of the respondents, this was the most important variable in the second delay-related theme.

Cooperation of '*qualified contractors*' in the '*early stages of design*' eliminates potential problems in subsequent phases. This was highlighted in several responses, including:

> *Contractors' experience can be defined as lessons learned.*

An alternative for a qualified contractor was suggested to be an expert with execution experience, also known as the '*execution–design interface*'.

The '*risk*' of possible problems in the '*supply of project materials*' such as cement, sand, reinforcement and the like, was said to require '*alternative sources*'. In other words, having '*plan B*' was considered a critical factor:

> *Alternatives should be of the same quality and widely accessible and, most importantly, verified by the client.*

Quality assurance was considered an '*inseparable*' component of major marine construction projects where quality is '*validated and documented*':

> *A clear example is performing slump and concrete performance tests to avoid negative consequences in the future.*

Quality validation '*confirms the appropriateness of the procedure'* and provides a pathway for '*rectification*' in the event of any issues. Overall, it '*prevents potential cost and time overruns*'.

Marine construction projects generally require a certain type of mass production such as piles, concrete pre-casts and box girders. '*Planning for mass production*' was thus considered by respondents as crucial, and may influence the critical path of the project. Thus, more pivotal than outsourcing or in-house mass production is '*on-time*' and '*on-budget*' delivery:

> *'As an example, installation can be commenced right after piling if prefabricated parts are ready'.*

The two additional variables listed below were recommended for inclusion by the participants:

- appropriate planning for timely procurement of materials and equipment to be provided from overseas, including customs and transportation
- appropriate expertise for effective planning.

The cause and effect relationship among the variables listed under the second delay-related theme provides insights from which a management plan can be formulated and successful completion of the project anticipated. This plan outlines the basis for the cooperation of the project team to follow the protocols and achieve the predefined objectives. The unique characteristics of marine construction projects require the allocation of adequate resources and the extensive expertise of a project team consisting of various disciplines.

7.4.3 D3. Safety Practices

The third delay-related theme is comprised of five variables. The central message of this theme is to take precautionary measures to avoid or mitigate risks to both personnel and equipment.

Reflecting the correlation coefficients reported in SEM, the importance of all variables in this theme was strongly verified and agreed by the respondents. They defined safety training as the '*legal responsibility*' of project stakeholders. They also provided some insightful comments in their responses as follows. Awareness of all personnel about the '*nature of the project*' and the '*possible risks*' is one of the requirements for each project. Many accidents are caused by '*lack of awareness*' by staff. Depending on the severity of an accident, the '*workflow can be affected*' and '*time overruns*' can be generated. Even a simple incident may put work on hold, which causes the project to be delayed:

> *A simple example of safety training is pre-start and toolbox meetings that can inform everyone about the safety aspects of the job and prevent incidents that delay the work.*

Marine construction projects are unique and thus the '*marine equipment*' used in these projects is indeed '*unique*' and '*distinct from other projects*':

> *The unique marine equipment is as critical as the experienced staff, as it is very difficult and even impossible to replace.*

In other words, marine project accidents are often '*more severe*' than onshore project accidents:

> *Heavy duty machinery is not easily replaceable. Replacement is time consuming and expensive. The safety problem of the crane in one of my projects had an effect on the schedule of around three months.*

'*Inspection procedures'* and '*periodic control measures'* are another important aspect of safety protocols. They '*prevent incidents and accidents'*, and lead to '*corrections'* and '*removal of defects and obstacles'*. Examples provided were '*checking the crane wire based on the operating hours'* and '*regular service'* of cranes, tug-boats and so on. Active and knowledgeable '*safety officers'* on job sites can help minimise risks.

Accidents during construction were believed by respondents to be very common:

> *They are inevitable, and damage of any kind disrupts the progress of the project.*

It is clearly stated in the *Health and Safety Act* that a fatality at any site will halt work at the site until a final investigation has been undertaken, which has an '*adverse effect*' on the project. '*Flexibility in planning*' and '*substitutions*' should be considered to keep the project operating, if permitted. Preventive actions such as the use of '*personal protective equipment*', '*professional operators with relevant certificates*' and so on, may prevent accidents and their negative consequences. Fewer accidents indicates that proper safety regulations have been implemented and the required training has been delivered. The parameter of '*accident record*', is one of the most important considerations when '*tendering*' and selecting a contractor. It is extremely important to verify certificates and the number of hours that people have worked without incident.

The participants recommended two additional variables:

- application of global and valid safety standards in each project
- checking of contractor eligibility in terms of safety at the tendering stage.

All variables in this theme concentrate on knowledge of safety within the framework of the project. In other words, the nature of the project and the potential risks within the project environment should be communicated to the project team. This can be achieved through safety training and would benefit from lessons learned in previous projects to promote the learning process. The focus of all variables is on a proactive rather than a reactive approach. Considering the complexity, dynamics, uncertainties and specific resources employed in marine construction, the effects of accidents may be catastrophic. Moreover, unpredictable weather conditions can have an impact on the resource-replacement process. This is why it is advisable to be proactive. Inspection procedures and periodic control measures are examples of proactive mechanisms.

7.4.4 D4. Instructions/Communications

The fourth delay-related theme consists of six variables and focuses on the detrimental effects of inappropriate interactions or instructions. Enforced by any discipline and originating from any source, improper instructions might affect the workflow of a project. For example, instructions developed from an inefficient design can have a negative impact on the schedule and expense of a project. As identified by the respondents, all included variables are highly associated with this theme.

Formal means of communication in projects are defined by '*project instructions*'. Any lack of or inadequate instruction has negative consequences for a project:

> *QA/QC procedures strongly rely on proper instructions.*

Overall, not only can issuing incorrect instructions have subsequent effects and consequences; it can also have a direct impact on time and cost. All respondents agreed with the negative impacts of instructions developed from '*unreliable estimates*'. This may '*cause massive delays*' during project execution. It is very important to have a '*realistic estimate*', which can be the basis for preparing the schedule and defining the required budget.

It was acknowledged by the experts that '*inaccurate information*' provided to contractors contributes to the '*redesign*', '*rework*' and thus '*overrun time and expense*'. A good example provided was '*geotechnical assumptions*' in piling activities of marine construction projects. In fact, it was considered '*very common in marine construction projects*' that '*poor geotechnical report*' leads to many '*changes*'.

With regard to the leading role of the consultant and the instructions given, it was seen as important for the consultant to have '*thorough knowledge of the job requirements*'. This is to '*ensure accurate and effective execution*'. An experienced consultant may assist the contractor in carrying out the work and '*reduce both the time*' of implementation and the '*cost*' of the project. This does not lessen the '*obligation of the contractor*' to conduct the job correctly, '*on schedule and on budget*'.

One key factor that '*always affects*' communications in a project was seen as '*cultural diversity*'. '*Experienced management*' that is familiar with '*cultural and social differences*' and can communicate well within this environment is very important in the project implementation process:

> *Human resource management also facilitates communications and interactions in this context.*

All variables under this theme are interrelated and illustrate the importance of well-developed instructions and communications for successful completion of a project. If not properly addressed, issues can occur at any stage. For example, an inefficient design that might be the result of inaccuracy in the initial phase of estimation will affect subsequent activities. Improper site instructions and discrepancies between tender documents and actual project circumstances are two examples indicating the implications of design inefficiency. It is also important to consider cultural diversity in remote areas where the majority of marine construction projects are implemented. This will facilitate communication to ensure proper implementation of instructions, and enhance teamwork and project collaboration.

7.4.5 D5. Management Approaches

This concept involves six variables that relate to the use of the best management approach to tackling various challenges and interacting with different disciplines.

Lack of effective cooperation among parties was identified as one implication of mismanagement:

> *This causes conflict and tension, poor collaboration and failure to address stakeholders' expectations—on-time completion in particular.*
>
> *This would be exacerbated, in particular, where the responsibilities, authorities and means of communication are not clearly established.*
>
> *Consistent collaboration between multidisciplinary stakeholders, such as the contractor, consultant and client, and the exchange of accurate and relevant information between them will indeed improve the productivity of the project.*
>
> *Cooperative collaboration between the parties avoids time and cost overruns in a project.*

Respondents identified that management inefficiency can be found in a number of disciplines, such as contract management:

> *An inappropriate contract impacts the project as much as an incompetent contractor. The reason for this is that a proper contract and its relevant clauses prohibits the imposition of costs on the project and are also effective in on-time completion.*
>
> *Ambiguities within the terms of the contract can lead to conflicts between the parties, and open the gateway to a claim by the contractor.*
>
> *Claim-related issues should then be rectified by the claims management department.*

Some contracts are standard and need to be amended for specific projects, even though they are similar.

The management team was also considered responsible for development and implementation of the most practicable construction strategy:

This part of the work should be coordinated by experts who have a deep and thorough knowledge of the project.

Without the implementation of an efficient strategy for construction and execution processes by an effective team, the desired results can never be achieved.

The construction strategy is considered the basis for determining the time and resources needed. Its practicality assists in delay mitigation/prevention.

Unstable management can lead to severe losses, particularly for contractors, when it comes to unique projects like marine construction:

It may be the product of hiring a manager with insufficient/irrelevant project experience… or … successive changes of key personnel in the project.

In the event of a necessary change in the management structure, all risks involved should be addressed in advance to minimise the possibility of negative impacts, time and budget overrun in particular.

Professional construction management is necessary to deliver a technically and financially viable project and coordinate efficiently among multiple disciplines:

An important factor in this context is adequate awareness of scope-related issues and how to deal with them, which ensures that the project stays on schedule and within budget.

Having an efficient construction management team can resolve unpredictable challenges that might arise before and during the construction phase and facilitate the implementation process.

Performance can be overlooked in the absence of effective construction management.

Additional variables recommended by the respondents were:

- failure to choose a suitable contractor based on the scope of the work, resulting from the form and process of bidding
- delay in resolving internal or external issues raised by client representatives
- involvement of client representatives in more than one project and lack of their full focus on one particular project.

One consistent factor among all variables is the importance of a functional/practical management system to establish policies, strategies, responsibilities and authorities within the project scope. This definitely improves the technical and financial efficiency of the project. For example, an inappropriate contract enforced by the client's contract management department may create conflict and challenges in the contractor's construction management strategy. Issues with a contract can include over-optimistic scheduling, under-allocation of budget and inappropriate instructions. In addition, as all the variables apply to risk management, claims management and contract management, all such cases must be reviewed and validated prior to the implementation phase.

7.4.6 D6. Design and Construction Issues

This theme covers six variables and outlines issues such as unskilled personnel and inaccurate assumptions at various phases of the project. It also reveals the detrimental effect of errors at the initial stage of the design that directly affect the construction process.

Considering the unique attributes and high complexity of marine construction projects, it is critical to have skilled personnel involved. As agreed by all participants, human resource management plays a major role here:

> *Using experienced staff can reduce the final costs as well as the project completion period and improve the quality of work.*
>
> *Rework is a predictable consequence of a novice project team.*
>
> *Human resource management is the discipline that must address this issue and ensure that qualified staff are appointed to critical roles.*

Irrespective of the discipline, insufficient knowledge and experience affects a project:

> *For example, the consultant can be considered the technical and professional interpreter between the client and the contractor. So, if this interpreter is not competent, it would certainly cause slowdowns and additional work problems. Choosing a consultant with ample expertise and high technical and engineering knowledge is therefore successful in the progress of the project and its development.*
>
> *Insufficient technical knowledge of the consultant creates conflict and slows the workflow (e.g. job permits, approval processes, safety standards and regulations).*
>
> *The practical knowledge of the designer/consultant contributes to practicality in design. This highlights the identification of an appropriate consultant as one of the primary considerations for a project.*

Any issue that emerges from design team dysfunction escalates to other levels and leads to rework and time loss. Participants agreed on the importance of this factor in the majority of marine construction projects in Iran as it causes delays and financial losses in various projects.

The design assumptions should be derived from reliable pilot studies to prevent potential issues in other stages, in particular construction:

> *Most clients are reluctant to perform pilot studies due to the extreme costs, which is not a prudent strategy. It effectively reduces costs as well as time for project implementation. Given the cost of these experiments, the best way to do it is to carry out a variety of pilot tests on very specific parts that are, in reality, vital to the project.*
>
> *Preliminary studies are the foundation of each project and all other stages are based upon that.*
>
> *In fact, this is due to the consultant 's lack of knowledge about the scope of the project. Failure to know the minimum standards and regulations could lead to significant errors in implementation.*
>
> *A few other factors that lead to the inability to perform proper pilot studies*

are an early start enforced by the client, financial issues of the client and the assumption that the project requirements are the same as a previous project.

Impractical design often creates problems in the construction process. This results in redesign, rework and schedule overrun:

> *It is very important that the designer has adequate and thorough knowledge of the project site as well as the philosophy and nature of the project. Otherwise, the output drawings would be an exception that has little to do with the objectives of the project, which can lead to catastrophe.*
>
> *A good example of impractical design is a very dense reinforcement mesh that causes problems with concreting and the final quality of the work.*
>
> *Unless the design is practical, the schedule will be delayed.*

Another design-related issue that can impact projects is unforeseen geotechnical problems. This often affects the construction process and may lead to redesign, depending on the severity of the problem:

> *A number of tests specified by the standards are required to resolve/minimise this type of issue. Consequently, in this context—which is the basis of designs and calculations and, ultimately, the preparation and submission of comprehensive executive plans—there can be no negligence. All required tests should be carried out.*

Additional variables recommended by the participants were:

- preparing shop drawings and 3D models and locating potential defects before issuing the drawings
- failing to determine the exact quantity of goods required in the list provided to the project procurement department by the engineering department
- inappropriate work procedures
- incorrect extrapolation of design assumptions from similar projects to existing ones.

All variables related to design and construction problems are interrelated. The central message is the importance of reliable assumptions, and practical and theoretical expertise of professionals from various disciplines; in particular, consultants and contractors. Potential issues arising from one factor could escalate to the next. Inaccuracy in design assumptions, for example, leads to impractical design and ultimately problems in project processes, including redesign, rework and scheduling overruns. An effective and qualified design team contributes to the functionality of the design. Another major factor that also contributes to inappropriate preliminary studies is a lack of client-side expertise and early start enforcement. This is the consequence of the lack of a thorough understanding about the scope and nature of the project. The final product thus deviates from the predefined schedule and budget.

7.4.7 D7. Organisational Structure

Seven variables are listed under this theme. Organisational structure is a framework that describes how certain tasks are oriented towards achieving an organisation's objectives. This include regulations, responsibilities and different departments within the organisation. The framework also regulates the information stream within the organisation.

Participants identified a strong association between the variables and their theme. One key factor firmly agreed by the respondents was the need to keep the organisation's structure up to date in terms of emerging technologies and the latest innovations:

> *The world around us is rapidly evolving, and the change involves improvement in all aspects of work and life. In order not to lag behind, subject to efficiency approval, it is important to incorporate these changes to our system. Otherwise, the organisation's efficiency will be very poor and incapable of competing with similar organisations.*
>
> *Outdated technology impacts the performance of the organisation. Examples include human error, inability to compete with other companies and delay in the completion of the project.*
>
> *The use of up-to-date technology in all areas of the project is imperative.*
>
> *Old technologies cannot compete with new ones, especially within marine construction environment, with high-end equiupment and day-to-day*

development.

The efficacy of VE has been verified by the majority of scholars. Employing this approach in an enterprise reduces costs, improves quality and saves time by offering alternative solutions:

> *In general, value engineering would be very successful if carried out by experts who know the definition and complexity of the project. It is not right to actually eliminate any of the work to minimise costs.*
>
> *Many organisations within marine construction environment have no idea how critical VE is.*
>
> *The long-term benefits of VE justify the initial upfront cost.*

Failure to consider appropriate channels of communication within the organisation causes disputes and conflicts, poor cooperation and failure to meet stakeholder requirements; in particular on-time completion:

> *To avoid any conflict, an organisational chart is required for the project. In fact, the means of communication needs to be defined and staff should be familiar with their job requirements.*
>
> *Communication is a significant concept in the project management knowledge literature. Inappropriate communication leads to time overrun.*

There is a strong need for adequate coordination in the multidisciplinary marine construction environment. Projects are unlikely to meet their predefined time and cost expectations unless the disciplines are well coordinated:

> *The organisation should make arrangements to ensure that such coordination is complete and uninterrupted and that any contradictions are prevented.*
>
> *For example in the design phase, coordination between different engineering groups, such as geotechnical engineering, civil, mechanic, safety, etc. is vital.*
>
> *Integrated management systems can be useful.*

The reliability of the contractor’s organisational structure plays a significant role in successful completion of the project:

As an example, an efficient on-site management structure reduces costs dramatically, avoids rework and enhances the schedule.

A reliable monitoring and controlling system within the contractor’s organisation is essential.

There is no doubt that site supervision improves efficiency and reduces the risk of rework. Control is a common method to prevent rework that leads to schedule overrun.

As agreed in all responses, responsibilities should be defined in the organisational structure and all stakeholders should adhere to their responsibilities to achieve project objectives:

Selecting dedicated and diligent people who are fimiliar with their responsibilities is highly effective in project success.

Having an organisational chart and a clear job description for each individual avoids ambiguity and confusion between staff.

Another area of project management is stakeholder management, to ensure that they are in line with the objectives of the project. Stakeholders must be responsible for the work that they intend to carry out.

Organisations will benefit from lessons learned and recorded documents in advancing their structure. Well-structured and organisation-wide documentation and databases promote efficient design and provide valuable guidance:

Having a decent archive and history of similar projects is very effective in the design and implementation phases, and reduces potential costs and accelerates the project.

It is like a cheap but the most efficient group of high-skilled employees that a company can hire.

Lessons learned from similar projects develop organisational expertise that can contribute to successful design in the future.

Additional variables recommended were:

- identifying and communicating the organisational chart in the head office as well as at the construction site
- project coordination procedures.

Related to these variables is a focus on collaboration and group interactions within an appropriate/up-to-date organisational framework aimed at enhancing the workflow of the project. Communications can be enhanced and tasks can be delegated through an effective organisational framework. The outcome will be a platform on which policies, procedures and protocols are based. In addition, an effective organisational framework facilitates a pathway by which new ideas can be communicated and developed through ideas generation mechanisms such as VE workshops. The latest technologies and methods, such as Building Information Modelling, can be used to improve interactions among various disciplines and achieve superior results in VE processes within a specific scope of work.

7.4.8 D8. Political/Cultural Factors

There are two variables mentioned under the eighth theme. The contribution of both to the achievement of intended objectives was strongly validated by the respondents. Political factors are, by definition, imposed by a government on the economy or on certain sectors, while cultural factors are environmental factors requiring complex strategies:

> *Both political and cultural factors can trigger a late start and disrupt the project at various stages.*
>
> *Political problems, such as sanctions, do have a massive impact on progress and can lead to significant delays and even termination of the project.*
>
> *Both factors are defined as a external risks and should be managed appropriately using risk management strategies.*

In one example provided by a participant from Iran:

> *difficulty in the importation of materials due to sanctions/political issues put*

a three-year pause on the project.

This was supported by another respondent:

multiple projects have been put on hold due to current sanctions in Iran.

Two additional factors were identified by the respondents that could be classified as political factors:

- lack of investment by private sector and foreign firms due to lack of political and economic stability in the country
- inability to interact with international banking authorities and use the payment mechanism known as an LC (letter of credit).

Regardless of from where they emerge, both political and cultural factors have an influence on a project's flow. They can force time overruns or the termination of projects. In addition, they can influence contractual agreements; in particular, in international projects where the investor is a foreign corporation or international banking authority. Unstable economic conditions triggered by political problems such as sanctions also exacerbate investment issues. Dispute resolution techniques need to be integrated into risk management policies in regions where political/cultural considerations are likely to have a strong effect on projects. Given that marine construction projects are highly dependent on the latest technology, high-end equipment and unique resources, political/cultural considerations that might restrict access to these items will be implemented differently from other types of projects and the consequences may be more severe.

7.4.9 D9. Environmental Uncertainty

Theme number nine contains four variables and refers to unpredictable factors influencing projects in the uncertain and complex marine environment.

All participants agreed about the severe impact of weather uncertainty on marine construction activities and suggested that marine construction projects should be placed into their own category when it comes to weather considerations. There is a risk that the whole project will become inoperable in the event of significant weather-related issues:

> *Weather conditions are one of the most essential elements to be considered when scheduling. Weather uncertainty disrupts the project cycle, leads to major delays and contributes to budget overruns.*
>
> *Using advanced weather prediction technology minimises errors and leads to accurate scheduling.*

High and low tides, as an additional uncertainty factor, can affect certain operations and should therefore be thought about at the planning stage of marine construction:

> *The analysis and evaluation of tidal conditions is crucial in marine construction projects. Important activities of the project, such as piling and installation of components/pre-casts, may be impacted by tidal conditions.*
>
> *Tidal waves are the main environmental concerns of marine construction projects, especially for those companies who cannot afford high-tech equipment. It is therefore important to prepare properly to deal with this phenomenon.*
>
> *By using high-end marine equipment such as a jack-up barge instead of a normal barge, tidal waves can have less influence on certain activities.*

As reported by the respondents, geotechnical assumptions are a common area of ambiguity in marine projects. Unreliable assumptions disrupt project development and can, depending on the severity, lead to the requirement for redesign:

> *Geological studies are generally carried out on the basis of the significance and form of project. The key factor is that the number of required tests should be carried out based on the standards. This should not be ignored, as this has rather high time and expense implications. Compensatory strategies should be considered in the case of unexpected issues.*
>
> *It is also recommended that qualified companies be used as a joint consultant along with the project consultant in the geotechnical department.*
>
> *The role of the design team in assessing and ensuring the reliability of the assumptions is critical.*
>
> *It is a common issue in marine construction piling activities that the designed*

piles in some areas cannot be driven to full length as a result of incorrect geotechnical assumptions. There is cost and time involved in truncating these piles to the cut-off level.

All variables under the uncertainty theme challenge scheduling theories in marine construction projects. If not correctly predicted or prevented, the project cycle can be interrupted, leading to significant delays and budget overruns. All issues arising from uncertainties in the dynamic marine environment can be addressed to a certain extent using advanced technologies and adopting up-to-date standards.

There is also an association between environmental factors discussed under the topic of uncertainty and the use of advanced technology explained in previous themes. This is consistent with the advantage of high-tech methods to mitigate the detrimental effects of uncertainties in marine construction projects.

7.4.10 D10. Extreme and Complex Resources

This theme includes five variables whose core message is to highlight the uniqueness of marine construction projects and how this relates to the diverse types of resource required for successful completion. Due to their dynamic nature and unique characteristics, marine projects require sophisticated technology and complex resources, different from land-based projects. This may include human resources, machinery and material:

Due to the unique nature of marine projects compared with similar on-land projects, personnel in different disciplines need to be highly experienced and knowledgeable. Unfamiliarity, in addition to damage and risks, slows down the project and causes cost overruns.

Lack of experienced operators for high-end equipment in marine projects may result in accidents during the construction process. Heavy-duty crane operators are a good example.

Skill shortage is a big issue in major marine construction projects.

The risks involved and the skills required in marine works are very different from those associated with on-land projects.

A qualified contractor as a valuable resource is essential for the achievement of project objectives:

To avoid time and cost overuns, as well as potential accidents and risks, the use of a qualified contractor is essential.

A contractor with qualified and specialised staff and appropriate machinery will complete any project and meet predefined quality, cost and time benchmarks.

The lack of an effective contractor/supplier management strategy could potentially turn a good contractor into a problematic one. Contractor management involves initial assessment, selection and recruitment, ongoing monitoring and evaluation and, ultimately, completion.

Due to the complexity and uniqueness of the required resources, they are not easily accessible and should be planned well in advance:

The resources needed for marine projects are mainly equipment and executive machinery, which must be included in the mobilisation as well as the schedule from the outset. Highly critical and strategic purchases should also be included in the schedule; and the prerequisites, mainly budget, should be specified. Lack of proper planning delays the implementation phase.

Efficient and effective preparation is needed to ensure that resources, both internal and external, are made available where and when necessary. This reduces the possibility of over-allocation or under-allocation.

Since most marine projects are located in remote areas, the allocation of resources is paramount.

Transport, assembly and disassembly of heavy duty equipment in marine projects should be considered when scheduling.

In terms of human resources in the multidisciplinary marine environment, efficiency is of considerable importance. It ultimately benefits the schedule and can be enhanced by training programs.

Additional variables recommended by the participants were:

- lack of an efficient resource management approach
- pressure to use a limited list of contractors/suppliers endorsed by the client.

Variables in the 10th delay-related theme underscore the disparity between marine and land-based construction projects in terms of resources and how they can be handled differently. These resources may include human, equipment and material resources. Because of the uniqueness of each of these elements, failure to consider them in the initial planning stages results in a deviation from predefined objectives. It should also be noted that the unique attributes of these resources constrains their substitution and availability. Weather considerations may intensify this. This again questions the theory of scheduling in marine construction projects and the degree to which a schedule must be in depth. Training programs and an effective approach to resource management will indeed help mitigate issues.

7.4.11 D11. Activity Estimation Errors

Activity estimation errors as the 11th underlying theme includes five variables and highlights the importance of accurate estimation. The main consequence of inaccuracy in estimation is failure of the schedule. Scheduling theory requires in-depth attention to avoid future complications at different stages of projects; time overrun in particular. All participants agreed that there is a high correlation between the variables and the underlying theme.

Scheduling should be based on what can be reasonably accomplished within the allotted time. An unrealistic work schedule affects the sequence of activities and generates time overruns:

> *The more precise and reliable the schedule is, the more effective and efficient it is for on-time completion. An unrealistic schedule may contribute to waste of resources.*
>
> *Actual situations and uncertainties need to be considered in scheduling.*

Expecting an impractical completion time for projects is another failure in estimation processes. This could raise the risk of construction phase errors and accidents:

Unrealistic scheduling enforced by the client could increase incidents and the potential for financial loss and personal injury. Precise and practicable scheduling to prevent such cases is therefore important and useful.

Marine projects need a supportive environment. The risk of pushing or tight schedules is so harmful. These projects are in need of a legitimate schedule with proper links.

There is a strong chance of inaccuracy in imposed schedules with the potential to delay on-time completion.

Inaccurate estimation of task durations affects the sequence of activities, changes the critical path in the schedule and generates time overruns in the phase of operation:

An inappropriate schedule forces higher costs and delays on the project. Only a precise schedule leads to defining the appropriate critical path.

This is more common in public projects where people are less skilled and capable than in private projects.

Activities affecting the critical path of the schedule should be monitored at all stages. Deviation from the critical path is the main cause of project delays.

Nonetheless, uncertainties and the complexity of marine construction in certain cases requires a degree of flexibility in scheduling; for example, in relation to pile driving and logistical support. This helps with the project schedule and can compensate for lost time in certain situations:

A flexible schedule for such projects is quite useful and helps in on-time completion. Of course, this flexibility should not override the project schedule.

It is particularly related to planners' skills and the reasonable breakdown of activities.

Flexibility in the schedule is crucial for marine construction projects.

Uncertainties in the marine environment exacerbate estimation errors. This is by far the most common factor triggering scheduling inaccuracy. Over/under-allocation of the valuable resources in marine construction is the product of initial estimation errors. An all-embracing schedule based on realistic estimates/assumptions and in-depth consideration of work scope requirements leads to successful completion.

7.4.12 D12. Owner's Stagnant Structure

This theme involves four variables whose central message is how owners can influence the dynamics of projects. Am owner's attitude will affect the efficiency of the project: it can either accelerate or slow down the workflow. This was agreed by all participants.

An owner's effective cooperation in the project helps to meet schedule and budget objectives. This cooperation can be achieved in a variety of ways. For example, the owner/client may motivate the contractor by offering certain financial incentives for on-time completion, which would benefit both the contractor and the client:

> *Contract agreements and their general conditions are clear and fixed. The provisions of the general terms of the contract allow for early finish and related financial benefits. Specific terms endorsed by the client/owner, under which particular financial incentives are offered, may also be used to assist with on-time delivery. It should be noted that minimum achievable completion time should be estimated by the experts so that quality is not compromised for an early finish. In certain cases, it has been observed that to earn financial incentives, the required quality and safety have been ignored and, unfortunately, casualties and damages have occurred.*
>
> *Considering incentives for contractors inspires them to finish the job ahead of schedule. It is also crucial to meet the technical requirements of the project.*
>
> *While finishing earlier than schedule provides cost savings for contractors, incentives encourage them take this more seriously.*
>
> *The form of contract is very important to make owners more accountable.*
>
> *An owner/client can be referred to as the end user here.*

A client/owner should be involved in the initial design process of the project. This prevents potential issues such as scope change and redesign, which directly affect the project schedule:

> *The design and the way in which the design consultant works is based on the requirements and the information provided by the client. In the event of failure to provide/properly deliver the information, the resulting output would not be advantageous to the project. This will have an impact on scheduling, resource allocation and contractor selection, all of which contribute to the overrun of time and costs.*
>
> *The client/end user, as the owner of the project, must have the necessary and sufficient cooperation with the design team to meet their requirements, to avoid rework/redesign.*
>
> *Regular meetings with the design team in the initial stages and discussing the expectations will eliminate future issues.*

Another aspect that may slow down projects at different stages, and that is imposed by the client, is unnecessary bureaucracy on the client side:

> *It is more common in project approvals and impedes project progress and delays on-time completion.*
>
> *Intense bureaucracy in any organisation will waste resources and time in advancing the project. The less this happens, the less detrimental it is to the success of the project.*
>
> *Bureaucracy depends on a variety of subjects, such as the client's culture (internal and external), project charter, stakeholders, etc.*
>
> *Having milestones in the work breakdown system of the project may help accelerate approval processes.*
>
> *Bureaucracy does not exist in an efficient system. At the beginning of each project, a coordination protocol should be developed to avoid any bureaucracy. All in it is meant to be clear.*

Additional variables recommended by participants were:

- involvement of client representatives in multiple projects and lack of appropriate focus on one project

- delay in land delivery imposed by the client
- major changes in the client's team
- lack of appropriate consideration of end user requirements
- unnecessary interference in technical cases by end users.

What connects the variables under this theme is the role of the owner/client in advancing the objectives of the project. An owner can influence the dynamics of marine construction projects through a variety of mechanisms. These include financial benefits, involvement in early design phases and clarification of expectations in the initial phases. This can be accomplished by a suitable form of contract; that is, one that demands the commitment of the owner to collaborate over the entire project cycle. This will reduce the chances of scope change. A robust organisational structure of a client firm eliminates the adverse effects of bureaucracy and encourages the flow of the project.

7.4.13 D13. Financial Issues

Financial issues in marine construction projects form the 13th theme of this study, which contains four variables. The central message, agreed upon by the participants, highlights fund-related issues and their universality in marine construction projects. They originate from various sources, including late payments, unpredictable financial markets and insufficient financing.

Owners/clients must predict and fulfil the cash flow requirements of their project if they are to succeed. Poor financial management tends to cause disruption and thus, delays in projects. This was agreed by all participants:

> *Project funding on the basis of actual requirements as well as reliable initial estimates and appropriate cash flow guarantees workflow and eliminates potential schedule overruns resulting from finance-related issues.*
>
> *Financial resources and how to allocate them should be considered in the initial stages of the project establishment.*
>
> *Cash flow is the cornerstone of a schedule.*

In light of the huge budgets in marine construction projects, the financial background of contractors plays an important role in the performance of projects and the achievement of predefined targets:

Financial capability influences both project workflow and staff productivity. Owing to the multiplicity of projects, some contractors prefer to use the predefined budget of other projects when there is a deficit in a particular project. This could slow down one project and be helpful to the other. Effective cash flow control reduces these issues.

This item is one of the most common issues in marine construction projects.

Proper financial evaluation by suppliers and contractors at the initial stage is important.

Another important finance-related factor that may influence projects is instability of prices. Price escalation is triggered by market instability and causes projects to deviate from the predefined budget and schedule. Further, fluctuation in prices disrupts cash flow control and creates economic challenges for stakeholders. Depending on the magnitude, both may interrupt or fully stop the project:

The client/owner should anticipate and manage these issues and provide the contractor with assistance in the event of a huge loss.

In case of price-related issues, the client/owner should take action by supporting the contractor by paying part of the procurement costs in the form of an invoice and preventing potential delays and interruptions in the workflow.

Countries affected by sanctions and experiencing intense fluctuations are a clear example of this.

Another example is countries with an unstable economy.

The parity rate should be foreseen for international projects where the payment currency is different from the one defined in the budget and impacts purchases.

Price fluctuations create problems if the budget defined does not accommodate current fluctuations.

In 2008, the steel price jumped drastically and affected the delivery of many projects. Clients supported contractors by allocating additional budget for the delivery of projects.

Additional variables identified by the respondents were:

- delay in reviewing finance-related items claimed by the contractor
- financial issues and staff productivity
- client failure in budget allocation due to insufficient knowledge of project scope.

It was observed that all variables under the financial issues theme are highly correlated. For example, an unstable financial market—referred to as price escalation/fluctuation in this study—will indeed have an impact on the financial soundness of both the contractor and the client, leading to schedule overrun. This highlights the role of clients in alleviating the impact of financial difficulties by adopting proactive cash flow management. However, financial issues for the contractor and the client disciplines seem to be interrelated. Unstable financial structure of a contractor leads to late completion and consequent failure to make revenue from the delayed enterprise for clients. Similarly, the client's failure to meet cash flow criteria forces inflation, delayed resources and cost overruns on contractors.

7.4.14 D14. Delay in Approval Processes

Theme 14 contains four variables and focuses on deterrent factors in facilitating approval processes that can impact a project’s workflow. The approvals process specifies the protocols to be followed for a completed task to be approved. It should be straightforward and functional so that workflow is not disrupted or stopped. According to the respondents, the variables are reasonably correlated to the theme.

Schedule overrun caused by late approval is very common, as indicated by all of the participants in this study. It can arise for various reasons, including delay in the approval of tasks, approval of test results and approval of documents/drawings. In general, any delayed approval caused by either the client or the consultant can interrupt activity sequences. This can also stop the workflow in projects, particularly if the task is located on a critical path of the schedule. The following views were expressed by participants in regard to approval processes:

> *To avoid interruption in implementation sequences, flexibility is required in the schedule for the tasks to be subject to approval processes. This prevents time overrun if these tasks are located in a critical path of the schedule. As an example, in marine construction, coating is subject to welding result approval in the pile preparation process.*
>
> *Delay in reporting test results, such as the welding test, the concrete compressive strength test and similar cases, will cause a delay in activity sequences.*
>
> *One solution may be to stipulate the time required for the processing of documents in the contract agreement.*
>
> *As long as an approval is not granted to the contractor, no activity can be initiated. This approval may be for a drawing or even a basic work order.*
>
> *Failure to define proper forms of communication is a common cause of late work approvals.*
>
> *Having milestones in the project's work breakdown system may speed up approval processes.*

The lack of proper cooperation between the three main disciplines of client, consultant and contractor was suggested by respondents as an additional variable that may lead to delayed approval.

Variables under this theme are associated to some extent. A late work approval can be the consequence of a delay in test result approval, document/drawing approval or shop drawing approval. However, test results may have an effect on the shop drawing preparation, in which case there is a need for modification/alteration of the drawings on the basis of the results. Delayed results can affect the preparation of the shop drawing. Similarly, late document/drawing approval affects shop drawing preparation and interrupts the workflow of the project. Moreover, delayed shop drawings lead to late test result approval when there is a need for additional tests based on the new specification.

7.4.15 D15. Construction Strategies

Two variables are listed under construction strategies as the 15th theme in this study. Construction strategies are mechanisms by which the construction process commences, is monitored and managed. The central message of this theme is the importance of using appropriate methods for major marine construction activities and the effectiveness of an accurate work breakdown to achieve the project objectives.

As agreed by the respondents, predefined strategies should be in place for some major operations, such as heavy lifting and underwater concreting, which minimise the risk of potential errors in the construction process:

> *Since major operations require a large amount of project resources and time, it is vital to develop strategies that are specific to them.*
>
> *Appropriate strategies directly impact quality and eliminate rework. Of course, it is critical that these methods of implementation are developed by qualified people and suitable for the type of work and the actual project requirements; otherwise there will be side issues.*
>
> *Poor implementation strategies mean uncertainty and low-quality work, especially in marine work where there are time constraints. Selecting a reputable contractor experienced in similar projects minimises this risk.*
>
> *A safe-work method statement reduces risks by proposing proper methods to prevent any risk associated with the activities.*

Further, the work breakdown, which determines the steps of the implementation process, should be precise and unique to the nature and requirements of the project, particularly in marine construction:

> *The breakdown of work must correspond to the operational and cost realities of the project in such a way that the outputs generated from it are accurate. Resource allocations should also be based on the approved work breakdown.*
>
> *A well-defined WBS is required for project deliverables.*

In the view of one respondent, the WBS is related to project planning strategies and procedures.

According to a general statement made by one participant, the contractor is responsible for preparing the execution methods, working procedures, circulation of documents, and specification and inspections procedures. Failure to take these steps will lead to errors, delays and damage to the project.

Recommended in one of the responses was the use of local suppliers/contractors in accordance with the scope/specifications of the projects. This may help in terms of accessibility, cost and better quality control.

With regard to the relationship between variables, it should be noted that the identification of major tasks in the project assists in the development of a more accurate work breakdown and contributes to effective resource allocation and execution procedures. This is important in marine construction projects. In addition, an accurate WBS results in an efficient risk breakdown system and helps in project risk management. It facilitates the process of implementing major activities and sets out a plan-ahead strategy in case potential risks become actual.

7.4.16 D16. Marine Equipment

The last delay-related theme includes two variables and mainly focuses on marine equipment and skills shortages for high-end marine machinery.

Marine equipment should be selected in accordance with the specifications of the project. Use of unresponsive marine equipment can result in accidents and time loss. A clear example is overloading a crane rather than hiring a heavy duty crane to reduce project costs:

> *A common reason for contractors not to use up-to-date/new equipment is the low budget allocated to the project in the tendering process. This makes them reluctant to use the appropriate machinery, so they can maximise their profits. Precise estimates of the budget at the initial stage and the selection of a qualified contractor eliminates the issue.*

For example, having a barge, tug-boat or pile driving machine suitable for the project scope and specifications is crucial.

The list of project machinery is one of the key components of the initial evaluations of contractors. If the wrong equipment is chosen, this will cause both delays and a claim by the contractor.

Further, the lack of trained operators for high-end marine construction equipment leads to accidents during the construction process and results in delayed completion:

Unique equipment requires skilled operators; contractors typically use their own appropriate and skilled operators, because of the high cost and specialised nature of this type of machinery. It should be noted that such equipment is not easily accessible and replacable in the marine construction environment.

It has been observed many times that low-skilled crane operators have caused damage resulting in financial and human losses and interruption in the project workflow.

In terms of insurance, the excess on an insurance policy is higher for an inexperienced driver/operator.

Three additional variables recommended by the participants were:

- lack of training for staff operating unique equipment
- lack of proper inspection and maintenance programs in machinery departments
- lack of in-advance plans for alternatives/substitutes.

The two variables under the marine equipment theme are interrelated. Lack of skill can turn a responsive machine into an unresponsive one. Skilled staff can be involved in allocating proper responsive equipment based on the project scope. This reduces the possible risk of employing inappropriate machinery. In addition, projects benefit from the participation of skilled people during the entire period, beginning with the initial stages. They contribute to the rectification of damages, help in the design of preventive maintenance programs and cooperate in preparing auditing procedures.

On the other side of the coin, the use of unresponsive equipment affects the abilities of staff. This decreases efficiency and effectiveness and raises stress levels. The detrimental impacts of a stressful atmosphere, especially around marine construction, can include environmental damage and overruns.

7.5 Nodes Developed Using the Coding Technique in NVivo

NVivo is a platform for the processing, development and representation of data, identifying key ideas in a qualitative analysis (Braun and Clarke, 2006). To commence the coding process, all responses to the open-ended questionnaire were precisely read and analysed, and key themes were identified. The coding was applied in such a way that the framework developed is easy to understand and interpret. Although the coding framework originated from the open-ended questionnaire responses, it was also assessed against main themes described in the literature review and quantitative part of the study. The main nodes developed are the most relevant underlying themes identified in the factor analysis in Chapter 6. Figures 7.1 and 7.2 provide illustrative example of the main delay and VE-related themes and the more comprehensive level nodes generated from the coding and review of the responses to the open-ended questionnaire.

In the NVivo coding process, 66 nodes for VE and 212 nodes for delay were formed on the basis of the open-ended questionnaire transcripts. The whole coding system is provided in Appendix 12 and 13, and is utilised in the next chapter to discuss the implications of the findings. Nodes correspond to a term, a phrase or a single word that represents an underlying concept.

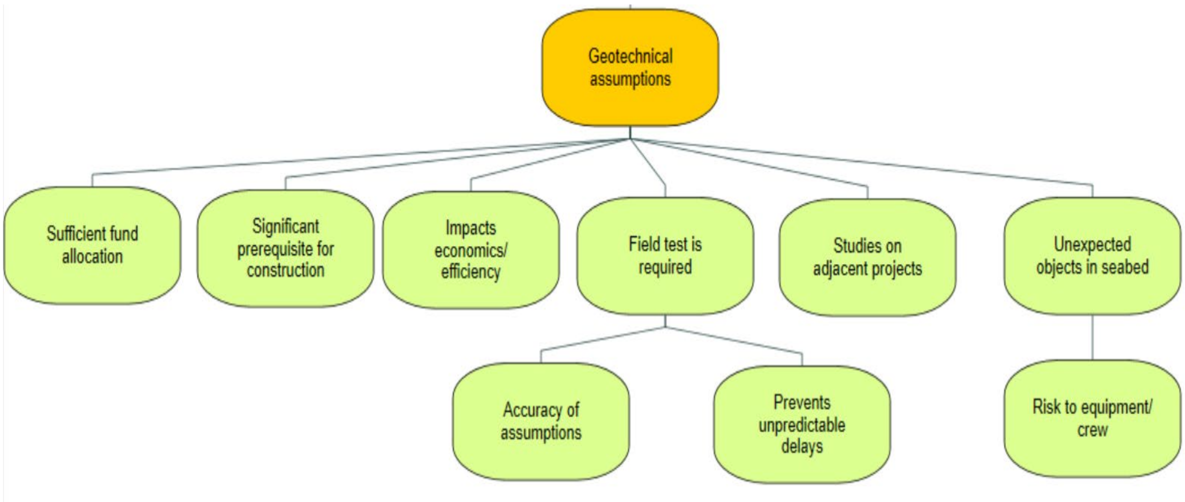


Figure 7.1: VE coding diagram

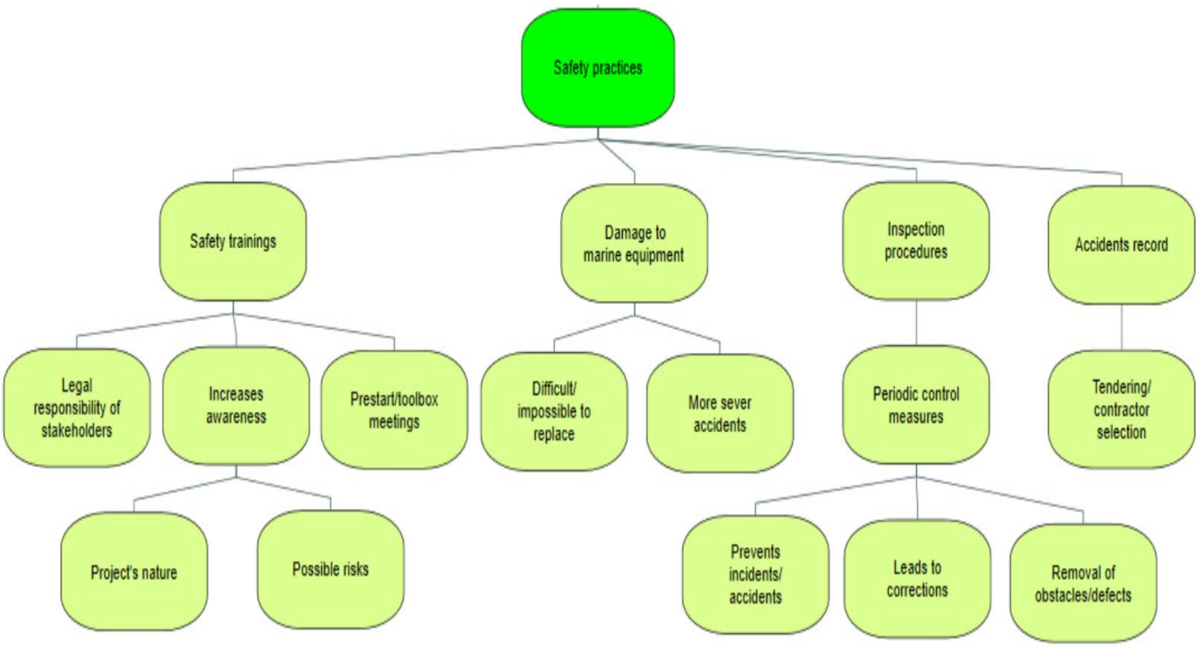


Figure 7.2: Delay coding diagram

7.6 Summary

In this chapter, external validation of the findings through an open-ended questionnaire was discussed. Responses in the form of explanations, agreements, suggestions, disagreements, practical examples and other useful feedback were reviewed. NVivo 12 software helped to code, organise and logically group information into themes and patterns, and to develop an intuitive understanding. This approach facilitated the process of obtaining insights from the responses.

Participants in the open-ended questionnaire survey were asked to assess the correlation between themes and corresponding variables. They were also asked to comment on the core message of the grouped variables presented to them and add constructive suggestions, preferably in the form of examples, to the provided findings. Feedback and viewpoints resulted from discussions on themes and correlations were consistent with the findings from the previous quantitative approaches, factor analysis and SEM in particular. Evaluation and analysis of the responses received contributed to the qualitative part of this study and confirmed the significance of the findings. Participants also provided additional recommendations with the potential to be considered in the future studies.

Finally, a framework was developed by employing the NVivo software and coding process. This was achieved through thorough interpretation and analysis of all the responses and identifying key themes. The resultant framework will be effective in the next chapter to discuss the implications of the findings.

CHAPTER 8: IMPLICATIONS OF FINDINGS

8.1 Introduction

For developing countries, marine infrastructure projects are of immense financial importance to economic growth. However, a vast literature indicates that late completion and delay are still rife in the marine construction industry. Responses to questionnaires sent to professionals around the world confirmed this as a phenomenon (Section 6.5.2). Moreover, potential strategies to enhance project efficiency in marine construction projects receive limited coverage in the academic literature. In this study, VE as a relatively new concept used in the marine construction industry has been explored to assess the potential of this method in development of delay mitigation strategies.

This study has added to the existing limited body of knowledge in the scope of marine construction projects by introducing potential VE protocols (Section 6.7.4) and how they can assist in scheduling theories. The developed structure offers a platform for managing projects and enhancing project schedules via a multidisciplinary team aiming to highlight alternative solutions, define alternative methods and introduce potential opportunities for value creation within the project.

The efficacy of this methodology was validated by the responses to the quantitative (Section 6.7) and qualitative questionnaires (Section 7.3).

The research implications from the insights developed from the findings and a description of how the findings might be applicable to policy, practice and theory are discussed below. Guidelines provide effective measures to be performed with respect to strategy, practice, theory and further study.

8.2 Scheduling Strategies

The outcomes from this research may influence scheduling methodologies employed in the marine construction industry. As confirmed by the participants in this research, completion delays in marine construction projects are extremely common, regardless of geographic location (Section 6.5.2). The survey revealed that 89% of respondents identified late delivery in their projects; this implies that it is almost impossible to meet predefined benchmarks—in particular the schedule—in major marine projects. This creates a significant challenge for scheduling strategies used in the analysis of project duration in marine projects. The emphasis should be on environmental uncertainties and how planning theories should incorporate them to eliminate their adverse effects on projects. Predictive/preventive mechanisms employed in the initial stage have been identified as useful for addressing uncertainties in this particular scope of work (Park et al., 2006; Karami and Olatunji, 2018a). Two significant environmental uncertainties in the marine environment are weather conditions and geotechnical uncertainties, both of which challenge the scheduling theory, disrupting operations and, as a consequence, leading to time and cost overruns (Section 7.3.3). A proactive approach helps with project flow.

Weather uncertainties demand the need for up-to-date predictive technologies to formulate more rational and practical scheduling. This is important from the risk management point of view since inclement weather conditions may impact safety and productivity of personnel, damage partially completed structures and equipment, and impact the quality of the work. Despite the use of credible sources, it is important to note that Mother Nature occasionally plays differently and there is still a need to consider unexpected events. Flexible timetables were agreed by the respondents as helpful for dealing with unforeseeable circumstances imposed by weather-related problems and detecting possible activities that may and may not be affected. Importantly, this flexibility should not override the schedule of the project (Section 7.3.1).

The second challenging factor for scheduling theories, which is a common area of ambiguity in the marine environment, is geotechnical uncertainties. They contribute substantially to the real-world technological and budgetary risks of projects. Identifiable uncertainties and the requirement for pilot studies to infer behaviour of geotechnical features on the job site were already known to prevent potential issues at later stages. The problem is the platform under which all parties are required to commit to facilitate pathways in terms of funds, communication, organisational structure, required expertise and contract requirements. In addition, persuading clients to provide sufficient funds for field tests to ensure design reliability has been recommended by marine construction experts (Section 7.3.2). This is important because potential problems may be identified during the test session, meaning that a more thorough study is required. A discrepancy between the contract document and the actual conditions, redesign, rework, waste of resources, and schedule and budget overruns are the consequences of clients' reluctance in this regard.

Conversely, and in the case of encountering unpredictable circumstances, it must be accepted that uncertainties are unavoidable in the marine construction scope of work. Plan-ahead packages and compensatory strategies are required to overcome detrimental impacts (Section 7.3.3). These should not be overlooked, but do have rather extensive time and budget implications. Overall, it must be ensured that (Griffin, 2018):

- Uncertainties are reasonably assessed and consistently integrated into design and scheduling processes.
- The impact of uncertainties does not override project expectations.
- Application of an analytical approach involving intensive observation and evaluation is in place.

In addition, and more importantly, the 'implementation of probabilistic over deterministic analysis methods to model variation' must be considered (Love et al., 2016). The implications of such observations will help to improve the practicality of scheduling strategies in marine construction projects.

Ultimately, qualified staff with relevant expertise should be involved in task assessments and scheduling procedures. Excessive optimism of estimators often leads to scheduling failures. Scheduling theories require careful consideration to avoid inaccuracies that might lead to a disaster.

8.3 Management Strategies

Management is used as a broad term in construction. This is highly significant when it comes to managing projects in an uncertain environment with complexities, cultural diversities and multiple disciplines. Effective management requires the definition of a detailed plan with realistic objectives, specific strategies for achieving these objectives, coordination and monitoring of project activities to support the strategic goals, and the allocation of the resources required to achieve the aim and objectives. This is discussed in the normative literature. What needs to be incorporated into conventional management strategies is the definition of the project scope and nature.

Management approaches for marine construction projects will not be practicable unless the effects of uncertainties, unforeseeable environmental conditions and geographical locations are taken into consideration. This was verified by the recommendations of the participants in this study (Section 7.4.5). Fit-for-purpose management techniques should determine how all of the aforementioned elements combine to trigger or intensify unexpected issues in marine infrastructures. Understanding the implications of each of these factors prevents disruption to task sequences, enhances efficiency and facilitates the resource allocation process.

A competent management team with relevant project expertise is as essential as management strategies in marine construction. Human resource management is the main department that undertakes this important requirement. Hiring a team with insufficient/irrelevant project experience or successive changes of key personnel in the management team can lead to severe losses. A dearth of experienced staff, as is common in this scope of work and was ranked highly by respondents in this study as having an impact on construction schedules, contributes to management issues.

The findings of this study also imply an effect of cultural factors in the environment of marine construction. Managing cultural diversity in remote/rural areas where most marine construction projects are being implemented is paramount (Section 7.4.8). Cultural diversity commonly affects project communications. Knowledgeable management, acquainted with cultural and social differences and the know-how to communicate effectively within this environment is very effective in project implementation and collaboration processes.

8.4 Finance-related Implications

Respondents scored the financial stability of the owner the highest among financial issues in this study. This was closely followed by the financial soundness of the contractor as a major factor in the successful completion of marine construction projects (Section 6.8.3). Authorities must investigate this during the initial stage of contractor selection. In the light of the vast budgets for marine construction projects, the credit record of contractors plays an important role. One challenging question is the reliability of the financial record of the contractor—which is based on their balance of accounts—when there is no way to assess their liabilities, such as outstanding salaries, outstanding debts to vendors and advance payments.

The findings of this study imply the importance of financial capabilities in marine development projects and the difficulties faced by developing countries in this regard. Inevitably, investors must predict and meet the funding requirements of a project if it is to succeed. They need to ensure that influential factors/uncertainties such as price fluctuations/escalations, sanctions and unstable economy are rationally anticipated, as they invariably must be incorporated into the cash flow management (Section 7.4.13).

Another reason for the value of financial capacity is that critical prerequisites, such as pilot studies, can be undermined through lack of adequate finance. Thus, a sufficient proportion of the project budget should be assigned to pilot testing at the initial stage to prevent any overrun arising from any necessary rework or redesign.

8.5 Contractor Selection Model

Marine construction projects are not suitable for all contractors; rather, they require contractors who are extremely qualified and willing to succeed. They must have outstanding capabilities and skills to address the complexities, risks and uncertainties that characterise the specialty of marine projects. Findings of this study imply that even where contractors are extremely skilled, the level of complacency is restricted (Section 7.4.1). The implication seems to be that pre-qualification procedures should be implemented in a different manner for marine construction projects, depending on client expectations and the particular characteristics of projects.

An appropriate pre-qualification framework applicable to the nature of unique marine infrastructures is required to ensure that the procurement strategy contributes to the long-term value of the project.

For example, it was already known that what makes a contractor package attractive to clients is high-level team expertise, technical and financial capacities and a good record of successful project deliveries of a similar scope. Candidates must also be efficient in communication, VE and negotiating skills. While most recent pre-qualification studies based on conventional projects outline simple factors such as financial stability, technological capacity, management practices and safety record, evaluation in the scope of marine projects involves more accurate assessment of these attributes on the basis of the specific characteristics of the project. For instance, how accurate is the information provided by the contractor on technical capability when on-the-job resource availability is uncertain during pre-qualification? How can clients assess the collaboration between nominated contractors and their potential subcontractors? What dimensions of the safety practices of contractors in previous projects can be transferred across to new projects, and what do they imply for the extremely specific marine project environment? Knowledge gaps regarding these concerns are significant. If pre-qualification is required to influence the success of the project, it must be addressed in the context of marine construction projects.

Clients should incorporate their project's unique attributes when enriching generic selection procedures to be applied in advanced marine projects. Distinctive attributes can be used as a mechanism to incorporate extra measures into the evaluation process. Moreover, marine projects include a variety of disciplines, some of which are specific and differ from project to project. An appropriate pre-qualification can allow clients to define these and their potential to collaborate in the project. In addition, marine projects require huge budgets. Generic assessments of financial capacity in conventional construction projects are often incorrect or misleading. Appropriate pre-qualification should incorporate optimisation of the financial performance of projects by verifying that the liabilities of contractors are known and do not compromise project processes.

Other factors defined that could contribute substantially to existing theories of pre-qualification include capabilities in emerging technologies, organisational research culture, technological innovations within the organisation, employment of alternative work strategies, actual efficiency in a similar scope, performance in a comparable region, responsive marine equipment, modality of successful project deliverables and a systemic problem-solving approach.

The implications of these findings contribute to enhancement of the practicality of contract selection theories in marine projects.

8.6 Risk Management

A high level of communication and integration with all stakeholders is required for an effective approach to risk management. Scholarly works confirm that collaboration can assist in detecting and mitigating risks before they occur. Risks, if properly managed, can mitigate the detrimental effects of schedule and budget overruns. What exacerbates the complexity in risk management strategies in marine construction environment is uncertainties. Avoidance of uncertainties contributes to inappropriate decisions before, during and after the implementation of projects (Grote, 2015). Qualitative uncertainties in the marine scope of work are more common than quantitative ones. This implies the need to manage uncertainties in marine construction projects in a clearer and more comprehensive way through risk management/preventive mechanisms (Section 7.3.1). Mismanagement of weather conditions and geotechnical assumptions, as two main forms of qualitative uncertainty, may be the consequence of insufficient information or ambiguity. Additional details do not always ensure the full elimination of uncertainties, but nonetheless offer new avenues for improvement. This improvement can be achieved through group collaboration. Evaluating risks more specific to projects—marine construction in this case—ideally in the initial stages, reduces impacts on the costs, schedules and efficiency of the project at a later stage. Employment of an appropriate platform for investigation of risk factors is of the highest priority. Findings from this study introduce

VE as the most functional platform (Section 7.3). Careful risk management by thorough consideration of the unique characteristics of marine projects—particularly uncertainties and risks relevant to the unique nature of the work—can be implemented using this methodology.

Identifying different risk scenarios through collaboration of stakeholders and the project team in VE workshops leads to development of an effective risk matrix. As the findings of the study suggest, reliable expertise, accurate information and lessons learned from similar projects under similar geographical conditions will provide a better understanding of the risks involved (Section 7.3.3). In addition, the participation of stakeholders before and during the development of a project is advantageous and underlines additional potential risks.

It should be noted that with a risk mitigation approach, the key aim is to reduce uncertainty to a reasonable level.

8.7 Value Engineering Capabilities

One of the important implications of this study is the benefits of introducing VE as a tool, not only to optimise cost, but also to help in schedule performance and prevention of disruptions. This study verifies that the high investment, high technology and risk, complexity and uncertain environment in marine construction projects requires a mechanism to envision potential issues and implement preventive/corrective strategies. This can be achieved by considering unique attributes while investigating alternatives. Unless this characteristic is thoroughly understood, the actual mechanism is unlikely to lead to successful completion.

VE has been validated by this study as a systematic mechanism with the potential to incorporate distinctive characteristics at the initial evaluation stages in marine construction projects; identify potential issues; and create suitable innovative solutions (Sections 6.7 and 7.3). In other words, a team of professionals who are experienced and acquainted with marine construction as a VE team, supports the project at various levels, enhances efficiency and increases the probability of success.

In terms of the complexity, multidisciplinary environment and specific characteristics of marine projects, this strategy has the capacity to adopt up-to-date technologies to enhance efficiency and achieve satisfaction among stakeholders. Since the basis of VE is the collaboration of various disciplines in a workshop to develop an optimal solution, sharing and collaboration through tools—such as 3D modelling—that incorporate entire disciplines can be facilitated (Section 7.4.7).

8.8 Marine Equipment

Marine construction projects require unique equipment and machinery. The findings of this study confirm that such equipment is not easily accessible and replaceable. Marine contractors can either hire or purchase it. Almost all of the high-end equipment needed is often booked years in advance, making planning difficult. Subject to financial capabilities, having an in-house equipment department is deemed a privilege that empowers contractors to plan accordingly on the basis of project requirements. This can also be considered a benefit at the pre-qualification stage. Contractors can also design and modify their equipment on the basis of project specifications. A deficiency in any particular piece of equipment may result in a massive overrun in schedule and budget.

In addition, marine machinery should be selected in accordance with project requirements. Unresponsive marine equipment can contribute to risks, accidents and time loss (Section 7.4.16). A low budget allocated to the project during the tendering process is a likely explanation for contractors not using fit-for-purpose equipment. This makes them hesitate to use the appropriate machinery, so that can increase their profits. Precise budget estimates in the initial stages and recruitment of a qualified contractor eliminate these problems.

A geography-specific issue with respect to marine equipment is the need for continuous repair and maintenance because of the inaccessibility of new equipment in Iran. Machinery manufactured inside the country is typically of poor quality, regardless of whether the components used are partially or completely manufactured within the country. The same principles generally apply to replacement parts. As described above, in-house machinery can be an efficient and cost-effective solution in this situation, while importing new equipment entails payment of a large customs duty. This demands a strong financial capability that most companies in Iran do not have. The inability to interact with national banking authorities and late payment sequences of clients exacerbate this issue.

8.9 Approval Procedures

As was already known, approvals procedures involve defining the steps to be followed for a completed task to be accepted. Under no circumstances can a contractor commence work without these approvals. Since marine projects are highly dependent on weather conditions, a very straightforward procedure for approval processes is required to avoid implications for operation sequences. For example, all tests, documentation and processes related to driven piles are important prerequisites for construction of suspended-deck jetties. Late approvals impede project progress and delay on-time completion. Preventing late approval is often not achievable unless there is a provision in the contract that stipulates the time allowed for the processing of documents. The findings of this study clearly support this (Section 7.4.14).

The organisational structure of the client/owner and related authorities should be formulated in such a way as to accelerate, and participate in, approval processes to prevent interruptions to the workflow. Defining an effective means of communication in this structure is of the greatest priority.

8.10 Application on Theories Around Delays

Delays in infrastructure projects are well documented in the normative literature. Knowledge of this unsatisfactory phenomenon is limited when it comes to scope-related delays and mechanisms by which mitigation strategies can be developed in certain environments.

Schedule overruns remain rife, reflecting the inconclusiveness of previous research findings. Most relevant studies have failed to understand the importance of key components of the construction industry, such as the project environment, as implied by the findings of this study in regard to delay mitigation theories (Section 3.4).

It is almost impossible to incorporate the long list of delay causations identified in this study into a clear train of thought, because these factors apply to project environments in a particular manner. Further, their interaction in a particular and nuanced scope is often obscure. Hence, this study sought to integrate the uniqueness of marine projects into delay detection processes and effective mitigation strategies.

Moreover, the unique attributes of projects in the marine environment render them more vulnerable to delays than other project environments. Attributes such as intense equipment and other resource requirements, uncertainties, multidisciplinary scope, inclement weather conditions and complex design principals define this uniqueness. Whenever mitigation strategies are appropriate and suitable for particular project scenarios with uniqueness taken into account, project deliverables will benefit (Section 3.1).

Identification of delay causations unique to marine construction projects helps to establish dedicated techniques relevant to scheduling to prevent and overcome hindrances generated by overruns. The VE method was validated by the respondents as having the potential to prevent issues with schedule performance in marine construction projects (Section 7.3).

It should be noted that although the causes of delay mentioned in the normative literature may be applicable to marine construction, some are much more severe in marine projects. It is critical for project stakeholders to be aware of this in such a way that they can establish their expectations to accommodate variability instead of laying unreasonable blame.

CHAPTER 9: CONCLUSION AND FURTHER STUDY

9.1 Introduction

Marine projects are prone to cost, resource allocation, quality and safety issues. These particular factors are a substantial component of delay causations in such projects. Moreover, productivity is restricted and environmental aspects of marine ecosystems are extremely unpredictable. This unpredictable scope of work requires the simultaneous participation of a broad range of disciplines and a rigorous realistic approach that takes into account these characteristics of marine projects and the situation of the environment in which they are located (Section 3.2).

The focus of this research was on defining important delay causations in marine construction projects and how the VE methodology can potentially mitigate the negative impacts of late completion and overruns. This conclusion chapter explains how this research contributes to schedule performance and value creation in marine construction projects. It briefly reviews the predefined objectives outlined in the first chapter and the process undertaken to accomplish those goals. Potential areas for further research and recommendations are then described.

9.2 Explanation of Original Contribution

This section describes the contribution of the conducted research study to mitigating overrun causations by focusing on scope-specific causations in marine projects, and whether they can be mitigated by specific VE processes.

The specific outcome of this study is identification of variables relevant to marine projects, both by theme and by relationship (Sections 6.7.2, 6.8.3, 6.9 and 6.13). Although some of the factors involved are typical of other construction projects, they contribute differently to marine construction projects and their potential impacts are thus completely different. Delay triggers can be ameliorated by investigating drivers in a particular project environment. This is indeed a constructive approach that helps in the development of mitigation measures, either preventive or corrective, and helps stakeholders and project management communities in marine construction projects properly evaluate and investigate the source of delays.

Further, this research reveals the feasibility of using scope-related and characteristic-oriented VE protocols in marine construction projects. Findings indicate that marine projects benefit from the implementation of the following VE protocols (Section 6.7.2):

- Accurate and reliable initial studies integrating objective science and empirical evidence. Implementation of this protocol avoids design errors and enhances the project schedule by considering factors such as the use of up-to-date technologies in design choices, taking note of results from previous studies on similar projects, involving industry experts in VE workshops, identifying and adopting appropriate practical methods used in similar projects, involving the contractor in consultations and decisions on design options, seeking expert knowledge to analyse task duration, monitoring weather conditions and developing plan-ahead packages.
- Evaluating unforeseeable ground and seabed conditions by performing pilot studies. Part of the application of this protocol ensures that a sufficient proportion of the budget is allotted to pilot studies in the initial stages of the project to prevent any overrun arising from the need for rework or redesign.
- Strategic planning by deep evaluation of the specific characteristics of marine projects; in particular taking into account risks and the high-risk environment. Two significant considerations involved in the implementation of this protocol are maintaining adequate flexibility in the schedule for the completion of all operations and considering the outsourcing of mass production activities. These considerations will help improve the schedule.
- Considering alternative methods of implementation and resourcing at the planning phase. Adopting this protocol involves determining and assessing the most appropriate and effective methods to allow tasks to be carried out and applying these methods to major and repetitive tasks that need to be carried out in the marine environment. This will eliminate excessive rework and enhance workflow.

Stakeholders would benefit from the adoption of these proposed protocols through improved efficiency and design consistency and minimisation of the level of risk.

9.3 Review of Objectives

The three objectives of this research as set out in Section 1.5 have been achieved via different steps. By employing a mixed method approach, these objectives were achieved and the outcomes verified using triangulation of data to confirm the validity of the findings. This section describes how the three objectives were met through the implementation of different research methodologies.

Objective 1: Identify value engineering variables appropriate for marine projects

Marine projects are unique in nature. It requires particular expertise and highly complex technology to perform the necessary work under unpredictable conditions, usually in regions where logistics support is remote and challenging. The nature of marine projects explains the need for rigorous management methods for such projects; yet, the same VE protocols are generally used for marine projects as for other types of projects. Evidence from previous studies suggests the occurrence of ongoing problems for marine projects that VE protocols are designed to prevent: cost and schedule overruns remain significant. To achieve the first objective, the focus of this study was to demonstrate the importance of applying context-specific VE protocols to marine construction projects, and to assess the validity of these protocols as strategies to avoid problems with schedule performance in marine projects. Responses from the survey demonstrated the efficacy of the use of VE protocols to anticipate and minimise problems that may occur during the lifecycle of a marine construction project.

Nineteen VE variables, grouped into four themes, were identified from the literature (Section 6.7.2). Using factor analysis, the study identified VE protocols from the literature that met important criteria to be considered for application at different stages of marine projects.

Findings from Objective 1 have been published in a high-ranked journal (see Supporting Publications in the front matter of the thesis). The findings will help VE stakeholders to increase efficiencies, untangle design and construction constraints and reduce risk levels. Future research will draw on these results to provide a foundation for describing cost and schedule performance concerns in marine projects.

Objective 2: Identify key delay causations in marine projects

Delays in infrastructure projects are well documented in the normative literature. However, very little is mentioned about environment-related factors that can contribute to the formulation of prevention measures. After meeting the first objective, this study investigated the key causes of overruns in marine construction projects as the second objective of the research.

Prior studies and a literature review were used to classify causal factors, which were included in a questionnaire so that key stakeholders in marine projects could provide their views on the importance of each. Questionnaire surveys were distributed to respondents from Australia, Iran, Hong Kong, Malaysia, Ecuador, South Africa and South Korea. In particular, data were collected from clients, contractors, consultants and other relevant parties and decision makers in the marine construction field. Participants assessed the importance of delay causations extracted from the literature. Analysis of the importance of each variable was conducted via descriptive statistics and a reductionist methodology. Using factor analysis, all variables were grouped into 16 underlying themes (Sections 6.8.2 and 6.8.3).

Results from Chapter 6 indicate that all variables are important: communication issues among stakeholders, inadequate planning, safety issues, deficient technical instructions and inappropriate management approaches. Others include design and construction issues, issues with project organisational structures, political and cultural factors, environmental uncertainties and complexity in resource management. The study also found that estimation errors, owner’s attitude, financial issues, delay in approval processes, construction strategies and unavailability of appropriate technologies for the work are influential factors. These results are in agreement with previous studies of other types of projects, although some of the causes are much more extreme in marine projects.

Findings from Objective 2 have been published in a high-ranked journal (see Supporting Publications in the front matter of the thesis).

Objective 3: Illustrate causality relationship between delay factors and value engineering protocols using a validated structural equation model (SEM)

SEM as a general statistical modelling technique provides a conceptual model that illustrates a structure for the correlation among obtained variables. As the third objective and to validate the model obtained from EFA, SEM was employed as the specific statistical method. This validated the extent to which the model obtained was consistent with the results. In other words, the structure of the observed variables was examined through CFA. Evaluating a primary set of items using an EFA model followed by a CFA framework is frequently recommended in scholarly works.

The developed structure offers a more meticulous assessment of the observed data as illustrated by a conceptual model. This approach was adopted in this research to develop a conceptual model that assists with data interpretation.

The whole SEM model including covariance between underlying themes was presented in Chapter 6 (Sections 6.9 and 6.13). The validity of the model was verified through the use of model fitness indices. Values show high correlation between variables and their themes. They also indicate high correlation among themes in each category of delay and VE. Both SEM models are included in published papers as part of the findings.

9.4 Limitations of the Study

Although it achieved its objectives, this research undoubtedly had some limitations. In the first instance, because of the diversity of marine projects, overrun causes are likely to occur in different forms in different project contexts. Further, economics, technology and local regulations affect project circumstances differently. Political problems, particularly sanctions, may trigger issues.

In addition, data for this study were collected two years before finalisation of this thesis. Most of the contributors were from Iran. It should be noted that these data will still not represent the global population of views around delay causations.

Another limitation factor that impacted this research was the enforcement of COVID-19-related regulations. The pandemic restricted the use of some research tools such as focus group interviews. In the qualitative part of this study, an open-ended questionnaire had to be designed as a new research tool to obtain the viewpoints of experts on the findings of the closed-ended questionnaire.

Moreover, the actual implementation of the findings has not been tested in a particular case study. Such a definitive outcome should be pursued.

9.5 Recommendations

The recommendations arising from this study are in accordance with the findings of the literature review, archival analysis of a VE report, questionnaire survey and finally the validation exercise using an open-ended questionnaire.

The following recommendations are listed in the three major categories of specific, general and guidelines for future studies.

9.5.1 Specific Recommendations

Specific recommendations can be listed as below:

- In terms of industry application and actual project situations, in line with the participants' points of view, stakeholders need to be fully aware of and collaborative in their organisational structure to enhance the performance of the project (Sections 7.4.12 and 7.4.14). A useful example is approval processes. Since marine projects are highly dependent on weather conditions, a very straightforward procedure for approvals is necessary to prevent implications for operation sequences. The organisational framework of the client/owner and relevant authorities should be defined in such a way that they are able to facilitate and engage in approval processes to avoid disruptions to the workflow. The definition of an efficient form of communication in this framework is of the utmost importance.

- Outcomes from this research challenge scheduling methodologies. It was confirmed by the participants in this research that completion delays in marine construction projects are extremely common, regardless of geographic location. Analysis of the results revealed that 89% of respondents identified they experienced late delivery in their projects (Section 6.5.3). Thus, it seems almost impossible to meet predefined benchmarks in major marine projects; in particular the schedule. This presents a significant challenge for scheduling strategies used for the analysis of project/task duration in marine projects. The emphasis should be on environmental uncertainties and how planning theories should incorporate them to eliminate their adverse effects on projects.
- Qualitative uncertainties in the marine scope of work are more common than quantitative ones. This implies the need to manage uncertainties in marine construction projects in a clearer and more comprehensive form through risk management/preventive mechanisms (Section 7.3.3). Stakeholders should ensure that uncertainties are reasonably assessed and consistently integrated into design and scheduling processes. In addition, expectations regarding the project should not be overridden by the impact of uncertainties. Finally, an analytical approach involving intensive observation and evaluation should be employed.
- One of the most important recommendations from this study is to introduce VE protocols as a tool; not only to optimise cost, but also to improve schedule performance and prevent disruptions (Section 3.8). This study has confirmed that the intensive investment, high technology and risk, complexity and unpredictable environment in marine construction projects require a mechanism to address the potential issues and enforce preventive/corrective strategies. This should be accomplished by considering these unique characteristics when researching alternatives. Until this feature is clearly understood, it is unlikely that such a mechanism will be successful.

- Adopting up-to-date technologies through VE methodologies to enhance efficiency and achieve satisfaction among stakeholders aimed at on-time completion is recommended (Section 6.7). Since VE is based on collaboration among various disciplines in a workshop to develop an optimal solution, sharing the information and collaborating via tools such as 3D modelling to incorporate entire disciplines is recommended.
- The applicability and practicality of up-to-date technologies should be considered in the marine scope of work Section (7.3.1).
- It is recommended that a VE team be brought on board as this makes the contractor package more attractive to clients/owners. Moreover, marine construction can benefit from implementing VE, particularly during the early stages of a project. Through the collaboration of experts and experienced industry professionals, VE workshops are designed to identify the most profitable and constructible options. Developing and modifying functions improves a project’s performance. Modifications can be assessed against the project schedule to satisfy the basic timeframe. Such modifications include re-strategising resourcing and evaluating the different effects this might have on a project’s components, reviewing the design assumptions and identifying alternative implementation methods that can assist in efficient project completion (Section 2.8.1).

9.5.2 General Recommendations

Below are general recommendations provided as guidelines that should be followed for the purpose of effective delay mitigation and value creation in marine construction projects:

- Potential strategies/VE protocols can be scope specific. Hence, the findings of this study suggest revising the strategies based on specific attributes and context of each project.
- This study suggests not overlooking possible failures relevant to the developed protocols/strategies.
- An efficient plan, which can be referred to as risk management, is required to conduct safe work during inclement weather conditions.

- Taking into consideration previous studies on similar projects in the region—subject to accessibility and especially at the design stage—is highly recommended.
- It is recommended to involve an experienced contractor before final approval of the drawings, to help foresee future potential issues in the construction phase and facilitate precise allocation of resources. This can accelerate the project's implementation with fewer possible errors.
- Consideration of design risk management methods is recommended to reduce errors and the time required for redesign.
- The presence of accurate work breakdowns is important in planning, managing the workflow and, above all, resource allocation to meet the schedule.
- A flexible timetable is required for interacting with unpredictable conditions imposed by weather-related issues and identifying potential activities that can and cannot be affected. This can be considered in risk matrix.
- Evaluating alternative resources will assist in maximising project value while maintaining cost effectiveness, quality and timeliness. Potential resources should ideally be accessible at all stages of the work, so that, in the case of any difficulties, access to other resources of the desired quality is possible.
- Predefined procedures and specifications, auditing systems and so on are integral components of every project. They should also be re-assessed from time to time on the basis of VE instructions to ensure practicality.
- Inspection procedures and periodic control measures are recommended as two important aspects of safety protocols. They prevent incidents and accidents, and lead to the correction and removal of defects and obstacles.
- Checking contractor eligibility in terms of safety at the tendering stage is highly recommended.
- Formal means of communication in projects should be defined by project instructions.
- Experienced management that is familiar with cultural and social differences and can communicate well within this environment is necessary in the project implementation process.
- To avoid interruptions in implementation sequences, flexibility is required in the schedule as tasks are subject to approval processes. This prevents time

overrun if these tasks are located in a critical path of the schedule.

- It is recommended to stipulate the time required for the processing of documents in the contract agreement to avoid delay as a consequence of late approval.
- Use of local suppliers/contractors depending on the scope/specifications of the projects is recommended. This may help in terms of accessibility, cost and better quality control.

9.5.3 Further Areas of Research and Recommendations for Future Studies

This research aimed to introduce VE as a mechanism with the potential to be used in marine projects to prevent or reduce schedule overruns. Experts were engaged in this study and four protocols were derived on the basis of the views they expressed, which verified the validity of VE as an effective method for use in the marine environment Section (6.7.4). The protocols predominantly highlight the significance of the following: maintaining a thorough design phase that uses information and empirical evidence; incorporating pilot studies during the design phase; ensuring detailed planning, including uncertainty; and assessing the usefulness of different strategies and resources at the early stages of the project. This can also be implemented in other types of projects such as road projects, high-rise and low-rise buildings, and other construction industry sectors.

Another possible area for future research on this subject is in investigating the respective influence of particular causes; for example, the relationship between project funding and project outcomes. In other words, what is an adequate amount of investment for successful delivery of a specific type of marine project?

Another area for potential future research on this topic is in the in-depth analysis of variables related to particular types and components of marine projects. For example, the same factor will produce different results in nearshore and offshore projects; factors affecting bridges could be different from those for dams; and underwater construction will face different scenarios in low-tide and high tide environments. In other words, scope-specific research is recommended.

As another area for further study, the researcher recommends seeking a more comprehensive model of contractor selection in marine construction projects. Definition of eligibility criteria for various types of marine projects with respect to their distinctive features and nature of work can be considered in the defined model. The researcher has published a conference paper on this topic (Karami and Olatunji, 2018b); however there is still more to add to this body of knowledge.

9.6 Conclusion

This research study adds to the literature regarding marine construction projects and potential strategies to mitigate negative impacts of overruns in this dynamic and uncertain environment.

Examining overrun issues in this study revealed that causations can be mitigated by investigating the drivers in a particular project environment. This is a constructive procedure that assists in establishing mitigation strategies—both preventive and corrective—and helps stakeholders and project managers in marine construction projects to investigate the origins of delays.

The most effective methodology investigated for value creation and strategy development in marine construction projects is identified by this research study as VE. This approach was introduced as a dedicated mechanism by which interaction between different disciplines and major stakeholders results in optimal completion. Theoretical and empirical knowledge is applied in VE gatherings to create, discuss, develop and extract the best practical solution to achieve the predefined objectives of projects.

When exploring the most applicable solutions, factors that should not be overlooked are environmental uncertainties and how planning theories can incorporate them to eliminate their adverse effects on projects. This study introduced uncertainties as integral components of the marine scope of work. They are unavoidable and must be accepted and controlled through plan-ahead strategies to overcome associated detrimental impacts. To mitigate potential issues disrupting the workflow in marine construction projects, this study emphasises the importance of ensuring that uncertainties are reasonably assessed and consistently integrated into design and scheduling process.

In addition, this study believes in the implementation of probabilistic rather than deterministic analysis while scheduling a formulation to incorporate the unique attributes of the marine scope of work, such as complexity, high level of uncertainties, dynamism and extreme risk (Section 3.2).

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APPENDICES

Appendix 1 Closed-ended Questionnaire

Curtin University

This survey will be used to develop and validate a conceptual model optimising value engineering protocols that can be implemented for delay mitigation. Please answer each question as accurate as possible. All your answers will be confidential. When you have completed this survey please return it using the provided link or email address. Thanks for your participation.

Q1 How many years of experience do you have in construction industry?

- ○ 1-5 years (1)
- ○ 5-10 years (2)
- ○ 10-15 years (3)
- ○ 15-20 years (4)
- ○ 20-25 years (5)
- ○ More than 25 years (6)

Q2 How often do projects face delay in your organisation?

- Always (1)
- Most of the time (2)
- About half the time (3)
- Sometimes (4)
- Never (5)

Q3 To what extent do you agree that cost overruns are caused by schedule overruns?

- Strongly agree (1)
- Agree (2)
- Somewhat agree (3)
- Neither agree nor disagree (4)
- Somewhat disagree (5)
- Disagree (6)
- Strongly disagree (7)

Q4 Have you ever been involved in marine projects?

- Definitely yes (1)
- Probably yes (2)
- Might or might not (3)
- Probably not (4)
- Definitely not (5)

Q5 How many years of experience do you have in marine projects?

- ◯ No experience (1)
- ◯ 1-5 years (2)
- ◯ 5-10 years (3)
- ◯ 10-15 years (4)
- ◯ 15-20 years (5)
- ◯ 20-25 years (6)
- ◯ More than 25 years (7)

Q6 To what extent do you think marine projects are affected by delay?

- ◯ Far too much (1)
- ◯ Moderately too much (2)
- ◯ Slightly too much (3)
- ◯ Neither too much nor too little (4)
- ◯ Slightly too little (5)
- ◯ Moderately too little (6)
- ◯ Far too little (7)

Q7 What level of importance do the following factors possess in delaying marine projects?

	Extremely important (5)	Very important (4)	Moderately important (3)	Slightly important (2)	Not at all important (1)
Weather conditions (1)	○	○	○	○	○
High and low tides (2)	○	○	○	○	○
Lack of proper marine equipment (3)	○	○	○	○	○
Financial difficulties to the owner (4)	○	○	○	○	○
Financial difficulties to the contractor (5)	○	○	○	○	○
Lack of experienced personnel (6)	○	○	○	○	○
Design errors and poor design (7)	○	○	○	○	○
Improper site instructions imposed on contractors (8)	○	○	○	○	○
Delay in land delivery (9)	○	○	○	○	○
Poor communications and management skills (10)	○	○	○	○	○
Poor site control by contractors (11)	○	○	○	○	○
Poor consultant's auditing system (12)	○	○	○	○	○
Lack of consultant's practical experience (13)	○	○	○	○	○
Contradiction between tender documents and actual situation (14)	○	○	○	○	○

Lack of execution methods for major activities (15)	○	○	○	○	○
Scope change imposed by the client (16)	○	○	○	○	○
Lack of resources (17)	○	○	○	○	○
Inappropriate contractor (18)	○	○	○	○	○
Estimation errors in early design phase (19)	○	○	○	○	○
Lack of on-time approval of the drawings and documents (20)	○	○	○	○	○
Lack of pilot study prior to construction phase (21)	○	○	○	○	○
Unrealistic timetable for major activities (22)	○	○	○	○	○
Lack of value engineering department in organisation (23)	○	○	○	○	○
Form of contract (24)	○	○	○	○	○
Conflicts and poor coordination between the parties in construction site (25)	○	○	○	○	○
Obsolete technology (26)	○	○	○	○	○
Slow site handover (27)	○	○	○	○	○
Unrealistic contract duration imposed by client (28)	○	○	○	○	○

Low speed of decision making in different parties (29)	○	○	○	○	○
Delays in subcontractors' work (30)	○	○	○	○	○
Unstable management structure and style of contractor (31)	○	○	○	○	○
Construction method (32)	○	○	○	○	○
Mistakes during construction due to inexperienced personnel (33)	○	○	○	○	○
Lack of responsibilities in different parties (34)	○	○	○	○	○
Delay in work approval (35)	○	○	○	○	○
Lack of proper quality assurance/control system in site (36)	○	○	○	○	○
Inefficient information stream (37)	○	○	○	○	○
Long waiting time for approval of test samples or test results (38)	○	○	○	○	○
Inadequate design team experience (39)	○	○	○	○	○
Impractical design (40)	○	○	○	○	○
Lack of proper communication between consultant and contractor (41)	○	○	○	○	○

Lack of communication between client and consultant (42)	○	○	○	○	○
Procurement and resource allocation (43)	○	○	○	○	○
Delay in importing materials from other countries due to political issues (44)	○	○	○	○	○
Escalation in resource prices (45)	○	○	○	○	○
Unskilled operators for certain marine equipment (46)	○	○	○	○	○
Labour skills/Productivity (47)	○	○	○	○	○
Social and cultural factor (48)	○	○	○	○	○
Uncooperative owner (49)	○	○	○	○	○
Insufficient communication between the owner and design team in the design phase (50)	○	○	○	○	○
Unavailability of professional construction management (51)	○	○	○	○	○
Unavailability of financial incentive for contractor to finish ahead of schedule (52)	○	○	○	○	○
Problems with neighbours (53)	○	○	○	○	○
Unforeseen ground conditions (54)	○	○	○	○	○

Price fluctuation (55)	○	○	○	○	○
Water table conditions on site (56)	○	○	○	○	○
Geological problems on site (57)	○	○	○	○	○
Preparation and approval of shop drawing (58)	○	○	○	○	○
Lack of database in estimating activity duration and resources (59)	○	○	○	○	○
Safety issues (60)	○	○	○	○	○
Damaging marine equipment during execution in site due to lack of safety (61)	○	○	○	○	○
Lack of safety training and meetings prior to commencing the construction (62)	○	○	○	○	○
Poor judgment and experience of involved people in estimating time and resources (63)	○	○	○	○	○
Inspection and testing procedures used in project (64)	○	○	○	○	○
Accident during construction (65)	○	○	○	○	○
Excessive bureaucracy in project-owner operation (66)	○	○	○	○	○
Lack of considering alternative resources (67)	○	○	○	○	○

Lack of an appropriate work breakdown system by the contractor (68)	○	○	○	○	○
Lack of having a flexible timetable for certain activities (69)	○	○	○	○	○
Not involving the contractor in early design phase (70)	○	○	○	○	○
Lack of optimising/monitoring resource allocation (71)	○	○	○	○	○
Lack of appropriate procedure to deal with repetitive tasks and mass production e.g. pre-casts and piles preparation (72)	○	○	○	○	○
Not utilising lessons learned from similar projects (73)	○	○	○	○	○

Q8 According to your experience regarding delay in construction projects, what do you want to add?

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Q9 To what extent are you familiar with the value engineering method?

- ○ Extremely familiar (1)
- ○ Very familiar (2)
- ○ Moderately familiar (3)
- ○ Slightly familiar (4)
- ○ Not familiar at all (5)

Q10 What is your opinion about the following sentence? 'Value engineering is just a cost-trimming tool'.

- ○ Strongly agree (1)
- ○ Somewhat agree (2)
- ○ Neither agree nor disagree (3)
- ○ Somewhat disagree (4)
- ○ Strongly disagree (5)

Q11 To what extent do you agree? 'Value engineering has the potential to be implemented in marine projects for the purpose of delay mitigation'.

- ○ Strongly agree (1)
- ○ Agree (2)
- ○ Somewhat agree (3)
- ○ Neither agree nor disagree (4)
- ○ Somewhat disagree (5)
- ○ Disagree (6)
- ○ Strongly disagree (7)

Q12 To what extent are you familiar with value management?

- ○ Extremely familiar (1)
- ○ Very familiar (2)
- ○ Moderately familiar (3)
- ○ Slightly familiar (4)
- ○ Not familiar at all (5)

Q13 Do you believe there is any contrast between value engineering and value management?

- ◯ Definitely yes (1)
- ◯ Probably yes (2)
- ◯ Might or might not (3)
- ◯ Probably not (4)
- ◯ Definitely not (5)

Q14 The value engineering and value management methodologies focus on elevating a project's functional value by using alternative methods and resources without compromising quality. To what extent this is true?

- ◯ Definitely true (1)
- ◯ Probably true (2)
- ◯ Neither true nor false (3)
- ◯ Probably false (4)
- ◯ Definitely false (5)

Q15 Marine projects strongly benefit from value engineering application in terms of cost and time. How true is this sentence?

- ◯ Definitely true (1)
- ◯ Probably true (2)
- ◯ Neither true nor false (3)
- ◯ Probably false (4)
- ◯ Definitely false (5)

Q16 Have you ever profited from value engineering application in a project?

- ○ Definitely yes (1)
- ○ Probably yes (2)
- ○ Might or might not (3)
- ○ Probably not (4)
- ○ Definitely not (5)

Q17 At which stages do you believe that a value engineering approach is applicable?

- ○ Feasibility study (1)
- ○ Basic design (2)
- ○ Detail design (3)
- ○ Construction (4)
- ○ Operation (5)
- ○ All of the above (6)

Q18 At which stage of the marine project lifecycle can value engineering application be more effective?

- ☐ Feasibility study (1)
- ☐ Basic design (2)
- ☐ Detail design (3)
- ☐ Construction (4)
- ☐ Operation (5)

Q19 To what extent do you agree that the following variables can be considered in a value engineering workshop to establish a delay mitigation strategy for marine projects?

	Strongly agree (1)	Agree (2)	Somewhat agree (3)	Neither agree nor disagree (4)	Somewhat disagree (5)	Disagree (6)	Strongly disagree (7)
Implementation methods for major tasks (1)	○	○	○	○	○	○	○
Contractor's involvement to Integrate expert's knowledge into design options (2)	○	○	○	○	○	○	○
Analysing alternative resources (3)	○	○	○	○	○	○	○
Analysing alternative methods (4)	○	○	○	○	○	○	○
Addressing the activities that can be affected by weather conditions (5)	○	○	○	○	○	○	○
establishing a flexible schedule for the activities that can be impacted due to weather conditions (6)	○	○	○	○	○	○	○
Having a detailed work breakdown for critical activities (7)	○	○	○	○	○	○	○
Specifying budget for pilot study to prevent unpredictable delays (8)	○	○	○	○	○	○	○
Considering pilot study regarding to the ground condition (9)	○	○	○	○	○	○	○

Monitor/Optimise resource allocations (10)	○	○	○	○	○	○	○
Having appropriate procedure for repetitive tasks and mass production e.g. pre-casts and piles preparation (11)	○	○	○	○	○	○	○
Utilising practical methods from similar projects (12)	○	○	○	○	○	○	○
Out sourcing mass productions such as pre-casts to save time (13)	○	○	○	○	○	○	○
Monitoring the weather conditions on a daily basis to plan ahead against sever situations (14)	○	○	○	○	○	○	○
If possible, utilising up-to-date technology in design options (15)	○	○	○	○	○	○	○
Considering the previous studies on similar projects in the region (16)	○	○	○	○	○	○	○
Plan-ahead packages to deal with inclement weather conditions (17)	○	○	○	○	○	○	○

Involving industry experts in creativity phase of value engineering workshop (18)	○	○	○	○	○	○	○
Using expert's knowledge to analyse the initial tasks duration on major activities to insure they are accurate (19)	○	○	○	○	○	○	○

Q20 According your experience in marine projects what do you want to add as effective value engineering variables on delay mitigation?

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Q21 Would you apply value engineering methodology in a project if you were the authorised decision maker?

- ○ Definitely yes (1)
- ○ Probably yes (2)
- ○ Might or might not (3)
- ○ Probably not (4)
- ○ Definitely not (5)

Q22 Would you please specify your current position and qualification?

Appendix 2 Open-ended Questionnaire

Open-ended Questionnaire

The purpose of this study is to examine delay causations and whether they can be mitigated by specific value engineering processes. Review of literature and case studies reported 73 delay variables and 19 value engineering variables. Employing factor analysis and reductionist methodology returned four themes for VE and 16 themes for delay variables (shown in Tables 1 and 2). Structural equation modelling (SEM) was used in the study. Reviewing the model fit indices indicated that the model satisfactorily fit the data and met the requirements.

To examine the findings through a qualitative approach, an open-ended questionnaire is designed. The aim is to obtain the opinions of stakeholders and experienced construction experts on this study's findings. You are invited as a potential participant. Please read the provided information in Tables 1 and 2 carefully and be confident that you understand the content before deciding to respond. You will be mainly asked to assess the findings and comment on below contexts:

- Correlation between each theme and corresponding variables
- The potential relationship between variables in each group of delay and VE

Please provide examples where necessary. The correlation between each theme and corresponding variables has been displayed in a sectional graph under each theme. There are also some general queries in Table 3 that need to be addressed.

Finally, at the end of this questionnaire, your impression about this work has been requested. Feel free to provide any comment in regards to this study which you think may be helpful in addressing and envisioning issues in marine construction projects.
If you require more space in any section of this questionnaire to provide your answers, please append additional pages related to the respective subject either separately or at the end of this document.

The questionnaire has also been translated into the Persian language for your convenience. Feel free to provide your answers using either the English or Persian version.

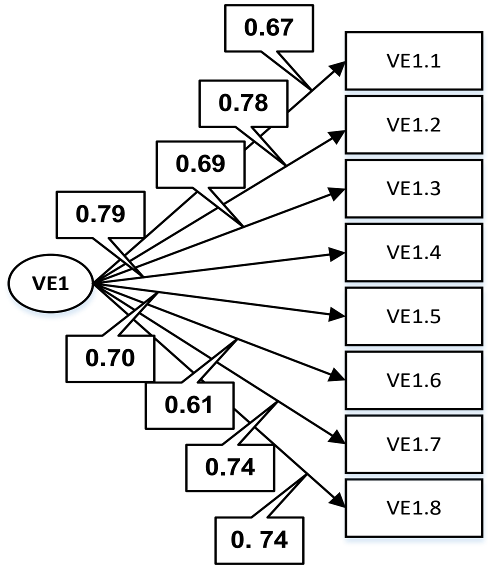
The study is being carried out by Mr Hamidreza Karami under the supervision of Associate professor Oluwole Alfred Olatunji from the School of Design and the Built Environment at Curtin University, Perth, Australia. Please complete the questionnaire and return it to one of the provided email addresses below. By completing and returning the questionnaire, you are giving consent for your response to be included in the study. All information that you provide will remain confidential and will be de-identified for all analyses.

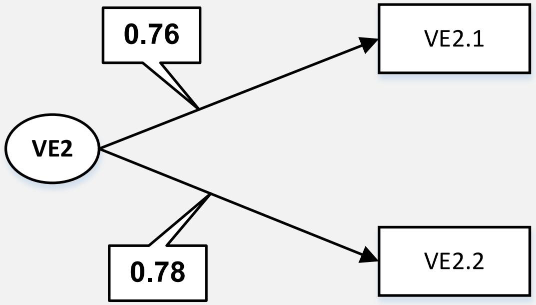
If you have any questions, feel free to contact me by phone (+61 422 358 182) or email (hamidreza.karami@postgrad.curtin.edu.au OR h.r.karami@gmail.com). Your response and time is greatly appreciated. If you would like a summary of the results, please do not hesitate to let me know.

Participant's signature……………………………………Date…………………...

I certify that I have explained the study to the volunteer and consider that she/he understands what is involved and freely consents to participation.
Researcher's name………………………………..…………………….................
Researcher's signature…………………………………..Date……………………

Table 1: Extracted VE protocols (underlined) and corresponding variables (in blue)

Extracted VE protocols	Corresponding variables	Participant comments
VE1. <u>Integrating statistics, knowledge and empirical practices into design options.</u> This refers to using all the potentials at the initial phases of design to minimise future errors and issues in later stages of the project.  	VE1.1 Using up-to-date technology in design options if possible. *Using latest technology adds value to the completed project and reduces potential issues and maintenance in operation phase.*	
	VE1.2 Considering previous studies on similar projects in the region. *This extremely helps towards efficient design and provides guidelines for design assumptions.*	
	VE1.3 Involving industry experts in the creativity phase of VE workshops. *Utilizing professional expertise in strategy development reduces the potential risks in the projects.*	
	VE1.4 Using practical methods from similar projects. *If possible, adopting methods from similar projects help with project schedule, resource allocation and risk reduction.*	
	VE1.5 Contractor's involvement to integrate expert knowledge into design options. *This helps in foreseeing future practical issues from the point of view of an expert, particularly the contractor.*	
	VE1.6 Using expert knowledge to analyse duration of initial tasks on major activities to ensure accuracy. *This validates the accuracy of scheduling.*	
	VE1.7 Monitoring weather conditions daily to plan ahead against severe weather conditions. *This means having access to up-to-date statistics for confronting environmental issues.*	
	VE1.8 Using plan-ahead packages to deal with inclement weather conditions. *This means having action plans to protect resources, crew and unfinished structures against severe weather conditions.*	

<table>
<tr><td colspan="3">Please suggest additional variables that may have been missed in above underlined theme (VE1).</td></tr>
<tr><td rowspan="2"><u>VE2. Geotechnical assumptions</u>
This relates to the assessment of geotechnical conditions and the implementation of precise pilot studies to mitigate potential issues in later stages, in particular the construction phase.

</td><td>VE2.1 Specifying budgets for pilot studies to prevent unpredictable delays. It is necessary to allocate a budget for precise pilot studies at initial stages of design.</td><td></td></tr>
<tr><td>VE2.2 Considering a pilot study in relation to the ground conditions. Commencing the construction phase without considering geotechnical assumptions can lead to major issues particularly in deep foundations and, more specifically, pile driving activities.</td><td></td></tr>
<tr><td colspan="3">Please suggest additional variables that may have been missed in above underlined theme (VE2).</td></tr>
<tr><td rowspan="3"><u>VE3. All-embracing schedule (work breakdown, resource allocation and inclement weather conditions)</u>
It applies to detail planning at various levels with clearly defined and assessed resource management, activity breakdowns and how the environmental conditions will impact those activities.</td><td>VE3.1 Having a detailed work breakdown for critical activities. There should be a sequenced breakdown for major activities such as pile driving to facilitate the implementation process and resource allocation.</td><td></td></tr>
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<tr><td>VE3.3 Establishing a flexible schedule for activities that can be affected by weather conditions. In some situations, uncertainties and the nature of marine construction demands a degree of scheduling flexibility, such as pile driving or logistical support.</td><td></td></tr>
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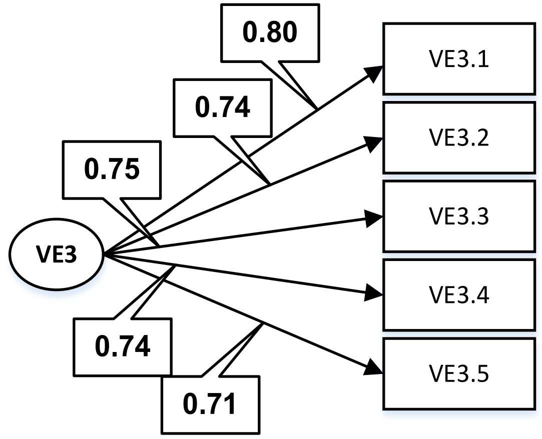
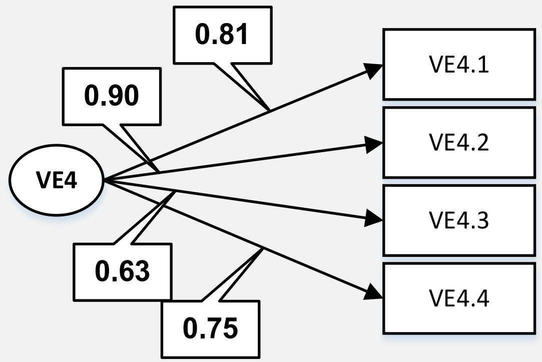
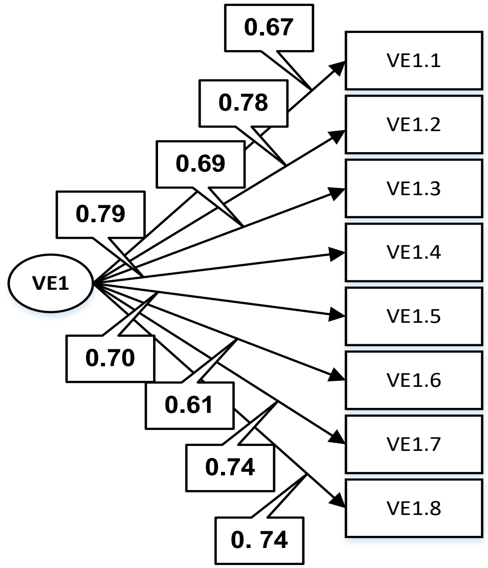
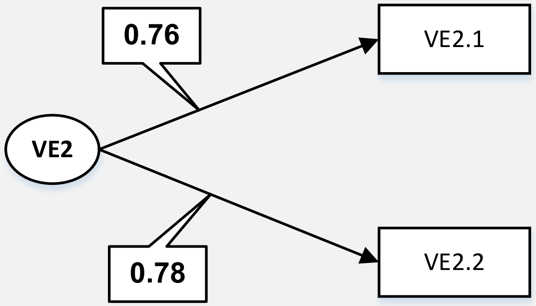
	VE3.4 Addressing activities that can be affected by weather conditions. *Such activities should be identified at planning stage to reduce the risk of overruns, cost and time in particular.*	
	VE3.5 Outsourcing mass productions such as pre-casts to save time. *Outsourcing is a practice which, if only managed properly, can save cost and time.*	
Please suggest additional variables that may have been missed in above underlined theme (VE3).		
<u>VE4. Processes and methods optimisation</u> It includes evaluating all procedure and methods towards risk reduction and adding value to the project. 	VE4.1 Analysing alternative methods. *This is part of value engineering work shop in which different strategies are discussed and the best is nominated.*	
	VE4.2 Analysing alternative resources. *It includes evaluating substitute resources that aims to maximise project value while maintaining cost-effectiveness, quality and time.*	
	VE4.3 Implementing methods for major tasks. *There should be predefined strategies for some major activities which reduces the risk and potential errors in construction phase such as heavy lifting and mass concreting.*	
	VE4.4 Having appropriate procedure for repetitive tasks and mass production. *It would be time and cost-effective to have predefined procedures for repetitive tasks and mass production in which required resources (Including manpower, equipment and material), delivery frequency and approval procedures are considered (e.g. Pile driving).*	

Please suggest additional variables that may have been missed in above underlined theme (VE4).		
Extracted VE protocols	**Corresponding variables**	**Participant comments**
VE1. <u>Integrating statistics, knowledge and empirical practices into design options.</u> This refers to using all the potentials at the initial phases of design to minimise the future errors and issues in later stages of the project. 	VE1.1 Using up-to-date technology in design options if possible. *Using latest technology adds value to the completed project and reduces potential issues and maintenance in operation phase.*	
	VE1.2 Considering previous studies on similar projects in the region. *This extremely helps towards efficient design and provides guidelines for design assumptions.*	
	VE1.3 Involving industry experts in the creativity phase of VE workshops. *Utilizing professional expertise in strategy development reduces the potential risks in the projects.*	
	VE1.4 Using practical methods from similar projects. *If possible, adopting methods from similar projects help with project schedule, resource allocation and risk reduction.*	
	VE1.5 Contractor's involvement to integrate expert knowledge into design options. *This helps in foreseeing future practical issues from the point of view of an expert, particularly the contractor.*	
	VE1.6 Using expert knowledge to analyse duration of initial tasks on major activities to ensure accuracy. *This validates the accuracy of scheduling.*	
	VE1.7 Monitoring weather conditions daily to plan ahead against severe weather conditions. *This means having access to up-to-date statistics for confronting environmental issues.*	
	VE1.8 Using plan-ahead packages to deal with inclement weather conditions. *This means having action plans to*	

	protect resources, crew and unfinished structures against severe weather conditions.	
Please suggest additional variables that may have been missed in above underlined theme (VE1).		
<u>VE2. Geotechnical assumptions</u> This relates to the assessment of geotechnical conditions and the implementation of precise pilot studies To mitigate potential issues in later stages, in particular the construction phase.  	VE2.1 Specifying budgets for pilot studies to prevent unpredictable delays. *It is necessary to allocate a budget for precise pilot studies at initial stages of design.*	
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<u>VE3. All-embracing schedule (work breakdown, resource allocation and inclement weather conditions)</u> It applies to detail planning at various levels with clearly defined and assessed resource management, activity breakdowns and how the environmental conditions will impact those activities.	VE3.1 Having a detailed work breakdown for critical activities. *There should be a sequenced breakdown for major activities such as pile driving to facilitate the implementation process and resource allocation.*	
	VE3.2 Monitoring/optimising resource allocation. *Unplanned allocation of resources like over-allocation or under-allocation leads to cost and time overruns.*	
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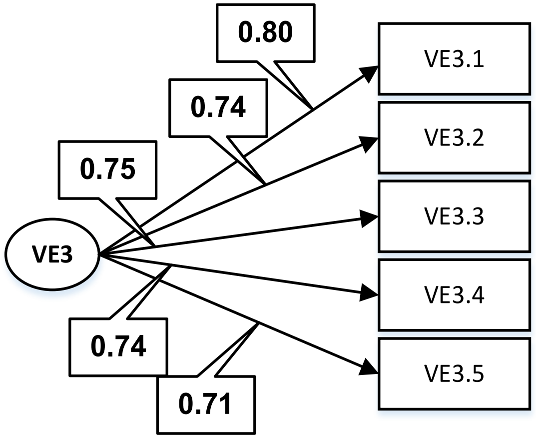
<tr><td rowspan="3">
</td><td>construction demands a degree of scheduling flexibility, such as pile driving or logistical support.</td><td></td></tr>
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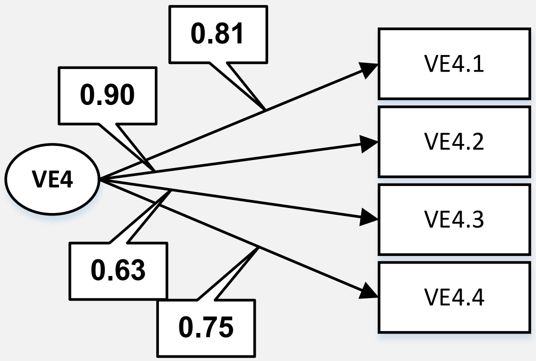
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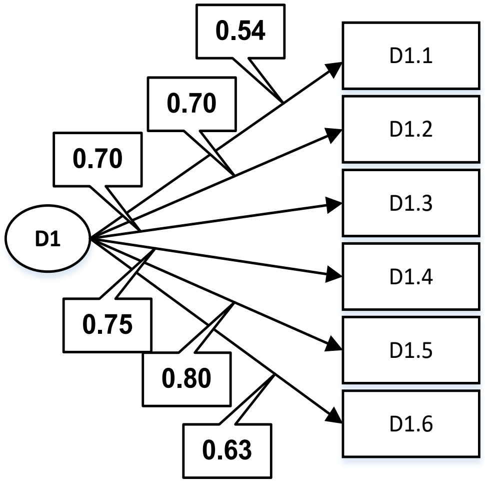
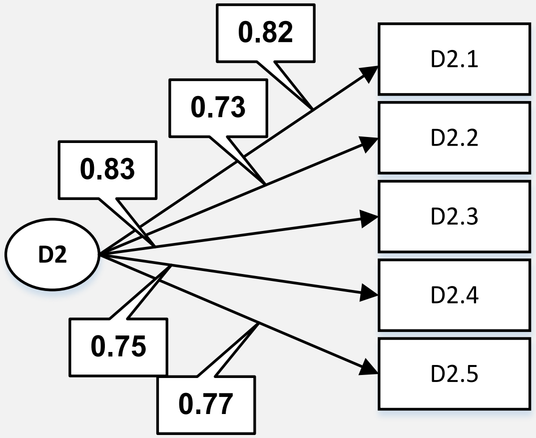
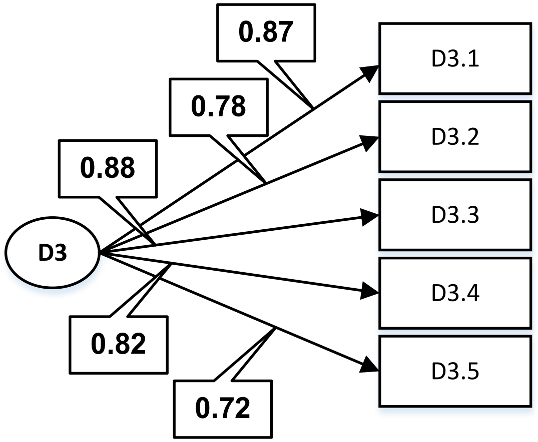
Please suggest additional variables that may have been missed in above underlined theme (VE4).

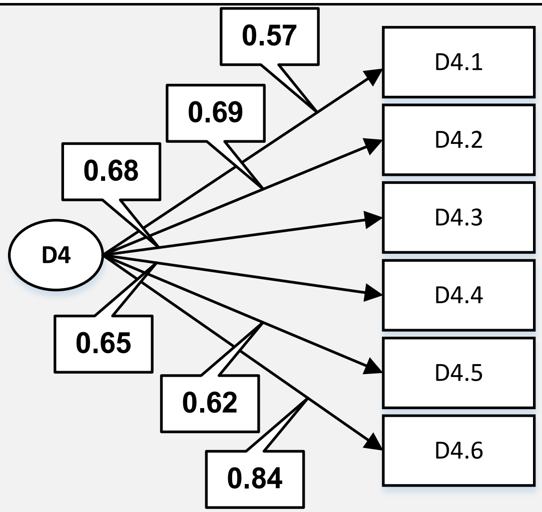
Please provide your comment/s on the relationship between the variables (VE1.1 to VE4.4).lease provide your comment/s on the relationship between the variables (VE1.1 to VE4.4).

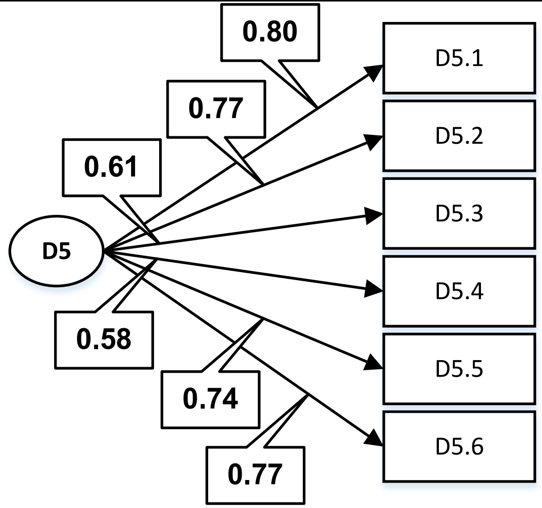
Table 2: Delay-related themes (underlined) and corresponding variables (in blue)

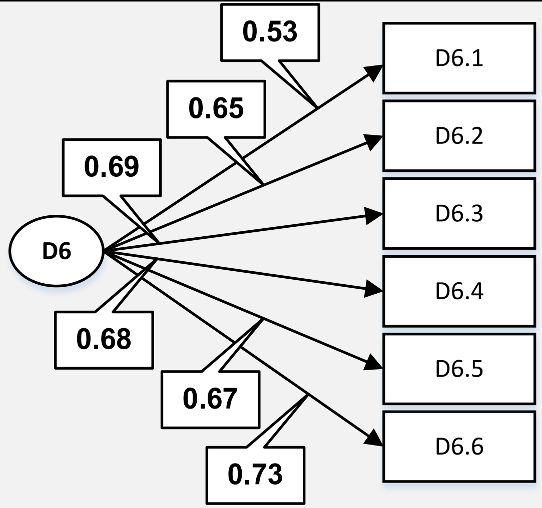
Delay theme	Corresponding variables	Participant comments
<u>D1 Client–contractor interruptions</u> This applies to various types of issues between client and contractor such as each party’s attitude, corruption, changing in scope or claim-related problems. 	D1.1 Delay in land delivery. *This leads to inability to generate income from delayed enterprise for clients and losing money to inflation, delayed resources and ongoing preliminaries for contractors.*	
	D1.2 Inappropriate decision processes. *Inadequate decision making in each party may have multiple origins, such as organisational problems, lack of sufficient database and novice managerial staff.*	
	D1.3 Delays in subcontractors’ job delivery. *It is a very common concern that usually emerges from financial issues, owing in particular to the payment sequences of the client.*	
	D1.4 Low speed in job site transfer. *Similar to 1.1, client-imposed incomplete delivery of the job site will impact the contractor in terms of delayed start and planning incapacity.*	
	D1.5 Inefficient information stream. *Inefficiency in sharing information relevant to the project, such as improper documentation, is the cause of potential problems and allegations.*	
	D1.6 Change orders imposed by the client. *This issue originates from numerous sources such as design related issues, omissions in scope and estimation errors at initial phases.*	

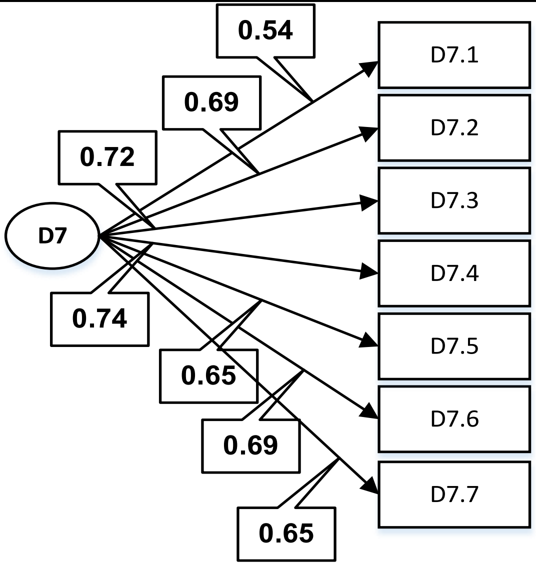
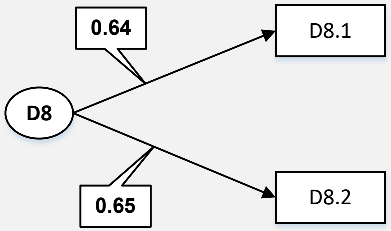
Please suggest additional variables that may have been missed in above underlined theme (D1).		
<u>D2. Inadequate planning</u> Planning applies to every necessary step that should be considered to define and achieve the project objectives. Failure in adequate planning leads to cost and time overruns.  	D2.1 Lack of optimising/monitoring resource allocation. *Resources should be used as and where appropriate otherwise they cause overruns on costs and schedules.*	
	D2.2 Not involving the contractor in early design phase. *The involvement of qualified contractors in initial stages of design reduces the potential errors in later phases, construction phase in particular.*	
	D2.3 Lack of considering alternative resources. *Substitution of the resources in some cases helps with project schedule. For example, using material of the same quality but easily available.*	
	D2.4 Lack of appropriate quality assurance system on site. *Validating the quality on site and recording it prevents future rework.*	
	D2.5 Lack of planning for mass production. *Appropriate planning for mass production which includes all required resources saves both time and expenses. This can be done in-house or out-sourced.*	
Please suggest additional variables that may have been missed in above underlined theme (D2).		
D3. Safety practices	D3.1 Lack of safety training and meetings prior to commencing construction. *Training and meetings*	

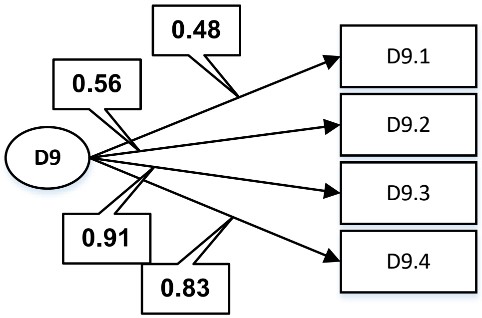
Safety applies to all precautionary measures intended to prevent or minimise risk to both personnel and equipment. 	*increase the staff's awareness, reduce injuries and accidents and ameliorate productivity among employees.*	
	D3.2 Safety issues. *Depending on the degree of severity, it may affect the work flow and create time overruns.*	
	D3.3 Damaging marine equipment during execution due to lack of safety. *Any damage to high-end marine equipment slows down the construction flow. They are not easy to replace.*	
	D3.4 Inspection procedures employed in construction site. *During thorough periodical inspections, any safety issue on the job site should be reported and taken action against.*	
	D3.5 Accident during construction. *Accidents can vary from damage to equipment to personal injury, with overruns in time and cost.*	
Please suggest additional variables that may have been missed in above underlined theme (D3).		
D4. Instructions/communications Inappropriate communications or guidelines in various disciplines originating from different factors can influence the project's workflow.	D4.1 Improper site instructions imposed on contractors. *Incorrect instructions enforced by either client or consultant lead to rework, time overrun and thus open the gateway for contractors to claim.*	
	D4.2 Contradiction between tender documents and actual situation. *Inaccurate information provided to contractors contributes to redesign, rework and thus overruns in time and expense (e.g. Geotechnical assumptions).*	
	D4.3 Poor consultant's auditing system. *A precise auditing system ensures quality and prevents any rectification or rework.*	

	D4.4 Social and cultural factor. *Cultural diversity and social factors can affect communications and human resource management in a project.*	
	D4.5 Lack of efficient design. *Instructions developed out of an inefficient design have a negative impact on schedule and expenses of the projects.*	
	D4.6 Lack of database in estimating activity duration and resources. *Instructions developed from unreliable estimates lead to time overruns.*	
Please suggest additional variables that may have been missed in above underlined theme (D4).		
D5. Management approaches This refers to using the best management strategy to address multiple challenges and interact with different disciplines.	D5.1 Lack of proper cooperation between consultant and contractor. *This creates conflicts and tensions, weak collaboration and failure to satisfy the stakeholders' expectations, on-time completion in particular.*	
	D5.2 Lack of cooperation between client and consultant. *This creates disputes and failure in achieving the project's objectives as planned.*	
	D5.3 Inadequate form of contract. *Contract management is a very important section within the client's department, where various contracts are produced for specific projects. Inadequate contract causes disputes and conflicts.*	
	D5.4 Construction method. *The most practical construction strategy should be developed and implemented by the management team.*	

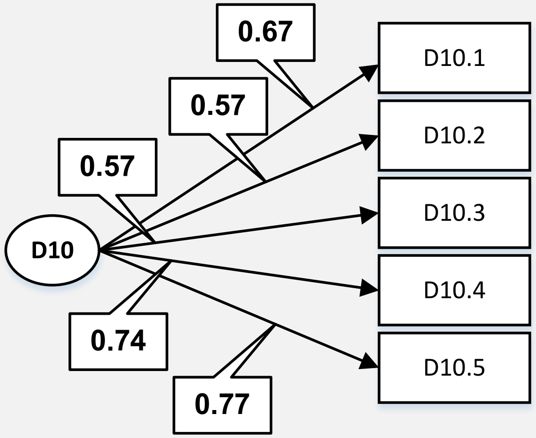
	D5.5 Unstable management structure and style of contractor. *Successful completion is not achieved unless the management system is well structured.*	
	D5.6 Unavailability of professional construction management. *Not having efficient construction management team leads to different issues such as time and cost overruns and thus stakeholders' dissatisfaction.*	
Please suggest additional variables that may have been missed in above underlined theme (D5).		
D6. Design and construction issues This definition includes issues such as unskilled personnel and inaccurate assumptions. Any error at initial design stages directly impacts the construction phase.	D6.1 Inexperienced personnel. *Using novice team members increases the risk levels, errors and leads to rework and ultimately time-loss.*	
	D6.2 Lack of consultant's practical experience. *Insufficient practical experience of consultant creates conflicts and delays the work flow (e.g. Work permits and approvals).*	
	D6.3 Inadequate design team experience. *Any issue that emerges from design team dysfunction escalates to other levels and leads to rework and time-loss.*	
	D6.4 Lack of pilot study prior to construction. *Design assumptions should be based on precise pilot studies to eliminate potential issues in other phases, construction in particular.*	

	D6.5 Impractical design. *Impractical design often creates issues in the construction process which lead to redesign, rework and schedule overrun.*	
	D6.6 Unforeseen ground conditions. *Unexpected geotechnical issues often interrupt the construction process and can lead to a redesign depending on the severity.*	
Please suggest additional variables that may have been missed in above underlined theme (D6).		
D7. Organisational structure An organisational structure is a framework that describes how certain tasks are oriented towards achieving an organisation's objectives. This include regulations, responsibilities and different departments within the organisation. The framework also regulates the information stream within the organisation.	D7.1 Outdated technology. *Outdated technology impacts the efficiency of the organisation. Examples include human error, failure to compete with other organisations and delay in project completion.*	
	D7.2 Lack of Value Engineering department in organisation. *Through involving the entire team, this approach reduces costs, improves the quality and saves time by offering alternative solutions.*	
	D7.3 Inappropriate communications. *This causes disputes and conflicts, poor cooperation and failure to meet the stakeholders' requirements, on-time completion in particular.*	
	D7.4 Inefficient coordination among critical disciplines. *Projects are unlikely to achieve their*	

	*predefined time and cost benchmarks unless the disciplines are well coordinated.*	
	D7.5 Poor site control by contractors. *Efficient on-site supervision lowers the risks dramatically, prevents rework and improves the schedule.*	
	D7.6 Lack of liabilities in different parties. *All stakeholders should adhere to their responsibilities to attain the project's objectives.*	
	D7.7 Not utilising lessons learned from similar projects. *Well-structured organisation-wide documentation and database help towards efficient design and provide useful guidelines.*	
Please suggest additional variables that may have been missed in above underlined theme (D7).		
D8. Political/cultural factors Political factors are imposed by the government on the economy or some sectors while cultural factors are environmental factors that require particular strategies. 	D8.1 Neighbours' interference. *In construction projects, having problems with neighbours can cause late start and also interrupt the project at different stages.*	
	D8.2 Delay in importing materials due to political conditions. *Political issues like sanctions have a direct effect on the schedule and can cause lengthy delays and even stop the project.*	
Please suggest additional variables that may have been missed in above underlined theme (D8).		

D9. Environmental uncertainties Refers to unpredictable factors influencing the project. 	D9.1 Weather considerations. *Weather instability interrupts the project's cycle, leads to significant delays and contributes to budget overruns.*	
	D9.2 High and low tides. *This phenomenon can influence certain operations, and should therefore be considered in the planning stage.*	
	D9.3 Conditions of water table on construction site. *Like above, activities which can be affected should be identified and planned ahead of time.*	
	D9.4 Unreliable geological assumptions. *Unreliable assumptions interrupt the construction process and can lead to a redesign depending on the extent.*	
Please suggest additional variables that may have been missed in above underlined theme (D9).		

D10. Extreme and complex resources Due to dynamic nature and unique characteristics, marine projects require sophisticated technology and complex resources, different from land-based projects. This may include human resources, machinery and material.	D10.1 Skill shortage. *Lack of experienced operators for high-end equipment in marine projects may result in accidents during the construction process.*	
	D10.2 Inappropriate contractor. *Taking into account the intense budget and specific attributes of marine projects, hiring an inexperienced contractor raises the risk of cost and time overrun.*	
	D10.3 Delayed resources. *Due to complexity and uniqueness of the resources, they are not immediately accessible and should be organized well in advance.*	
	D10.4 Procurement and resource allocation. *An effective and consistent planning is required to ensure that resources are made available where and when necessary. This eliminates the risk of over-allocation or under-allocation.*	

	D10.5 Labour's productivity. *Within this multidisciplinary environment, the productivity of the work force is of great importance which directly impacts the schedule and can be improved by training programmes.*	
Please suggest additional variables that may have been missed in above underlined theme (D10).		
D11. Activity estimation errors Estimation errors often result in scheduling failure. Scheduling theory requires in-depth attention to prevent potential issues in different stages of the projects, time overrun in particular.	D11.1 Over-optimism scheduling. *In estimation process, you should consider what you can realistically achieve within the allocated time. Unrealistic scheduling influences the activity sequences and creates time overrun.*	
	D11.2 Estimation errors in early design phase. *Estimation inaccuracies at the early stages could lead to a catastrophe and deviation from predefined time and budget objectives.*	
	D11.3 Impractical contract duration imposed by client. *This originates from lack of scheduling knowledge and not being involved in initial planning stages. Expecting an impractical completion time raises the risk of construction-phase errors and accidents.*	
	D11.4 Poor judgment and experience in estimation processes. *Estimation inaccuracies directly impact*	

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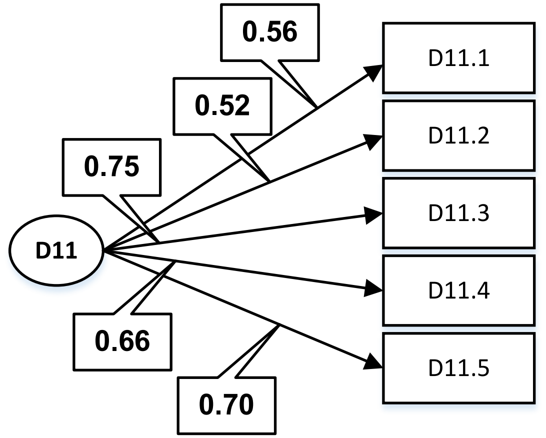
<td rowspan="2"></td>
<td>the tasks sequences, leading to change of critical path in project’s schedule and creating delays in operation phase.</td>
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<td>D11.5 Not adopting flexible timetable for certain tasks. Uncertainties and the complexity of marine construction in certain cases require a degree of flexibility in the scheduling, such as pile driving or logistical support. This helps with project schedule and can compensate time-loss in certain situations.</td>
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<td colspan="3">Please suggest additional variables that may have been missed in above underlined theme (D11).</td>
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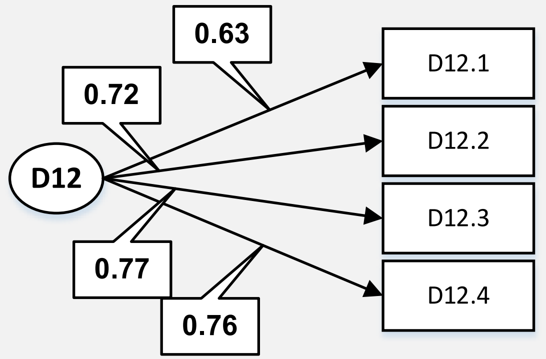
<td rowspan="4">D12. Owner’s stagnant structure
The attitude of the owner can influence the project’s efficiency. It can either accelerate or decelerate the workflow.
</td>
<td>D12.1 Lack of financial incentive for contractor to finish ahead of schedule. Incentives contribute to on-time completion in which both contractor and client would benefit from.</td>
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<td>D12.2 Uncooperative owner. Client/owner who is unwilling to contribute will lose income from delayed enterprise.</td>
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<td>D12.3 Insufficient communication of owner and design team in design phase. Involving the owner in the initial design phase is essential. It eliminates the potential issues such as scope change and redesign which directly impact the project’s schedule.</td>
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<td>D12.4 Extreme bureaucracy in client’s organisation. Excessive bureaucracy on client side, especially in terms of project approvals, interrupts the project’s flow and delays on-time completion.</td>
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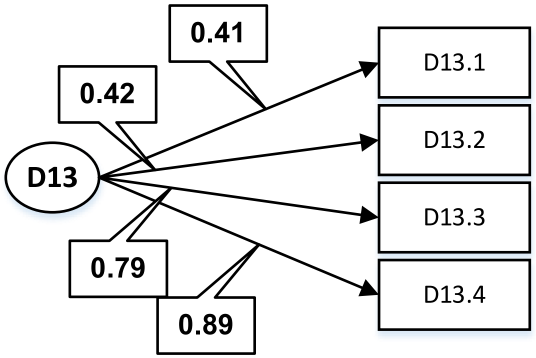
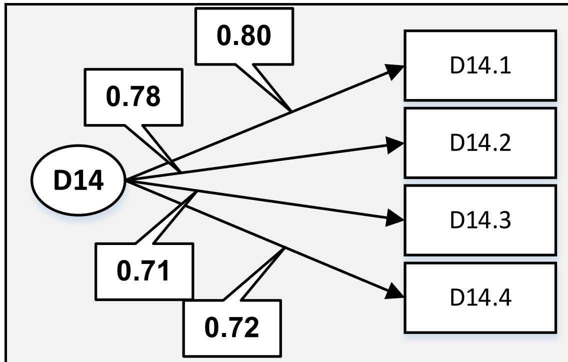
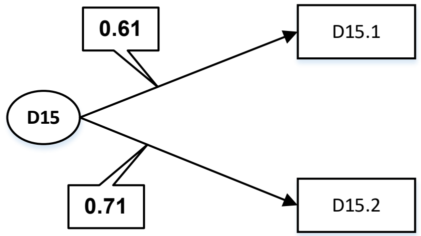
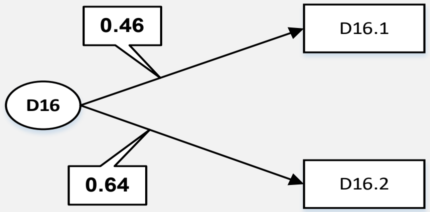
Please suggest additional variables that may have been missed in above underlined theme (D12).		
D13. Financial issues Financial issues are very common in construction projects with various sources, including late payments, unpredictable financial market and insufficient financing. 	D13.1 Owner's financial security. *Owners/clients must foresee and satisfy cash flow requirements of their project if they intend to succeed. Poor cash flow management causes interruption and consequently delays in projects.*	
	D13.2 Financial difficulties of the contractor. *Contractor's financial issues may have a direct effect on the work flow. For example, inability to purchase required material or hire equipment affect the work flow while not paying the employees influences the productivity. Financial capability of the contractors in marine projects is very important.*	
	D13.3 Escalation in resource prices. *Price escalation is caused by instability in market which affects the stakeholders' financial situation and deviates the project from predefined budget and time. It can completely stop the project, depending on the severity.*	
	D13.4 Price fluctuations. *Fluctuation in prices interrupts the cash flow management and leads to economic difficulties for stakeholders. This may interrupt or stop the project's work flow.*	
Please suggest additional variables that may have been missed in above underlined theme (D13).		
D14. Delay in approval processes Approval process mean specifying the protocols to follow, for the completed task to be approved. It should be straightforward and functional so that workflow is not disrupted or stopped.	D14.1 Late work approval. *Delay in task approval can interrupt or stop the work flow in the projects, particularly if it is located on the schedule's critical path.*	
	D14.2 Delay in test results approval. *Delay in providing the test results can lead to interruption in operation sequences. As an example of marine*	

	*construction, late approval of welding results may delay the next stage of coating in pile preparation process.*	
	D14.3 Delay in documents/drawings approval. *Delayed document / drawing approval often leads to delay for the projects. One remedy could be to stipulate the permissible document processing period in the contract documentations.*	
	D14.4 Shop drawings' preparation and approval. *Shop drawings, normally prepared by the contractor before construction commences, supplement working drawings. On-time preparation and approval facilitates the construction process and eliminates potential confusions.*	
Please suggest additional variables that may have been missed in above underlined theme (D14).		
D15. Construction strategies hey are mechanisms through which the construction process commences, is monitored and managed. 	D15.1 Lack of execution methods for major tasks. *Predefined strategies should be in place for certain major operations, such as heavy lifting and under water concreting, which reduce the risk and possible errors in the construction process.*	
	D15.2 Inappropriate work breakdown system by the contractor. *Failure to develop a sequenced breakdown for the project activities interrupts the implementation process and creates inefficiency in allocated resources.*	
Please suggest additional variables that may have been missed in above underlined theme (D15).		
D16. Marine equipment	D16.1 Unresponsive marine equipment. *The marine equipment should be chosen in*	

<table>
<tr>
<td rowspan="2">It is crucial to evaluate in advance the type and size of equipment required when planning for a marine construction project.

</td>
<td>accordance with the project requirements. For example, overloading a crane rather than hiring a heavy duty crane will result in accidents and time-loss. Another example is using outdated equipment that decelerates the work flow.</td>
<td></td>
</tr>
<tr>
<td>D16.2 Skill shortage for high-end marine equipment. Dearth of experienced operators for high-end equipment in marine construction leads to accidents during the construction process.</td>
<td></td>
</tr>
<tr>
<td colspan="3">Please suggest additional variables that may have been missed in above underlined theme (D16).</td>
</tr>
</table>

Please provide your comment/s on the relationship between the variables (D1.1 to D16.2).

Table 3: General queries

No.	Question	Description
1	Please describe your current position and/or qualifications.	
2	How many years' of experience do you have in marine construction projects? Private or public sector?	
3	How often the projects are facing delay in your organisation?	
4	Please identify the best time / s (lifecycle) for implementing the VE in marine projects that will have a greater effect on reducing potential overrun issues.	

Please provide your impression about this work. What is your overall perception on likelihood of addressing the delay issues through implementing VE protocols? Please provide examples if necessary.

Appendix 3 Consent Form for Open-ended Questionnaire

Curtin University

Causality Analysis of Construction Delays and Value Engineering Protocols in Marine Projects

I (Participant's name) being over the age of 18 years, hereby consent to participate as requested in open-ended survey questionnaire for the research project on 'Causality Analysis of Construction Delays and Value Engineering Protocols in Marine Projects'.

I further confirm that:

1. I have read the information provided.
2. Details of procedures and any risks have been explained to my satisfaction.
3. I am aware that I should retain a copy of the Information Sheet and Consent Form for future reference.
4. I understand that:

- I may not directly benefit from taking part in this research
- I am free to withdraw from the project at any time and am free to decline to answer particular questions
- While the information gained in this study will be published as explained, I will not be identified, and individual information will remain confidential
- Whether I participate or not, or withdraw after participating, will have no effect on any treatment or service that is being provided to me

5. I have had the opportunity to discuss taking part in this research with a family member or friend.

Participant's signature……………………………………Date…………………...

I certify that I have explained the study to the volunteer and consider that she/he understands what is involved and freely consents to participation.

Researcher's name…………………………………………………………..................

Researcher's signature…………………………………..Date……………………

If you have any questions about this survey feel free to contact me through below email addresses (hamidreza.karami@postgrad.curtin.edu.au OR h.r.karami@gmail.com).

Appendix 4 Information Statement for Open-ended Questionnaire

Hamidreza Karami

Curtin University

Construction Management

You are invited to participate in a Higher Degree Research on 'Causality Analysis of Construction Delays and Value Engineering Protocols in Marine Projects'. The purpose in this research is to examine delay causations and whether they can be mitigated by specific value engineering processes. I decided to use a qualitative approach to determine the external validity of the findings, in particular an open-ended questionnaire. This requires obtaining the opinions of stakeholders and experienced construction experts. You are invited as a possible participant in this study. Please read this sheet carefully and be confident that you understand its contents before deciding whether to participate.

The study is being carried out by Mr Hamidreza Karami under the supervision of Associate professor Oluwole Olatunji from the School of Design and the Built Environment at Curtin University, Perth, Australia. This open-ended survey questionnaire requires you to contribute to the research by using your experiences and knowledge to assess the validity of the results. Findings from the early stages of the research will be provided and you require to express your point of view on this. Please return the questionnaire within two months of receiving the documents. Apart from giving up your time, we do not expect any risks or costs associated with taking part in this study.

All personal and identifiable information collected as part of this study will be kept confidential. All responses will be de-identified at the point of data analysis. Results from this study may be published in scientific journals, conference presentations and may also be used to support further research projects. All electronic and hardcopy data collected as part of this study will be stored during and after the study in a confidential folder on the Curtin University, Faculty of Humanities research drive. Only the investigators of this study will have access to this data. This data will be kept for a maximum of 7 years for the purposes of this research. By providing your consent, you are agreeing to us collecting personal information about you for the purposes of this research study. Your information will only be used for the purposes outlined in this Participant Information Statement, unless you consent otherwise. Your information will be stored securely and kept strictly confidential, except as required by law. Study findings may be published, but you will not be individually identifiable in these publications.

When you have read this information, I will discuss it with you further and answer any questions you may have. If you would like to know more at any stage, please feel free to contact either me or Associate professor Oluwole Olatunji (Oluwole.Olatunji@curtin.edu.au). Further, you are welcome to tell other people about the study. If you would like a summary of the results, please do not hesitate to let me know using provided contact details.

Participation in this study is voluntary. You are not under any obligation to consent to participate and if you do consent, you can withdraw at any stage. You can withdraw your consent by advising the researcher either verbally or via email.

Curtin University HREC has approved this study (HRE2017-0641). Should you wish to discuss the study with someone not directly involved, in particular, any matters concerning the conduct of the study or your rights as a participant, or you wish to make a confidential complaint, you may contact the Ethics Officer on (08) 9266 9223 or the Manager, Research Integrity on (08) 9266 7093 or email hrec@curtin.edu.au. Any complaint will be investigated promptly and you will be informed of the outcome.

This information sheet is for you to keep

Appendix 5 Invitation Letter for Open-ended Questionnaire

Curtin University

Causality Analysis of Construction Delays and Value Engineering Protocols in Marine Projects

Dear Participant:

In a Higher Degree Research, I am conducting a study on 'Causality Analysis of Construction Delays and Value Engineering Protocols in Marine Projects'. To investigate the external validity of the findings, I decided to use the views of stakeholders and experienced construction experts using an open-ended survey questionnaire.

Please complete the questionnaire for this study (you will find this attached). Your participation will help us to investigate critical value engineering protocols and delay causations in marine construction projects. Your participation in the survey is completely voluntary and all of your responses will be kept confidential.

Please complete the survey within two months of receiving the documents. You may return the survey to my email address (see below) if you choose to fill the survey manually.

By completing and returning the survey you are giving consent for your response to be included in the study. All information that you provide will remain confidential and will be de-identified for all analyses.

If you have any questions about this survey feel free to contact me by phone (+61 422 358 182) or email (hamidreza.karami@postgrad.curtin.edu.au OR h.r.karami@gmail.com).

Your response and time is greatly appreciated. If you would like a summary of the results, please do not hesitate to let me know.

Sincerely yours,

Hamidreza Karami

Curtin University

Construction Management

Appendix 6 Consent Form for Closed-ended Questionnaire

Curtin University

Causality Analysis of Construction Delays and Value Engineering Protocols in Marine Projects

I (Participant's name) being over the age of 18 years, hereby consent to participate as requested in the (Interview or Survey) for the research project on 'Causality Analysis of Construction Delays and Value Engineering Protocols in Marine Projects'. I further confirm that:

1. I have read the information provided.
2. Details of procedures and any risks have been explained to my satisfaction.
3. I agree to audio/video recording of my information and participation.
4. I am aware that I should retain a copy of the Information Sheet and Consent Form for future reference.
5. I understand that:

- I may not directly benefit from taking part in this research.
- I am free to withdraw from the project at any time and am free to decline to answer particular questions.
- While the information gained in this study will be published as explained, I will not be identified, and individual information will remain confidential.
- Whether I participate or not, or withdraw after participating, will have no effect on any treatment or service that is being provided to me.
- I may ask that the recording/observation be stopped at any time, and that I may withdraw at any time from the session or the research without disadvantage.

6. I have had the opportunity to discuss taking part in this research with a family member or friend.

Participant's signature……………………………………Date…………………...

I certify that I have explained the study to the volunteer and consider that she/he understands what is involved and freely consents to participation.

Researcher's name………………………………….……………………….................

Researcher's signature…………………………………..Date…………………….

If you have any questions about this survey feel free to contact me by phone (+61 422 358 182) or email (hamidreza.karami@postgrad.curtin.edu.au OR h.r.karami@gmail.com).

Appendix 7 Information Statement for Closed-ended Questionnaire

Causality Analysis of Construction Delays and Value Engineering Protocols in Marine Projects

Hamidreza Karami
Curtin University
Construction Management

You are invited to participate in a Higher Degree Research on ‘Causality Analysis of Construction Delays and Value Engineering Protocols in Marine Projects’. The study will create a conceptual model that can help in applying VE to mitigate schedule overruns, results from which will provide a new approach to improve schedule performance in marine projects. My aim is to obtain data on the opinions of stakeholders and experienced construction experts using questionnaire surveys and focus group interview. You are invited as a possible participant in this study. Please read this sheet carefully and be confident that you understand its contents before deciding whether to participate.

The study is being carried out by Mr Hamidreza Karami under the supervision of Dr Oluwole Olatunji from the School of Built Environment at Curtin University of Technology, Perth, Australia. This study involves completing a survey regarding your experiences about Value Engineering utilisation and delay causations in construction projects. It is anticipated that the survey would take approximately 30 minutes to complete. Apart from giving up your time, we do not expect any risks or costs associated with taking part in this study.

As a participant in this study, you will be involved in activities such as audio/video taping, questionnaires and focus groups interviews. All personal and identifiable information collected as part of this study will be kept confidential. All survey responses will be de-identified at the point of data extraction for the purpose of analysis. Results from this study may be published in scientific journals, conference presentations and may also be used to support further research projects. All electronic and hardcopy data collected as part of this study will be stored during and after the study in a confidential folder on the Curtin University,nFaculty of Humanities research drive. Only the investigators of this study will have access to this data. This data will be kept for a maximum of 7 years for the purposes of this research. By providing your consent, you are agreeing to us collecting personal information about you for the purposes of this research study. Your information will only be used for the purposes outlined in this Participant Information Statement, unless you consent otherwise. Your information will be stored securely and kept strictly confidential, except as required by law. Study findings may be published, but you will not be individually identifiable in these publications.

When you have read this information, I will discuss it with you further and answer any questions you may have. If you would like to know more at any stage, please feel free to contact either me or Dr Oluwole Olatunji (Oluwole.Olatunji@curtin.edu.au). Further, you are welcome to tell other people about the study. If you would like a summary of the results, please do not hesitate to let me know using provided contact details.

Participation in this study is voluntary. You are not under any obligation to consent to complete the questionnaire/survey and if you do consent, you can withdraw at any stage. You can withdraw your consent by advising the researcher either verbally or via email.

Curtin University HREC has approved this study (HRE2017-0641). Should you wish to discuss the study with someone not directly involved, in particular, any matters concerning the conduct of the study or your rights as a participant, or you wish to make a confidential complaint, you may contact the Ethics Officer on (08) 9266 9223 or the Manager, Research Integrity on (08) 9266 7093 or email hrec@curtin.edu.au. Any complaint will be investigated promptly and you will be informed of the outcome.

This information sheet is for you to keep

Appendix 8 Invitation Letter for Closed-ended Questionnaire

Survey Participation Request
Dear Participant:

In a Higher Degree Research, I am conducting a study on 'utilising value engineering methodology as a delay mitigation tool in near shore and offshore projects'. One of my intentions is to obtain data on the opinions of stakeholders and experienced construction experts using questionnaire surveys and focus group interview. The study will create a conceptual model that can help in applying VE to mitigate schedule overruns, results from which will provide a new approach to improve schedule performance in marine projects.

Please complete the questionnaire for this study (you will find this attached or through the link supplied below). Your participation will help us to understand critical value engineering factors and delay causations in near shore and offshore projects. It is anticipated that the survey would take approximately 30 minutes to complete. Your participation in the survey is completely voluntary and all of your responses will be kept confidential. Please complete the survey by (Return Date). You may return the survey to my email address (see below) if you choose to fill the survey manually; if you complete the survey online, the online system will report your responses to me directly.

By completing and returning the survey you are giving consent for your response to be included in the study. All information that you provide will remain confidential and will be de-identified for all analyses.

If you have any questions about this survey feel free to contact me by phone (+61 422 358 182) or email (hamidreza.karami@postgrad.curtin.edu.au OR h.r.karami@gmail.com).

Your response and time is greatly appreciated. If you would like a summary of the results, please do not hesitate to let me know.

Sincerely yours,

Hamidreza Karami
Curtin University of Technology
Construction Management

Appendix 9-Anti-image correlation matrix for delay variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73
1	.668[a]
2	-0.360	.776[a]
3	-0.047	-0.140	.807[a]
4	0.144	0.031	0.127	.622[a]
5	-0.124	-0.039	-0.223	-0.682	.614[a]
6	-0.129	-0.100	0.028	0.010	-0.218	.831[a]
7	0.142	-0.084	0.059	0.046	-0.266	0.079	.747[a]
8	-0.324	0.126	-0.195	-0.157	0.288	-0.171	-0.580	.726[a]
9	-0.242	0.203	-0.125	-0.138	0.012	0.211	-0.087	0.090	.852[a]
10	-0.205	0.067	-0.182	-0.462	0.574	-0.249	-0.440	0.413	0.077	.785[a]
11	0.284	-0.035	0.082	0.399	-0.357	-0.236	0.044	-0.120	-0.345	-0.328	.868[a]
12	-0.036	-0.039	0.116	-0.172	0.054	0.050	0.155	-0.168	0.047	-0.062	-0.224	.864[a]
13	-0.153	0.156	-0.069	-0.124	0.166	-0.072	-0.024	0.156	0.209	0.159	0.027	-0.277	.905[a]
14	-0.024	-0.055	-0.021	0.162	-0.140	0.122	0.072	-0.198	-0.044	-0.133	-0.009	0.197	-0.255	.907[a]
15	0.237	-0.140	-0.178	-0.099	-0.011	0.008	0.395	-0.333	-0.100	-0.227	-0.117	0.136	-0.105	-0.054	.847[a]
16	-0.021	-0.013	0.073	0.069	-0.038	0.134	-0.198	0.180	0.029	-0.085	0.000	0.108	-0.070	0.136	-0.156	.913[a]
17	-0.005	-0.006	0.263	-0.122	-0.232	0.357	0.302	-0.319	-0.018	-0.337	-0.093	0.151	-0.048	0.017	0.159	-0.076	.736[a]
18	0.046	0.068	-0.121	0.284	-0.029	-0.279	-0.252	0.095	-0.070	0.035	0.093	-0.246	-0.109	-0.106	-0.308	-0.094	-0.400	.703[a]
19	-0.088	-0.004	-0.065	0.038	-0.049	0.027	-0.077	-0.011	0.154	0.063	-0.172	-0.316	0.001	-0.060	-0.057	-0.160	-0.082	0.263	.884[a]
20	0.234	-0.033	0.154	0.121	-0.294	0.243	0.107	-0.292	-0.052	-0.284	0.164	0.022	-0.158	0.124	-0.102	0.065	0.240	0.012	-0.174	.921[a]
21	0.088	-0.021	-0.126	0.091	-0.043	0.060	0.119	0.006	0.050	-0.124	-0.092	-0.132	0.030	-0.067	0.109	0.004	0.112	-0.033	0.137	-0.132	.916[a]
22	-0.150	0.042	-0.267	-0.298	0.087	-0.006	0.071	0.062	0.089	0.208	-0.226	0.265	0.036	0.006	0.152	-0.138	0.126	-0.268	-0.193	-0.164	-0.070	.807[a]
23	0.091	-0.093	-0.064	-0.211	0.122	-0.023	-0.139	0.119	0.016	0.183	-0.104	-0.110	0.111	-0.286	0.116	-0.109	0.040	-0.036	-0.053	-0.048	-0.192	0.259	.864[a]
24	-0.028	0.293	-0.066	0.105	0.050	-0.120	-0.267	0.190	0.054	0.129	0.238	-0.282	0.139	-0.210	-0.280	0.034	-0.347	0.233	0.082	-0.049	0.012	-0.114	-0.079	.851[a]
25	-0.028	-0.153	0.176	0.242	-0.379	0.353	0.328	-0.289	0.085	-0.540	-0.055	-0.100	-0.043	0.005	0.153	0.036	0.327	0.012	0.085	0.092	0.168	-0.176	-0.165	-0.297	.849[a]
26	0.009	-0.120	-0.151	-0.082	0.217	0.050	-0.291	0.261	-0.068	0.216	0.004	-0.003	0.011	0.303	-0.249	0.257	-0.057	-0.117	-0.100	0.025	-0.078	0.141	0.008	-0.040	-0.333	.822[a]
27	0.072	0.042	-0.037	0.332	-0.098	-0.172	0.033	-0.061	-0.094	-0.060	0.099	-0.180	-0.030	-0.069	-0.164	-0.189	-0.251	0.397	0.115	0.045	0.066	-0.331	-0.226	0.055	0.042	-0.247	.883[a]
28	-0.141	0.076	-0.172	-0.381	0.225	-0.010	-0.075	0.129	0.123	0.154	-0.151	0.155	0.106	-0.086	0.104	-0.006	-0.016	-0.191	-0.058	-0.197	-0.188	0.155	0.106	0.082	-0.084	-0.050	-0.363	.917[a]
29	0.118	-0.219	0.124	0.081	-0.101	0.022	-0.012	0.061	0.002	-0.156	0.115	-0.146	0.017	-0.016	-0.098	0.070	0.153	-0.057	0.045	0.186	0.053	-0.065	-0.083	-0.124	0.036	0.215	-0.111	-0.135	.931[a]
30	-0.100	-0.007	-0.162	-0.162	0.139	-0.064	0.037	0.092	-0.251	0.326	0.030	-0.020	0.026	-0.009	0.107	-0.207	-0.126	-0.137	-0.162	-0.093	-0.167	0.360	0.338	-0.082	-0.243	0.172	-0.154	0.038	-0.251	.875[a]
31	-0.021	0.109	0.253	-0.084	0.193	-0.020	0.090	0.011	-0.101	0.013	-0.102	-0.053	0.132	-0.003	-0.117	0.109	0.060	-0.111	-0.069	-0.142	-0.005	-0.194	-0.068	0.108	-0.104	0.081	0.038	-0.061	-0.064	-0.107	.931[a]
32	-0.179	0.050	-0.044	0.107	-0.029	-0.045	-0.328	0.223	0.000	0.141	0.118	-0.158	-0.132	0.053	-0.169	0.095	-0.282	0.228	0.130	-0.022	-0.090	-0.171	-0.141	0.149	-0.198	0.005	0.058	-0.081	0.137	-0.072	-0.198	.860[a]
33	0.174	-0.008	-0.056	0.115	-0.162	0.079	0.307	-0.340	-0.160	-0.343	0.103	0.212	-0.281	0.286	0.317	0.108	0.175	-0.280	-0.135	0.059	0.001	0.092	-0.324	-0.148	0.193	0.032	-0.079	-0.056	-0.047	-0.023	-0.004	-0.175	.855[a]
34	0.084	-0.022	0.186	0.117	-0.119	0.015	-0.051	0.009	-0.198	0.054	0.026	-0.011	-0.184	-0.148	0.084	-0.233	0.103	0.021	-0.112	0.086	-0.097	-0.001	0.163	0.092	-0.002	-0.221	0.020	-0.008	-0.154	0.035	-0.152	0.011	-0.151	.927[a]
35	0.168	-0.149	0.139	0.090	0.012	-0.186	-0.207	0.125	-0.044	0.089	0.094	0.175	-0.135	0.004	-0.060	0.166	-0.085	0.007	-0.175	-0.069	-0.134	0.012	0.162	-0.152	-0.155	0.132	-0.056	-0.226	0.037	-0.029	-0.015	0.157	-0.109	-0.101	.917[a]
36	0.003	0.070	0.012	-0.103	0.195	-0.144	0.021	-0.062	-0.159	0.072	0.020	-0.124	-0.012	-0.084	0.177	-0.184	-0.125	0.083	0.055	-0.118	-0.090	0.020	0.053	0.139	-0.186	-0.054	-0.027	-0.056	-0.075	0.227	0.231	0.083	-0.039	0.027	-0.177	.935[a]
37	0.085	0.027	-0.012	0.151	-0.036	-0.095	0.054	-0.189	0.021	-0.197	0.068	0.076	0.023	0.109	0.010	0.055	-0.061	0.259	-0.009	0.071	0.183	-0.418	-0.316	-0.031	0.057	-0.236	0.311	-0.168	-0.153	-0.307	-0.061	0.098	0.042	-0.194	0.012	-0.181	.925[a]
38	-0.152	-0.098	0.123	0.075	-0.114	0.136	0.146	-0.055	-0.007	-0.146	-0.173	-0.140	0.032	-0.001	0.001	-0.142	0.051	0.059	0.313	-0.228	0.157	-0.082	-0.155	0.027	0.289	-0.054	0.001	0.097	0.088	-0.178	0.150	-0.201	-0.061	-0.023	-0.358	-0.049	-0.096	.904[a]
39	-0.139	0.098	0.139	-0.098	0.138	-0.260	-0.267	0.189	-0.011	0.348	-0.072	-0.127	-0.003	-0.164	-0.264	-0.149	-0.077	0.124	0.099	-0.038	-0.217	-0.004	-0.082	0.009	-0.196	0.042	0.148	-0.078	0.120	0.085	0.088	0.146	-0.321	0.113	0.102	0.144	-0.113	-0.066	.876[a]
40	0.062	0.043	-0.329	-0.194	0.234	-0.001	-0.075	0.160	0.131	0.199	-0.027	-0.026	0.224	-0.120	0.054	-0.006	-0.300	-0.026	-0.071	-0.128	0.103	0.113	0.341	0.206	-0.145	0.015	-0.091	0.138	-0.312	0.257	-0.126	-0.187	-0.143	-0.077	0.003	-0.104	-0.023	-0.117	-0.434	.860[a]
41	0.012	0.061	0.313	0.075	-0.208	-0.095	0.034	-0.145	0.038	-0.147	-0.038	0.052	-0.149	0.001	0.193	0.116	0.146	-0.272	-0.056	0.072	0.002	0.020	-0.008	-0.084	0.137	-0.205	-0.202	-0.033	0.012	-0.106	0.043	-0.078	0.067	0.026	0.215	0.084	-0.050	-0.036	0.177	-0.296	.900[a]
42	0.073	-0.007	-0.293	-0.123	0.152	0.065	0.120	-0.082	0.059	0.036	0.019	0.125	0.088	0.125	-0.059	-0.208	-0.071	0.103	0.132	-0.025	0.050	0.037	-0.117	0.008	-0.107	0.076	0.101	0.057	0.031	-0.053	-0.219	0.028	0.056	0.030	-0.229	-0.166	0.107	-0.046	-0.174	0.198	-0.605	.910[a]
43	-0.044	0.116	-0.166	-0.075	0.079	-0.213	-0.369	0.350	0.245	0.273	-0.090	0.096	-0.066	-0.150	-0.092	-0.024	-0.281	0.024	0.008	-0.176	-0.147	0.152	0.123	0.146	-0.223	0.016	0.039	0.238	-0.084	-0.130	-0.262	0.030	-0.130	0.102	0.193	-0.303	-0.062	-0.040	0.166	0.035	0.111	-0.028	.850[a]
44	-0.116	0.032	0.036	-0.076	0.030	0.083	0.114	-0.056	0.083	0.021	-0.109	0.305	0.053	0.233	0.027	-0.059	0.123	-0.346	-0.044	-0.151	0.008	0.168	-0.187	-0.125	-0.104	0.109	-0.220	0.065	0.077	0.038	0.094	-0.027	0.207	-0.154	0.066	-0.004	0.002	-0.046	-0.006	-0.056	0.076	0.139	-0.087	.878[a]
45	0.071	0.041	0.031	0.065	0.070	-0.132	0.066	-0.127	-0.041	0.028	0.235	-0.144	0.319	-0.066	-0.076	-0.098	-0.223	0.062	0.036	-0.066	0.094	-0.231	-0.162	0.199	-0.132	-0.020	0.062	-0.105	-0.022	-0.050	0.172	0.005	-0.054	-0.179	-0.035	0.235	0.161	0.059	-0.014	0.138	-0.111	0.026	-0.253	0.025	.843[a]
46	-0.018	0.037	0.132	-0.013	0.021	-0.077	-0.053	-0.070	0.114	-0.184	0.067	0.104	-0.027	-0.120	0.222	0.014	0.051	-0.038	-0.063	-0.019	-0.120	-0.078	-0.013	0.011	0.142	-0.284	-0.133	0.030	0.033	-0.211	-0.048	0.130	0.127	-0.016	0.113	0.050	0.096	-0.182	-0.105	-0.073	0.238	-0.033	0.098	0.036	-0.139	.934[a]
47	0.020	0.130	-0.104	-0.082	0.135	-0.223	-0.198	0.269	0.019	0.170	0.029	-0.310	0.105	-0.130	0.001	-0.007	-0.248	-0.037	0.041	-0.098	0.130	0.032	0.106	0.317	-0.173	-0.097	0.026	0.095	-0.073	0.033	0.008	0.062	-0.173	0.186	-0.091	0.091	-0.138	-0.001	0.005	0.231	0.084	-0.087	0.117	-0.378	-0.006	-0.138	.916[a]
48	0.127	-0.112	0.220	-0.009	-0.003	0.034	0.155	-0.167	-0.276	-0.081	0.081	0.032	-0.051	-0.077	-0.006	0.089	0.248	-0.095	-0.195	0.084	-0.216	-0.011	0.070	-0.256	0.094	0.083	-0.110	0.007	0.270	0.058	0.091	-0.116	0.096	-0.012	0.153	-0.111	-0.130	-0.101	0.104	-0.165	-0.012	0.009	-0.196	0.096	-0.039	0.116	-0.369	.880[a]
49	0.179	-0.168	-0.074	-0.207	0.086	0.017	0.108	-0.057	-0.217	0.024	-0.010	0.050	-0.060	0.044	0.257	0.197	0.217	-0.160	-0.058	-0.020	0.281	0.133	0.143	-0.195	-0.113	0.250	-0.374	-0.003	0.086	0.085	0.148	-0.083	0.113	-0.124	-0.024	0.108	-0.040	-0.046	-0.175	0.011	-0.071	-0.094	-0.301	-0.101	0.045	-0.124	0.044	0.031	.869[a]
50	0.016	0.130	-0.063	0.110	0.086	-0.157	-0.518	0.327	-0.017	0.184	0.220	-0.203	-0.041	-0.125	-0.385	-0.042	-0.537	0.386	-0.041	-0.063	-0.280	-0.191	0.014	0.371	-0.230	0.061	0.206	0.077	-0.053	0.055	-0.121	0.302	-0.201	0.052	0.090	0.095	0.014	-0.076	0.179	0.122	-0.063	0.014	0.360	-0.137	0.020	0.051	0.186	-0.188	-0.492	.833[a]
51	-0.151	0.070	0.025	0.264	-0.251	0.146	0.289	-0.205	0.027	-0.384	0.084	0.138	-0.043	0.181	0.112	0.048	0.103	-0.059	0.049	0.092	0.089	-0.182	-0.373	-0.157	0.292	-0.227	0.249	-0.194	-0.085	-0.134	-0.079	-0.077	0.330	-0.106	-0.230	-0.043	0.241	0.174	-0.189	-0.201	-0.018	0.008	-0.234	0.028	0.087	0.045	-0.183	-0.031	-0.115	-0.233	.898[a]
52	0.077	-0.148	0.028	0.289	-0.288	0.119	0.098	-0.221	-0.074	-0.258	0.096	-0.351	-0.059	0.043	0.069	-0.097	0.033	0.172	0.229	-0.007	0.025	-0.165	0.123	0.063	0.297	-0.071	0.150	-0.060	0.021	-0.015	-0.046	0.059	-0.042	0.017	-0.132	0.077	-0.002	0.399	-0.230	0.015	-0.051	-0.163	-0.200	-0.266	-0.015	-0.128	0.070	-0.161	0.017	0.003	0.048	.872[a]
53	0.112	-0.170	0.070	0.097	-0.036	-0.123	0.004	-0.031	-0.161	0.136	0.210	-0.277	-0.032	0.028	-0.037	-0.094	-0.127	0.148	0.070	-0.019	-0.060	-0.079	0.173	-0.047	-0.111	0.163	0.142	-0.284	0.010	0.294	-0.007	0.020	-0.176	0.061	0.132	0.101	-0.077	-0.070	0.152	0.080	-0.204	-0.017	-0.123	-0.230	0.104	-0.198	0.092	0.073	0.154	0.000	-0.088	0.124	.897[a]
54	-0.039	-0.061	0.228	-0.116	0.060	0.000	0.165	-0.241	-0.133	-0.018	-0.163	0.081	-0.201	-0.005	-0.036	-0.189	0.271	0.027	-0.037	0.014	-0.206	0.006	0.051	-0.212	0.135	-0.065	-0.016	0.104	0.045	0.001	0.104	-0.102	0.034	0.210	-0.181	0.154	-0.168	0.118	0.156	-0.343	0.064	0.013	-0.152	0.041	-0.154	0.002	-0.169	0.262	-0.086	-0.109	-0.037	0.053	-0.218	.927[a]
55	-0.236	-0.053	-0.070	-0.384	0.159	0.120	-0.020	0.180	0.195	0.166	-0.421	0.190	-0.019	-0.066	0.199	0.143	0.177	-0.262	0.034	-0.163	0.017	0.273	0.229	-0.212	0.001	-0.007	-0.267	0.203	-0.097	0.119	0.041	-0.134	0.009	-0.070	-0.028	-0.091	-0.074	0.064	-0.006	-0.078	0.170	-0.175	0.148	0.020	-0.551	0.069	0.044	-0.056	0.230	-0.222	0.057	-0.134	-0.155	-0.011	.849[a]
56	-0.152	0.022	-0.303	0.116	-0.130	0.279	0.120	0.021	-0.018	-0.088	0.050	-0.096	0.228	0.092	-0.140	0.128	0.028	0.068	-0.002	0.001	0.071	0.094	-0.127	0.032	0.127	0.101	0.074	0.037	-0.002	0.144	0.027	0.029	-0.008	-0.236	-0.216	-0.046	0.060	-0.088	-0.114	0.119	-0.269	0.223	-0.270	0.013	0.099	-0.247	-0.140	0.042	0.030	-0.031	0.046	0.005	-0.115	-0.119	-0.105	.866[a]
57	0.006	-0.105	0.131	-0.116	0.142	-0.127	-0.189	0.091	0.093	0.068	-0.097	0.252	-0.123	-0.032	0.084	-0.168	-0.053	-0.103	-0.123	0.087	-0.176	0.063	0.089	-0.089	-0.018	-0.135	0.007	0.077	-0.022	-0.097	-0.244	-0.030	0.033	0.198	0.228	-0.143	0.000	-0.136	0.065	-0.013	0.141	-0.085	0.374	0.114	-0.211	0.299	-0.018	-0.037	-0.319	0.116	-0.037	-0.159	-0.152	-0.024	0.041	-0.603	.887[a]
58	0.210	-0.066	0.185	-0.007	-0.008	-0.016	0.131	-0.283	-0.181	-0.155	0.087	0.203	-0.143	0.050	0.109	-0.018	0.273	-0.156	-0.080	0.010	0.182	-0.036	-0.130	-0.158	0.078	-0.093	-0.115	-0.043	-0.165	-0.199	0.084	-0.179	0.332	0.022	0.023	-0.066	0.158	-0.096	-0.113	-0.109	0.178	-0.083	-0.076	0.159	0.045	0.017	-0.056	0.008	0.245	-0.168	0.088	-0.143	-0.155	0.186	0.003	-0.208	0.030	.902[a]
59	-0.055	0.065	-0.186	0.076	-0.043	-0.097	-0.275	0.119	0.034	0.108	0.010	-0.169	-0.013	-0.139	-0.293	-0.004	-0.048	0.436	0.176	0.028	-0.052	-0.017	-0.079	0.135	0.001	-0.006	0.166	0.067	0.024	-0.147	-0.211	0.174	-0.193	-0.074	0.143	-0.258	0.082	0.017	0.166	0.035	-0.131	0.043	0.166	-0.194	-0.033	-0.037	-0.086	0.002	-0.217	0.197	-0.183	0.056	0.017	-0.031	-0.247	0.150	-0.040	-0.218	.922[a]
60	-0.027	0.067	0.122	0.186	-0.186	0.130	-0.235	-0.070	-0.027	-0.014	0.102	-0.292	-0.025	0.184	-0.269	0.097	0.153	0.103	0.263	0.179	0.049	-0.108	0.085	0.050	0.022	0.140	0.057	-0.169	0.223	-0.180	-0.054	0.154	-0.071	-0.025	-0.093	-0.056	-0.059	0.005	-0.010	-0.122	0.016	-0.027	-0.187	-0.022	-0.019	-0.152	0.010	0.053	0.042	0.008	-0.059	0.231	-0.020	0.190	-0.145	0.065	-0.137	0.096	0.071	.900[a]
61	0.164	0.115	-0.034	-0.091	-0.115	0.061	0.289	-0.171	-0.122	-0.184	0.090	0.213	0.046	-0.057	0.099	-0.002	0.246	-0.250	-0.182	0.086	-0.121	0.218	-0.001	-0.010	-0.005	-0.045	-0.083	0.159	-0.148	0.183	0.095	-0.305	0.221	-0.048	0.068	-0.043	-0.099	-0.100	-0.005	0.039	0.047	-0.075	-0.001	0.089	-0.065	-0.156	-0.109	0.184	-0.012	-0.147	-0.028	-0.119	-0.064	-0.086	0.007	0.102	0.042	0.032	0.009	-0.320	.920[a]
62	-0.124	-0.209	-0.002	-0.016	0.042	0.109	0.107	0.001	0.265	-0.058	-0.301	0.120	-0.135	0.110	-0.078	-0.048	0.040	0.147	0.183	-0.006	0.063	-0.073	-0.255	-0.291	0.284	0.003	0.106	-0.011	0.106	-0.279	-0.092	-0.061	0.038	-0.180	0.001	-0.208	0.132	0.188	-0.021	-0.126	-0.080	0.155	0.110	0.043	-0.093	0.116	-0.278	0.012	-0.117	-0.108	0.128	-0.049	-0.068	0.070	0.034	-0.010	0.153	-0.083	0.240	-0.235	-0.286	.907[a]
63	-0.116	-0.041	0.047	0.125	0.072	-0.079	-0.109	0.264	-0.012	0.035	0.057	0.174	0.016	0.103	-0.195	0.278	-0.340	0.089	-0.051	-0.239	0.075	-0.252	-0.143	0.061	-0.140	0.101	0.087	-0.101	0.003	-0.089	0.119	0.195	-0.122	-0.172	0.119	-0.136	0.218	0.030	-0.052	0.037	-0.128	0.037	0.017	0.054	0.116	0.018	-0.118	-0.010	0.035	0.144	0.194	-0.095	-0.015	-0.196	-0.001	0.017	-0.015	-0.055	-0.146	-0.053	-0.238	0.012	.915[a]
64	0.032	-0.306	-0.065	-0.140	0.260	-0.172	-0.230	0.220	-0.214	0.320	-0.041	-0.081	-0.067	-0.059	0.030	0.140	-0.155	-0.021	-0.148	-0.105	-0.112	0.126	0.352	-0.182	-0.159	0.190	-0.199	0.068	0.037	0.255	-0.064	0.105	-0.169	0.112	0.203	-0.059	-0.135	-0.259	0.076	0.117	-0.053	-0.102	0.093	-0.060	-0.055	-0.056	0.064	0.146	0.250	-0.023	-0.272	-0.099	0.220	0.060	0.121	-0.056	0.011	0.103	-0.038	-0.013	-0.201	-0.189	0.049	.900[a]
65	0.015	0.095	0.060	0.045	-0.211	-0.141	0.422	-0.226	-0.116	-0.218	0.185	-0.044	0.179	-0.177	0.214	-0.143	0.189	-0.135	-0.017	-0.019	0.182	0.025	-0.094	-0.036	0.019	-0.232	-0.090	0.018	0.097	-0.030	0.090	-0.105	0.022	-0.087	-0.129	0.125	0.043	0.156	0.019	-0.072	0.178	-0.054	-0.208	-0.004	0.233	0.121	-0.017	0.136	0.182	-0.254	0.151	-0.010	0.053	-0.045	-0.078	-0.013	-0.289	0.110	0.012	-0.194	0.123	-0.089	-0.068	-0.253	.886[a]
66	-0.132	0.170	-0.147	-0.286	0.296	0.222	-0.257	0.189	0.165	0.294	-0.030	-0.049	0.078	-0.157	-0.224	0.044	-0.244	-0.003	-0.075	0.100	-0.166	0.003	0.078	0.294	-0.202	0.098	0.018	0.086	-0.166	0.062	-0.092	0.194	-0.118	0.164	-0.182	0.031	-0.137	-0.163	-0.013	0.279	-0.284	0.285	0.088	-0.133	0.104	-0.059	0.201	-0.172	-0.199	0.331	-0.090	-0.169	-0.136	-0.040	-0.070	0.106	0.063	-0.169	-0.081	0.062	-0.122	-0.137	0.053	0.019	-0.403	.866[a]
67	0.139	0.034	-0.033	0.005	-0.067	-0.006	0.366	-0.200	-0.068	-0.264	0.021	0.015	0.038	-0.109	0.241	0.003	0.092	-0.012	-0.052	0.049	0.042	0.140	-0.092	-0.003	0.187	-0.095	-0.019	-0.090	0.002	-0.033	0.187	-0.296	0.247	0.018	-0.251	0.167	-0.097	0.033	-0.059	-0.132	0.062	0.047	-0.083	-0.020	0.057	0.054	-0.027	0.023	0.103	-0.215	0.116	-0.054	-0.107	0.062	0.011	0.186	-0.189	0.009	-0.280	-0.234	0.160	0.025	-0.126	-0.112	0.107	-0.027	.923[a]
68	0.042	-0.087	-0.128	0.065	-0.032	-0.061	0.236	-0.164	0.062	-0.134	-0.043	-0.208	0.190	0.102	0.110	-0.227	-0.039	0.146	0.309	-0.001	0.274	-0.173	-0.094	-0.080	0.118	-0.025	0.094	-0.067	0.068	-0.057	0.049	-0.079	-0.093	-0.310	-0.188	0.089	0.216	0.315	-0.142	0.051	-0.090	0.081	-0.250	-0.018	0.313	-0.156	-0.030	-0.141	0.094	-0.222	0.126	0.308	0.110	-0.118	-0.083	0.143	-0.192	-0.165	-0.010	0.067	-0.153	0.202	-0.019	-0.230	0.174	-0.275	0.052	.894[a]
69	-0.090	-0.116	0.104	0.082	0.090	-0.125	-0.248	0.239	-0.089	0.250	0.037	0.134	-0.062	0.015	-0.143	0.035	-0.266	0.005	-0.167	-0.259	-0.213	-0.063	0.005	-0.122	-0.141	0.070	0.191	-0.075	-0.056	0.120	0.055	0.104	-0.095	0.153	0.210	0.003	-0.039	0.031	0.208	-0.040	-0.140	-0.122	0.175	0.077	-0.066	-0.060	0.015	-0.045	-0.157	0.271	0.056	-0.058	0.244	0.043	0.045	-0.252	0.128	-0.002	-0.060	-0.159	-0.132	-0.114	0.233	0.231	-0.093	-0.003	-0.310	-0.344	.893[a]
70	-0.172	0.239	-0.254	-0.029	-0.019	0.112	-0.324	0.249	0.339	0.188	-0.067	0.074	-0.011	0.201	-0.247	0.128	-0.049	0.011	0.002	0.045	-0.001	0.139	-0.176	0.125	-0.201	0.195	-0.008	0.086	-0.041	-0.069	-0.195	0.218	-0.023	-0.060	0.083	-0.280	0.071	-0.202	0.089	0.042	-0.039	0.140	0.323	0.098	-0.112	-0.096	0.067	-0.265	-0.189	0.238	-0.106	-0.206	-0.146	-0.258	0.035	0.192	-0.021	-0.156	0.281	0.135	-0.007	-0.011	-0.033	-0.143	-0.229	0.230	-0.249	-0.179	0.076	.855[a]
71	-0.036	-0.023	0.152	0.110	0.024	-0.142	0.003	-0.038	0.000	-0.003	-0.027	-0.140	0.033	-0.088	0.027	-0.036	-0.136	0.111	0.076	-0.079	0.016	-0.197	0.082	0.181	0.034	-0.057	0.129	0.011	0.001	0.010	0.038	0.042	-0.091	-0.056	0.001	0.080	-0.024	0.223	-0.114	0.204	-0.016	-0.107	-0.153	-0.146	0.107	0.027	0.061	-0.009	-0.010	-0.006	-0.083	0.356	0.129	-0.019	-0.150	-0.165	0.024	-0.147	0.053	0.056	-0.048	0.017	-0.006	-0.098	0.035	-0.059	-0.281	0.146	-0.099	-0.322	.942[a]
72	0.160	-0.073	0.078	0.033	-0.271	0.222	0.198	-0.124	-0.087	-0.180	-0.001	0.046	-0.157	0.141	0.212	0.042	0.406	-0.253	-0.111	0.274	0.109	0.187	0.160	-0.204	0.076	0.042	-0.359	-0.135	0.070	0.119	-0.005	-0.084	0.093	0.129	0.074	0.052	-0.175	-0.192	-0.094	-0.139	0.213	-0.222	-0.227	0.149	-0.180	-0.098	-0.151	0.137	0.324	-0.399	-0.095	-0.082	-0.052	0.081	0.172	0.001	0.015	0.216	-0.210	0.153	0.200	-0.128	-0.188	0.117	0.018	-0.227	0.104	-0.028	-0.302	-0.166	-0.193	.884[a]
73	-0.239	0.244	-0.109	0.031	0.042	0.147	-0.056	0.161	0.194	0.050	-0.043	-0.072	0.096	-0.037	-0.200	-0.125	-0.086	0.024	0.022	0.077	-0.026	-0.038	-0.121	0.160	-0.086	-0.054	0.231	-0.103	0.004	-0.058	0.018	0.115	-0.128	0.165	-0.208	0.070	-0.040	-0.030	0.099	-0.084	-0.174	0.199	0.157	-0.052	-0.001	-0.009	0.105	-0.142	-0.304	0.143	0.052	-0.177	-0.013	-0.046	-0.111	0.077	0.080	-0.222	-0.110	-0.014	-0.032	-0.003	-0.003	-0.216	-0.098	0.333	0.075	-0.052	0.092	0.197	-0.209	-0.191	.908[a]

Appendix 10 Ethics Approval

Curtin University

Office of Research and Development

GPO Box U1987
Perth Western Australia 6845

Telephone +61 8 9266 7863
Facsimile +61 8 9266 3793
Web research.curtin.edu.au

14-Sep-2017

Name: Oluwole Olatunji
Department/School: Department of Construction Management
Email: Oluwole.Olatunji@curtin.edu.au

Dear Oluwole Olatunji

RE: Ethics Office approval
Approval number: HRE2017-0641

Thank you for submitting your application to the Human Research Ethics Office for the project **Using Value Engineering to minimize likelihood of construction delays in near shore and offshore projects**.

Your application was reviewed through the Curtin University Negligible risk review process.

The review outcome is: **Approved**.

Your proposal meets the requirements described in the National Health and Medical Research Council's (NHMRC) *National Statement on Ethical Conduct in Human Research (2007)*.

Approval is granted for a period of one year from **14-Sep-2017** to **13-Sep-2018**. Continuation of approval will be granted on an annual basis following submission of an annual report.

Appendix 11 Ethics Amendment Approval

Curtin University

Research Office at Curtin

GPO Box U1987
Perth Western Australia 6845

Telephone +61 8 9266 7863
Facsimile +61 8 9266 3793
Web research.curtin.edu.au

30-Apr-2020

Name: Oluwole Olatunji
Department/School: Department of Construction Management
Email: Oluwole.Olatunji@curtin.edu.au

Dear Oluwole Olatunji

RE: Amendment approval
Approval number: HRE2017-0641

Thank you for submitting an amendment request to the Human Research Ethics Office for the project **Causality Analysis of Construction Delays and Value Engineering Protocols in Marine Projects**.

Your amendment request has been reviewed and the review outcome is: **Approved**

The amendment approval number is HRE2017-0641-06 approved on 30-Apr-2020.

The following amendments were approved:

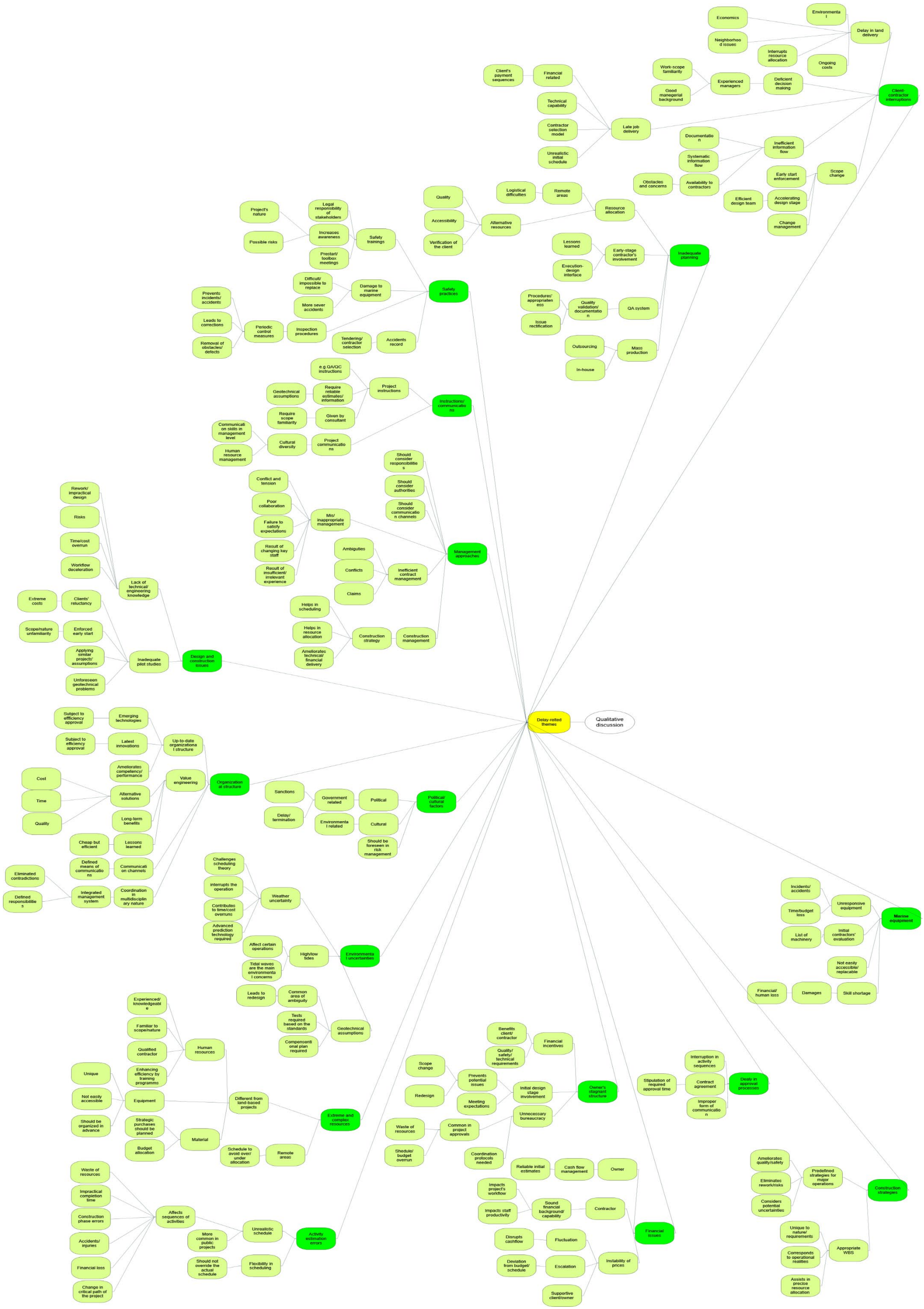
1) Due to global COVID-19 pandemic which enforces social distancing, I have decided to validate my model through a different way that still follows the preceding goals but using a different research tool. I have prepared an open-ended survey questionnaire instead of conducting a focus group interview, in which the validity of all findings will be externally examined by asking for the opinions of the experts. The questionnaire will be emailed to the potential participants.

2) I would like to slightly change the wording on the title from "Using Value Engineering to minimize likelihood of construction delays in near shore and offshore projects" to "Causality Analysis of Construction Delays and Value Engineering Protocols in Marine Projects".

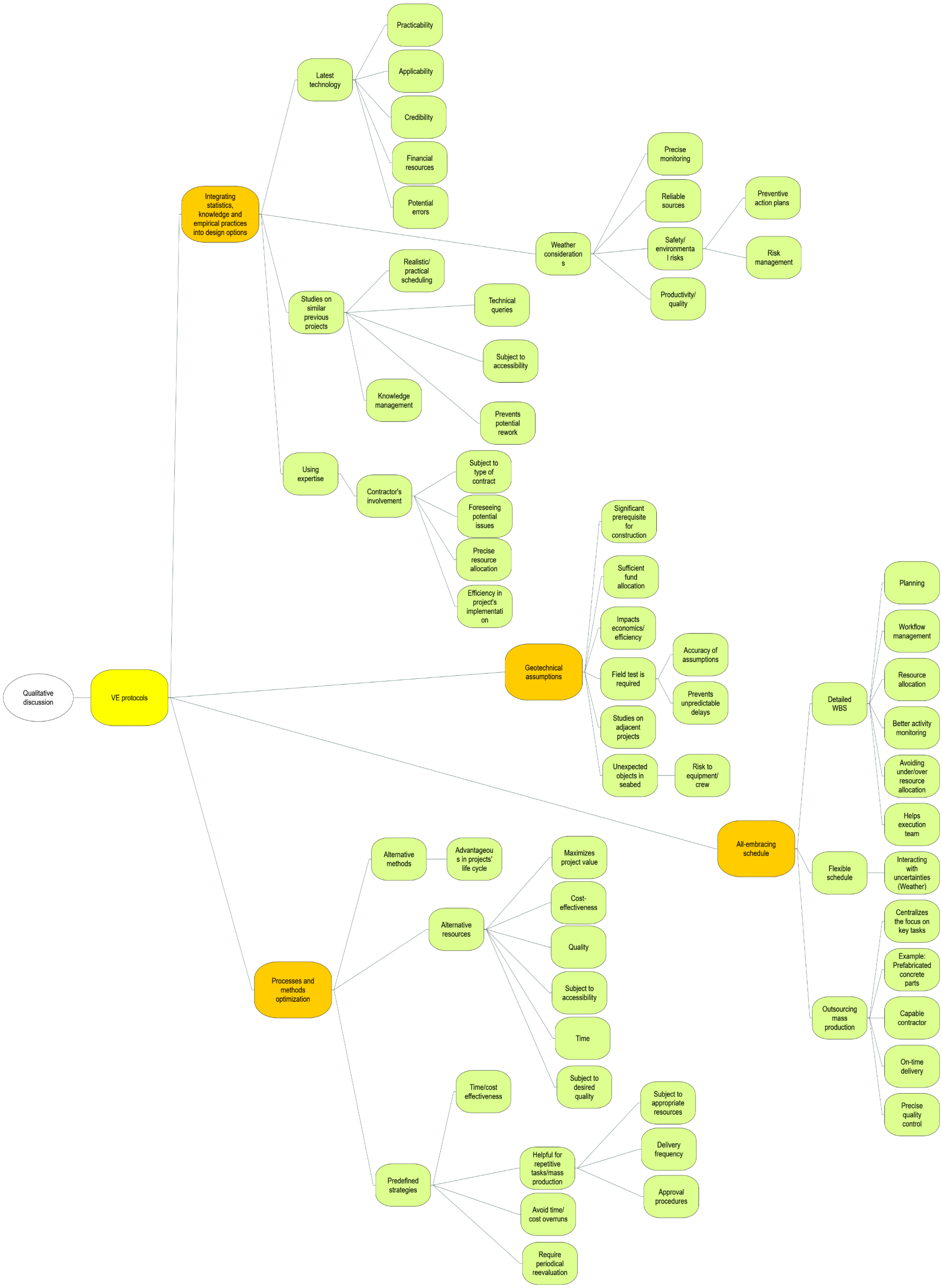
Condition of Approval.

It is the responsibility of the Chief Investigator to ensure that any activity undertaken under this project adheres to the latest available advice from the Government or the University regarding COVID-19.

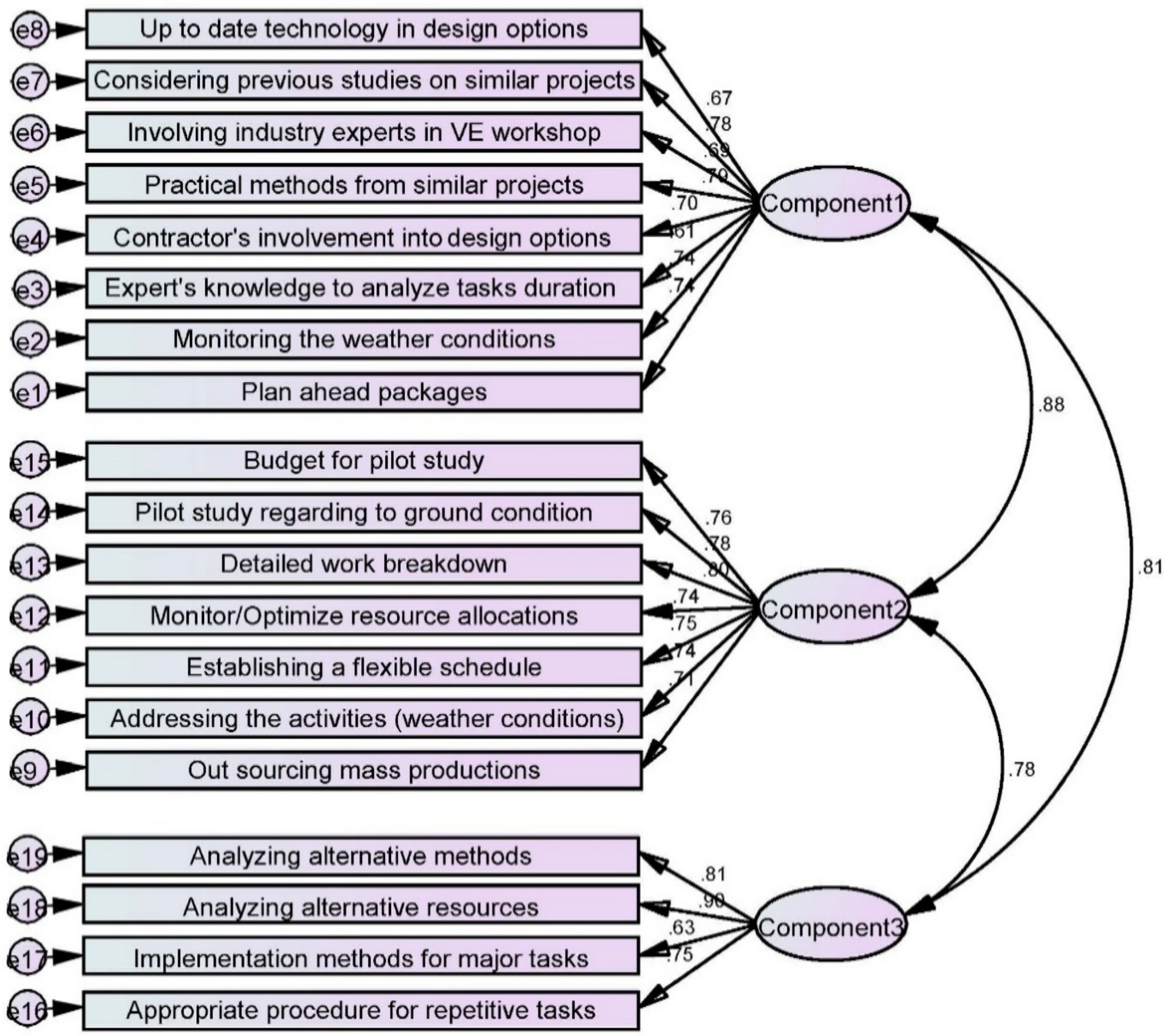
Appendix 12 NVivo coding figure for delay-related themes



Appendix 13 NVivo coding figure for VE-related themes



Appendix 14 VE Graphical Path Diagram -SEM Output



Appendix 15 Delay and VE Variables- Shapiro-Wilk Normality Test

Delay variables	Shapiro-Wilk		
	Statistic	Degrees of freedom	Significance
Weather conditions	0.816	126	0.000
High and low tides	0.902	126	0.000
Lack of proper marine equipment	0.792	126	0.000
Financial difficulties to the owner	0.773	126	0.000
Financial difficulties to the contractor	0.785	126	0.000
Lack of experienced personnel	0.818	126	0.000
Design errors and poor design	0.838	126	0.000
Improper site instructions imposed on contractors	0.881	126	0.000
Delay in land delivery	0.892	126	0.000
Poor communications and management skills	0.825	126	0.000
Poor site control by contractors	0.859	126	0.000
Poor consultant's auditing system	0.881	126	0.000
Lack of consultant's practical experience	0.870	126	0.000
Contradiction between tender documents and actual situation	0.863	126	0.000
Lack of execution methods for major activities	0.841	126	0.000
Scope change imposed by the client	0.884	126	0.000
Lack of resources	0.845	126	0.000
Inappropriate contractor	0.793	126	0.000
Estimation errors in early design phase	0.869	126	0.000
Lack of on-time approval of the drawings and documents	0.887	126	0.000

Lack of pilot study prior to construction phase	0.871	126	0.000
Unrealistic timetable for major activities	0.838	126	0.000
Lack of Value Engineering department in organisation	0.875	126	0.000
Form of contract	0.902	126	0.000
Conflicts and poor coordination between the parties in construction site	0.886	126	0.000
Obsolete technology	0.869	126	0.000
Slow site handover	0.884	126	0.000
Unrealistic contract duration imposed by client	0.872	126	0.000
Low speed of decision making in different parties	0.891	126	0.000
Delays in subcontractors' work	0.881	126	0.000
Unstable management structure and style of contractor	0.839	126	0.000
Construction method	0.850	126	0.000
Mistakes during construction due to inexperienced personnel	0.863	126	0.000
Lack of responsibilities in different parties	0.883	126	0.000
Delay in work approval	0.899	126	0.000
Lack of proper quality assurance/control system in site	0.886	126	0.000
Inefficient information stream	0.892	126	0.000
Long waiting time for approval of test samples or test results	0.907	126	0.000
Inadequate design team experience	0.859	126	0.000
Impractical design	0.838	126	0.000

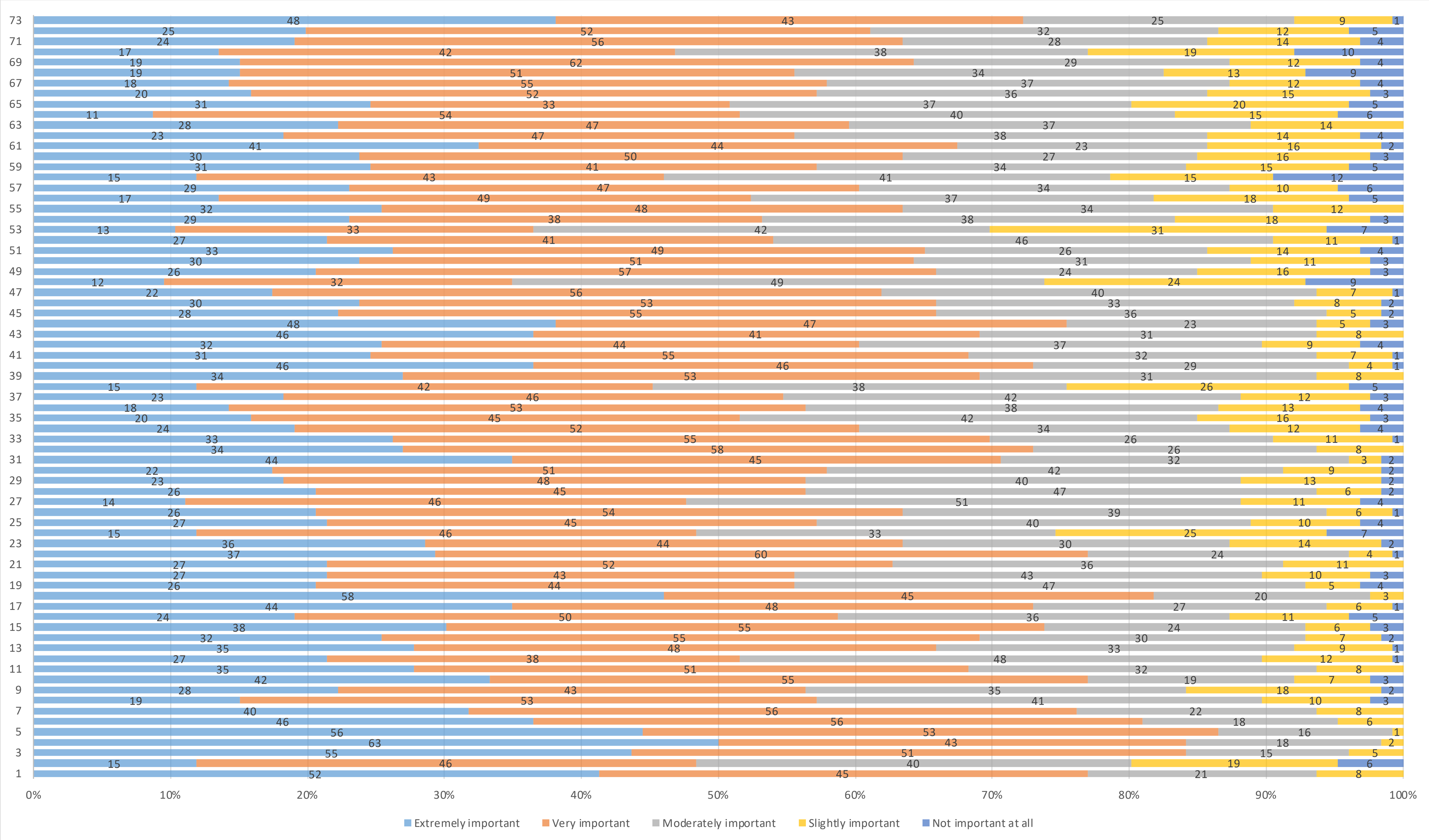
Lack of proper communication between consultant and contractor	0.866	126	0.000
Lack of communication between client and consultant	0.879	126	0.000
Procurement and resource allocation	0.841	126	0.000
Delay in importing materials from other countries due to political issues	0.823	126	0.000
Escalation in resource prices	0.863	126	0.000
Unskilled operators for certain marine equipment	0.871	126	0.000
Labour skills/Productivity	0.870	126	0.000
Social and cultural factor	0.912	126	0.000
Uncooperative owner	0.868	126	0.000
Insufficient communication between the owner and design team in the design phase	0.877	126	0.000
Unavailability of professional construction management	0.872	126	0.000
Unavailability of financial incentive for contractor to finish ahead of schedule	0.882	126	0.000
Problems with neighbours	0.913	126	0.000
Unforeseen ground conditions	0.895	126	0.000
Price fluctuation	0.869	126	0.000
Water table conditions on site	0.897	126	0.000
Geological problems on site	0.879	126	0.000
Preparation and approval of shop drawing	0.897	126	0.000
Lack of database in estimating activity duration and resources	0.890	126	0.000
Safety issues	0.878	126	0.000

Damaging marine equipment during execution in site due to lack of safety	0.857	126	0.000
Lack of safety training and meetings prior to commencing the construction	0.894	126	0.000
Poor judgment and experience of involved people in estimating time and resources	0.875	126	0.000
Inspection and testing procedures used in project	0.878	126	0.000
Accident during construction	0.896	126	0.000
Excessive bureaucracy in project-owner operation	0.889	126	0.000
Lack of considering alternative resources	0.880	126	0.000
Lack of an appropriate work breakdown system by the contractor	0.883	126	0.000
Lack of having a flexible timetable for certain activities	0.860	126	0.000
Not involving the contractor in early design phase	0.906	126	0.000
Lack of optimising/monitoring resource allocation	0.874	126	0.000
Lack of appropriate procedure to deal with repetitive tasks and mass production e.g. pre-casts and piles preparation	0.880	126	0.000
Not utilising lessons learned from similar projects	0.839	126	0.000

VE variables	Shapiro-Wilk		
	Statistic	Degrees of freedom	Significance
Implementation methods for major tasks	0.776	126	0.000
Contractor's involvement to Integrate expert’s knowledge into design options	0.833	126	0.000
Analysing alternative resources	0.825	126	0.000
Analysing alternative methods	0.838	126	0.000
Addressing the activities that can be affected by weather conditions	0.836	126	0.000
establishing a flexible schedule for the activities that can be impacted due to weather conditions	0.861	126	0.000
Having a detailed work breakdown for critical activities	0.828	126	0.000
Specifying budget for pilot study to prevent unpredictable delays	0.858	126	0.000
Considering pilot study regarding to the ground condition	0.867	126	0.000
Monitor/Optimise resource allocations	0.852	126	0.000
Having appropriate procedure for repetitive tasks and mass production e.g. pre-casts and piles preparation	0.868	126	0.000
Utilising practical methods from similar projects	0.811	126	0.000
Out sourcing mass productions such as pre-casts to save time	0.868	126	0.000

Monitoring the weather conditions on a daily basis to plan ahead against sever situations	0.854	126	0.000
If possible, utilising up-to-date technology in design options	0.791	126	0.000
Considering the previous studies on similar projects in the region	0.812	126	0.000
Plan-ahead packages to deal with inclement weather conditions	0.860	126	0.000
Involving industry experts in creativity phase of Value Engineering workshop	0.821	126	0.000
Using expert's knowledge to analyse the initial tasks duration on major activities to insure they are accurate	0.795	126	0.000

Appendix 16 Participants' Ratings on Delay Variables



Appendix 17 Delay graphical path diagram-SEM output